LOCKS SAFES AND SECURITY

The hardcover book, Locks Safes and Security by Marc Weber Tobias 2nd edition, was published in 2002. This work was followed by an electronic version called LSS+ CD a few years latter.

The LSS+ CD contains a lot more content than the book. Content has been updated as of 2004. It is released with 3 separate security levels, Public, Locksmith, and Government.

This document is a pdf version of the material extracted from LSS+. It contains material at Public, Locksmith and Government Levels

Locksmith vs Government Level Material:

Book 1 Chapters 1 thru 23 are identical
Book 2 Chapter 24 thru 30 are identical
Book 2 Chapter 31 is different (Decoding)
Book 2 Chapter 32 is identical
Book 3 Chapters 33 thru 36 are identical
Book 4 Chapters 37 thru 39 are identical
Book 4 Chapter 40 is different (Alarms)

LSS+ Electronic Infobase Edition of Locks, Safes, and Security

Version 5.0-04185

This infobase includes the revised editions of The Art of Manipulation;(1) A Treatise on Fire & Thief-Proof Depositories and Locks and Keys(2), originally published in London, in 1850; and Locks and Safes: The Construction of Locks(3), by A.C.Hobs. Locks, Safes, and Security(4) was first published in 1970 by Charles C. Thomas Publishers, Springfield, Illinois. The Second Edition was released in 2000. Supplementary materials can be found at the website www.security.org.(5)

Created by Marc Weber Tobias, B.S., J.D.

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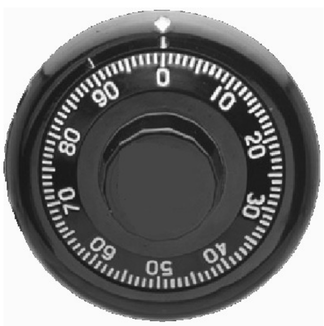
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LOCKS, SAFES, AND SECURITY

Electronic Infobase Version 5.0, based upon the Second Edition, published by Charles C. Thomas, Springfield Illinois, 2000. The original edition was published in 1970 and is no longer available.

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Figure LSS+3511 This was a peel and punch attack to access the bolts (left). A classic peel attack is shown (right)

Figure LSS+3512, examples of peeling of the outer skin on the top of the container and the rivets popped.

Figure LSS+3513 Prying and wedging.

Figure LSS+3514 A safe that has had the door pulled loose by the application of extreme pressure.

Figure LSS+3515, (ISP 38-3563 left, and 39-3563 right). The result of pounding of components.

Figure LSS+3516, Bolts were sheared from shock waves through the use of the welded bar to the front of the door.

Figure LSS+3517. Example of punching. Pressure was applied to the hinge side.

Figure LSS+3518. This was a pound attack. The door was pounded with many hits.
Figure LSS+3519, An attack by the use of a wedge to pry apart and separate portions of the container.
Figure LSS+3520, The top of the safe was cut into to provide access to the bolt works.
Figure LSS+3521 Attacks by torch. In the middle picture, an inept attempt to open the safe by cutting through the side.
Figure LSS+3522. Attack using a torch where there was obviously no knowledge of where to cut.
Figure LSS+3523 Additional examples of the use of a torch. In the photographs, the lock box is burned out.
Figure LSS+3524 Lines scored by an oxyacetylene torch in the outer shell of a Chubb safe.
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Figure LSS+3529. The thermic lance develops high temperature and can be utilized virtually anywhere.
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Figure LSS+3534 A fixed drill rig.
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Figure LSS+3536 Core drill can produce a large hole for access to the bolt works or lock box.
Figure LSS+3537 Critical drillpoints are shown. This is a rear view, with the lock case removed.
Figure LSS+3538 (ISP 23-2963) Deflector plates made of angle iron are added to deter drilling.
Figure LSS+3539 (ISP 104-3563) The bolt is punched out of the way in

order for the handle cam to be rotated.

Figure LSS+3540 Burglars drilled into the side of the safe to punch and drive the bolt out of the way.

Figure LSS+3541 A scope is inserted to obtain a view of the wheel pack.
Figure LSS+3542 The fence is a prime target for drilling, either the soldered link or the actual fence material.

Figure LSS+3543 Progression of movement of the fence into the gate of the wheel pack.
Figure LSS+3544 A 90 degree angle view with a borescope using a mirror on a Mosler MR 302.

Figure LSS+3545 Locating the fence for drilling.

Figure LSS+3546 A lever fence that has been drilled, and then removed.

Figure LSS+3547 Drilled relockers and zoom view.

Figure LSS+3548 Mosler MR-302 point of penetration.
Figure LSS+3549 Hole drilled through cover plate.
Figure LSS+3550 Side drilling and scoping the lock case.

Figure LSS+3551 Floor safe that has been angle drilled to view wheel pack.

Figure LSS+3552 Safe drilled from the top of safe to lock box to view the wheel pack.

Figure LSS+3553 Many burglaries are simulated.

Figure LSS+3554 The burglar uses a drill without much knowledge of the safe.

3563-15 Individual must have knowledge

3563-16 Tool knowledge of the burglar

3563-17 Time limit for burglary

3563-1819 Proficiency in burglarizing types of safes

LSS201: A primer on the burglary of safes, Courtesy of Bill Sherlock.

LSS201: Forensics and locks, Courtesy of Bill Sherlock.

LSS202: Steve Mattoon on the use of explosives to gain entry.

Chapter 36 Non-Destructive Methods of Entry

Chapter 37 Standards and Testing

Chapter 38 Security: Analysis and Reduction of Risk

LSS202: Ross Anderson on security engineering

Chapter 39 Security: Physical Protective Measures

Chapter 40 Alarm Systems

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LSS401: Buried Cable sensors

LSS401: Fence alarm system

LSS401: Microwave sensor systems

LSS401: Outside passive infrared sensors

LSS401: Photoelectric sensors

LSS401: Thermal imaging and sensing

LSS401: Video logging and capture systems

LSS401: Alarm contact devices, including magnetic switches

LSS401: Discussion regarding pressure mats

LSS401: Embedded screen wires

LSS401: Alarm foil

LSS401: Grid wires in alarm systems

LSS401: Ribbon switch material as a sensor

LSS402: Shock sensors for glass break detection

LSS402: Other types of shock detection sensors

LSS402: Trip wires in alarm systems

LSS402: Alarm monitoring systems

LSS402 Defeat techniques for different sensor technologies

LSS402: Glass break sensors and how they work

LSS402: Issues with microwave sensors

LSS402: Alarm sounders and notification devices

LSS402: Ultrasonic alarm sensors

LSS402: Proximity sensor technology

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LSS403: Shock sensors utilized to protect fences

LSS403: Magnetic point sensors

LSS403: Dual technology devices utilized in outside environments

LSS403: Ross Anderson on alarm system monitoring

LSS403: Magnasphere technology

LSS403: DOE on perimeter sensors and their defeat

LSS403: DOE on alarm assessment

LSS403: DOE on sensor technology

LSS403: DOE on layers exterior protection

LSS403: DOE on a typical plan of attack on a facility

LSS403: Defeat of magnetic switches, including BMS

BOOK ONE: THE BASICS

The Fundamentals of Locks, Safes, and Security

PART A: General Principles

General Introduction To Locks and Keys

LOCKS, SAFES, AND SECURITY provides detailed information on the construction, theory, bypass, and analyses of modern locking mechanisms and security containers. The scope of this beginning chapter shall be to present a summary and chronology of major technical achievements of locking mechanisms during the past four thousand years. Particular emphasis will be placed upon developments since the beginning of the nineteenth century.

The historical development of **safes, combination locks, and lock picking** are topics presented elsewhere, but not covered in this chapter. Detailed relevant historical developments for each type of locking system are provided at the beginning of the chapter describing that mechanism.

Lock makers have demonstrated tremendous intellectual energy, cleverness, and skill for over forty centuries. These craftsmen would continually improve upon designs, playing a never-ending game of "security chess" with their opponents; the burglar. As each new feature was designed into a lock to frustrate methods of bypass, a resourceful locksmith, engineer, or criminal, in order to circumvent the last innovation, would develop new techniques.

It is difficult to fathom the problems presented by early security needs. Consider living thousands of years ago as a wealthy landholder, merchant, or banker. You have land holdings and have amassed many possessions of great value. Perhaps you are a merchant, jeweler, or moneylender. How do you protect your valuables, your castle, and your family from robbers and thieves? In the beginning, there were no vaults, electronic alarm systems, safe-deposit boxes, high-security locks, or other devices that could guarantee security. Extremely inefficient yet effective, the hired watchmen together with constant vigil provided the only real security to protect your possessions from the thieves and robbers of the day.

At some point, the local blacksmith is consulted, and asked if there is a way to provide better security through fortified enclosures and secret fasteners or locks. So, the blacksmith sets to work on the problem, apparently in many different parts of the world simultaneously. Such a demand for security was experienced that a special guild would emerge for those who dealt with such problems: locksmiths.

Remember, there is no machine shop, no security industry, nor any high-security locks or enclosures. The only materials are wood, brass, bronze, and iron. There are no factories, sophisticated metallurgy, or machinery to make the small and intricate components found in modern locks.

There was essentially nothing to draw from in the blacksmith's experience to solve the problem of protecting people and their assets. There is no history of technological developments. It is the beginning.

So how did we arrive at the end of the twentieth century with such an array of simple to highly sophisticated and secure locking devices and enclosures designed to protect people and their assets. Assets, as defined in our modern world, now include information, perhaps of such a sensitive and valuable nature that improper or unauthorized disclosure or acquisition could literally result in the destruction of the planet.

Chapter 1, then, traces the slow evolution of the lock through four thousand years to present state-of-the-art designs. The organization of the chapter attempts to present the logical steps that must have occurred in the development process.

LSS+ CD/ROM presents an in-depth overview of the history of locks, offering an extensive collection of photographs of both ancient and modern devices. In order to provide the reader with the rich history and perspective of the development of the modern lock, the author has revised two major works of the nineteenth century that are considered the source reference works on the subject of locks, safes, and security.

Fire and Thief-proof Depositories and Locks and Keys, was written by George Price in 1850. This is one of the most comprehensive and authoritative works on locks and safes, providing a chronicle of innovations and developments in locks and safes from their inception.

Locks and Safes: The Construction of Locks was written by Alfred C. Hobbs and edited by Charles Tomlinson in 1868. This book provides another chronicle of the technology of early locking devices, and traces the conceptual changes in design as relates to security. Interestingly, both of these individuals were American lawyers. Mr. Hobbs is credited with having been the first person to bypass the Bramah lock, produced in London. This feat, as will be described subsequently, set the stage for a race for higher security and new designs in locking mechanisms at the Great Exhibition of 1851 in London. That race continues today.

CHAPTER ONE: HISTORY

The Lock: Four Thousand Years of Technology

"And the key of the House of David will I lay upon His Shoulder."
-Isaiah, CH. XXII, V. 22

Master Exhibit Summary

1_1.0 Introduction

Apparently the need for greater security was felt in a number of societies at about the same time. Around 2000 B.C., evidence can be found that man began to construct the primitive locking devices that would lay the groundwork for forty centuries of development, culminating in today's sophisticated technology.

1_1.1 Original References to Locks and Keys

It is unknown when the original mechanism that could fairly be

described as a lock was really created. It appears that the first reference to locks was noted by **Joseph Bonomi(49)** in Ninevah and its Palaces. This described one of the frescos discovered in the ancient biblical city of Ninevah that showed a picture of a lock. The fresco was painted by an Egyptian artist, which provided evidence of dating to that era. The remains of an actual lock, corresponding to the fresco, were found in the ruins of a sumptuous palace near Ninevah. It is believed that this is the oldest lock in existence.

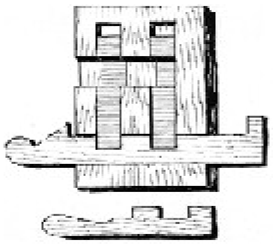
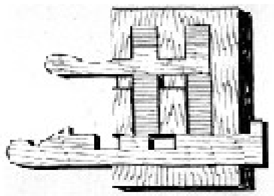
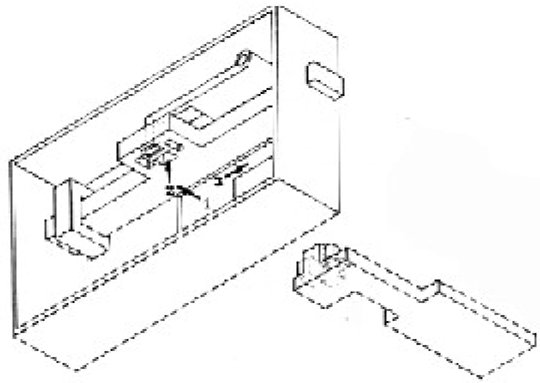
The reference in Bonomi's book described a lock as having secured the gate of an apartment in one of the palaces near Ninevah. He wrote that **"the gate was fastened by a large wooden lock, the wooden key with iron pegs at one end to lift the iron pins in the lock, being so much as a man can carry."** He described the length of the key as ranging from a foot to two feet. The reference clearly described the Egyptian pin tumbler lock.

There are a number of references to locks and keys in the Bible, leaving no doubt that the lock as we understand the concept today, has existed for at least forty centuries.

1_1.2 The First Fasteners and Locks: Greek and Egyptian

It is logical to believe that primitive man's treasures were initially buried or hidden in caves, hollow trunks of trees, or other physical locations that could be easily created or exploited. Once doors or other solid surfaces were employed to secure a perimeter, the next obvious step would have been the capability of locking the door in place. In the beginning, of course, there were no latches as we understand the term today. It appears that the Greeks, who developed crude wooden fastening devices on the inside face of the door, conceived the initial concept of using bars and boltwork. These bolts were lifted from the outside by a cord passing through a hole in the door; later a crude key was utilized.

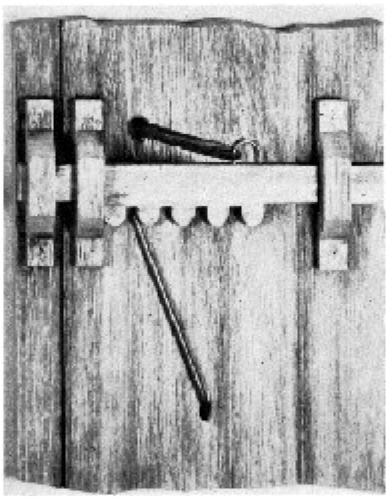
Realizing that one of the drawbacks of the Egyptian lock was its vulnerability to attack, the Greeks placed their locks on the inside of the door but provided access to the mechanism from the outside through a keyhole. Although it is unknown whether the Greeks took these ideas from the Romans, they are credited with the concept of interior locking mechanisms, operable from either side of the door.

They utilized a massive bolt with a large sickle-shaped key. It had a semi-circular blade, measuring a foot or more in diameter, and a long handle that tapered to a blunt point. The Greek "keys" would often be inlaid with precious metals, for locks were utilized by the wealthy. The major problem with the Greek design was that there were very few different key patterns available. Thus, there was little security against bypass through the use of primitive "skeleton keys." The only possible variations (or differs) were those of curvature and length of the key.

1_1.3 The Greek Influence

The development of the Greek and Egyptian door locks appear to have occurred at about the same time. Interestingly, Greeks are credited with making simple bolt-locking mechanisms available to the middle class, while the Egyptian pin tumbler locks were affordable only by the wealthy. In the days of Homer, doors were tied shut with intricately knotted ropes. They were so cleverly laced that only the owner could find the correct method of unknotting them. Moreover, the superstitious beliefs of the times insured that no one would dare to tamper with the ropes, lest a curse fall upon them and their families. Ropes, of course, gave way to a number of different configurations involving the use of a beam of wood mounted to the door.



Some evidence suggests that the first mechanical barring of a door was by a cross-beam that was dropped into sockets or by sliding staples affixed to the door. It is theorized that a vertical pin was probably dropped into a slide to secure the beam. If the beam were to be placed on the outside of the door, then the locking pin would have to be hidden, yet retained and accessible through a hole in the beam or staple. In order to make the lock function from outside, the cross-beam was shortened into a long bolt which was made hollow to allow the pin to be reached. To move the bolt, a **key** was fashioned that had pegs matching the hidden pins within the bolt.

A variation of this early lock was a configuration wherein the pins were reached by holes in the staple, not through the bolt. This design was very popular and was utilized in different parts of the world, including Scandinavia, the Faro Islands, Africa, and the Balkan states. There was a principal difference between the Greek and Egyptian lock. In the Greek mechanism, the key moved pins into position to allow release of the bolt, which then was moved back by hand. In the Egyptian lock, the key actually was used to withdraw the bolt.

The next improvement was mounting the bolt on the inside surface of the door. Keys appear to have been sickle-shaped pieces of iron, apparently put through a hole in the door and used to push or pull a retaining pin.

The final "primitive" style lock also placed the bolt on the inside surface of the door, but with the addition of a **spring** that would spread against the sides of a staple. The key would compress the spring to open the lock; the bolt could then be

withdrawn.

The Greeks are credited with the concept of interior bolt mechanisms accessible through a keyhole. It is interesting and curious that they never applied their intellectual abilities to the design of locks, as did the Egyptians and Romans, in spite of the great academic, political, and scientific achievements of Athens.

1_1.4 The Original Egyptian Pin Tumbler Design

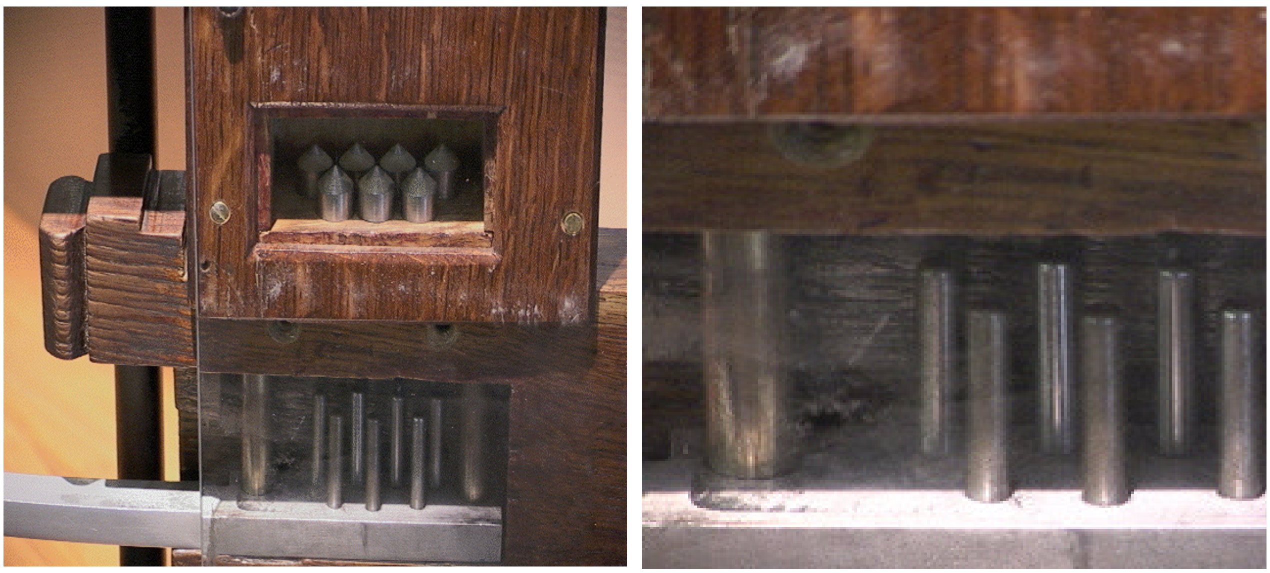
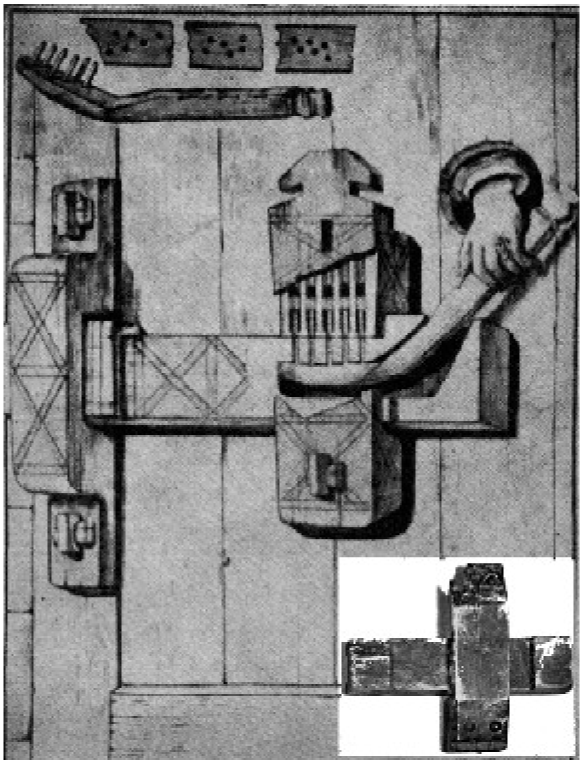


Figure LSS+101. A mock-up of the original Egyptian lock, produced by the British Museum, London. This replica shows the interaction of the protruding pegs with the internal pins.

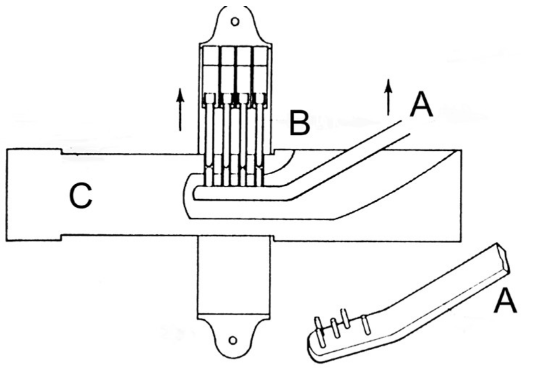
The Egyptian craftsmen are responsible for conceiving one of the principles upon which all modern lock designs are based; the pin tumbler. Their invention would ultimately lead Linus Yale to perfecting and patenting the modern version of that mechanism.

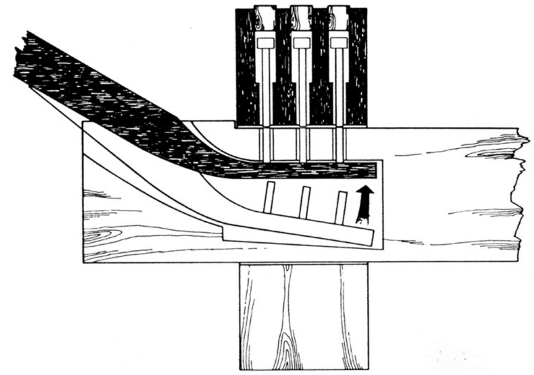
The real genius of the Egyptians was in conceiving **double-acting detainers** that had to be lifted to the correct level in order to create a **shear line** to allow the lock to operate. Their clever innovation set the stage for the development of every mechanical locking mechanism in existence today.

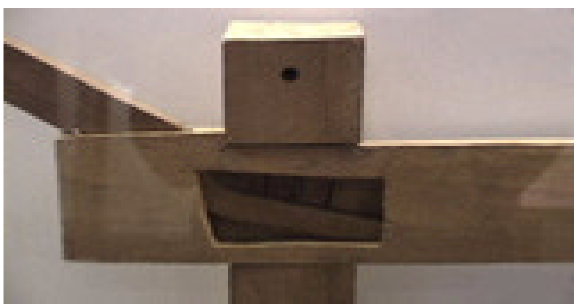


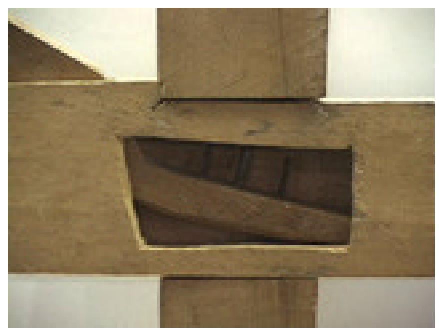
Yale would base his lock design upon this principle, with the further refinement that the detainers or pin tumblers could not be lifted too high or too low: they would have to be raised precisely to the correct height.

The Egyptian lock was attached to the outside surface of the door. First made of wood, later models were constructed of brass and iron and ornamented with inlaid pearls, gold, and silver. The locks measured two to three feet in length. The mechanism was housed in a rectangular container into which the bolt would slide. Inside this hollow container was placed several irregularly shaped wooden pegs or pins, usually numbering from three to seven. They were arranged in random patterns and were set to move up and down. When in the locked position, the pins rested half in the bolt and half within the main lock housing.


B
A
C
A








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INV.1868-18

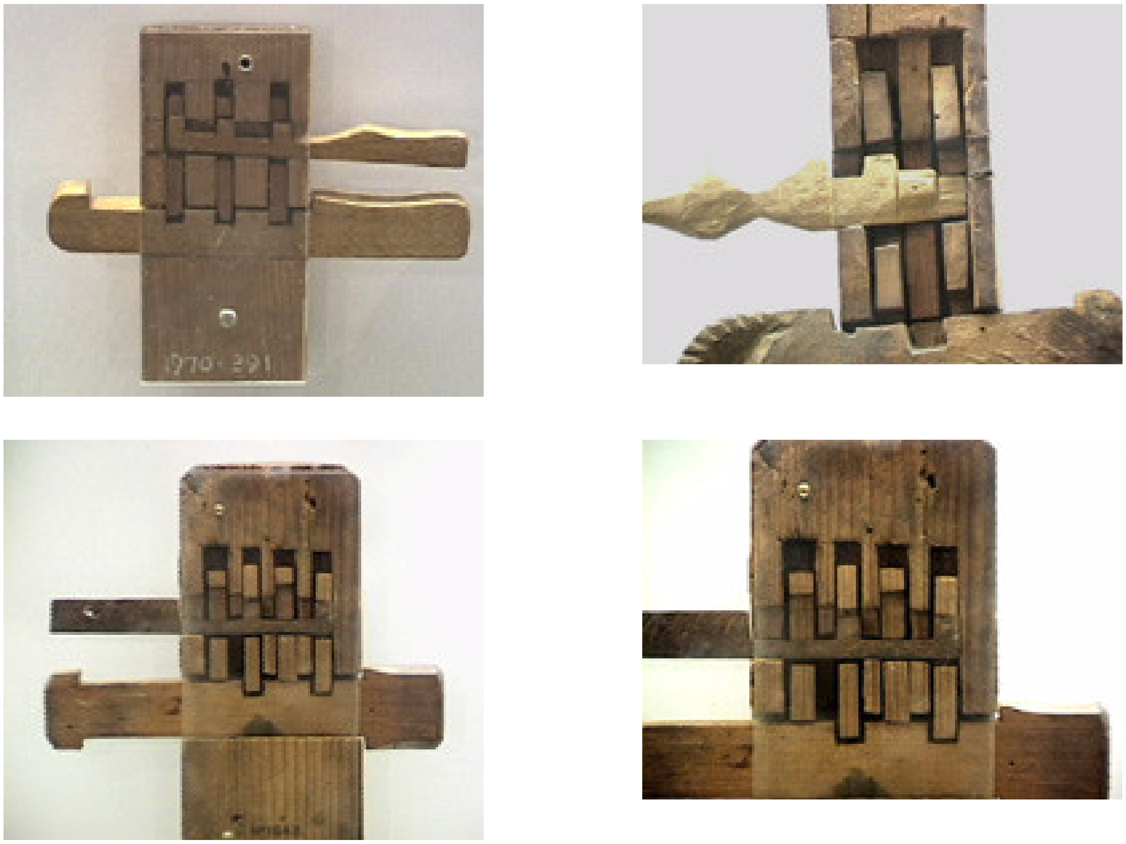
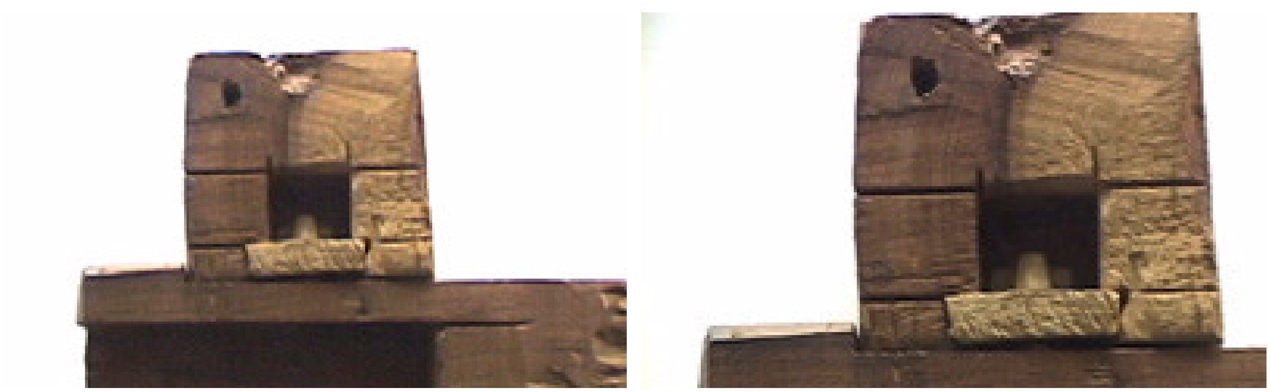


Figure LSS+102. Examples of different approaches to the original Egyptian pin tumbler design. These locks have been gathered from different countries, and demonstrate that the idea of using pins or pegs to secure a moving bolt or locking piece was not unique to any one society, although the Egyptians are credited with the initial concept. These exhibits are on display at the Science Museum in London.





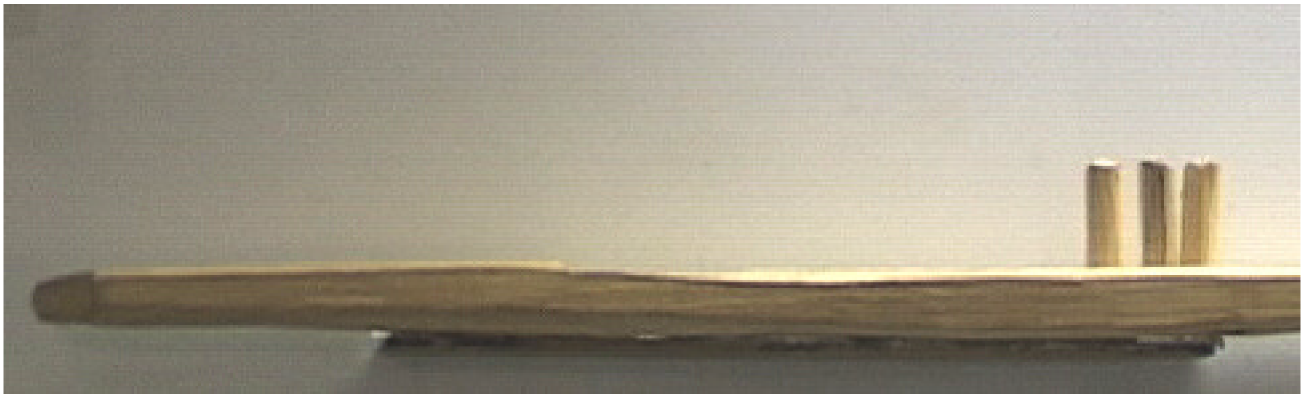



Figure LSS+103. An example of a pin tumbler lock found in North Africa during the last century.

The key for the Egyptian lock was also two to three feet in length and had wooden pegs inset in a vertical position at one end. These pegs were placed on the key to match the pin positions inside the lock. The function of the internal pins was to hold the bolt solid in the lock housing. Keys came to represent a sign of spiritual and temporal power. They symbolized man's ability to gain access to those things he considered to be of greatest significance.

The pin tumbler concept was widely imitated, and even to this day similar locks are occasionally dug up in places as remote from each other as ancient Assyria, Scotland, Japan, and America. Apparently the skill and techniques of the ancient lock makers, as well as the fundamental soundness in design, survived the fall of great empires and even time itself.

1_1.5   Early Roman Locks

The craftsmen of the ancient Roman Empire are credited with a number of major advancements in the development of the lock. Recognizing basic defects in earlier devices, they took the best of the Greek and Egyptian designs to produce sophisticated locks, as well as the revolutionary **warded** design. They also popularized padlocks, originally developed by the Chinese. The Roman artisans were familiar with working in metals; thus they dispensed with large bolts and keys. They recognized that smaller keyholes made locks more difficult to pick. Their keyholes were mounted on the interior surface of the door and were operated with a key from the outside. Although keys for the Greek and Egyptian locks were

quite cumbersome, the Roman counterpart was small, ornate, and intricate.

Evidence of the sophistication of Roman lock design can be found in the ruins of the ancient city of Pompeii which was engulfed by the volcano Vesuvius in 64 A.D. One of the significant finds in the lava of Pompeii was the discovery that keys were required to rotate within locks **less than 360º** to actuate the bolt. Thus, it appears that the Romans were the first to introduce a **spring-loaded bolt** into their locking mechanism, thereby eliminating the problems encountered in gravity-locking devices.

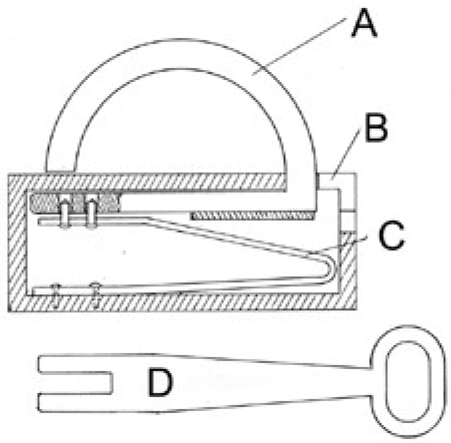
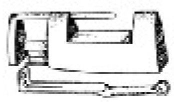
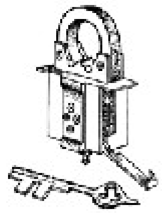
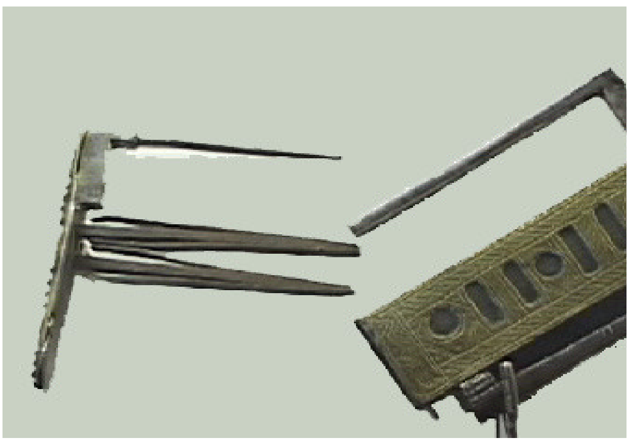




Figure LSS+104. An example of a seventeenth century Persian padlock.

1_1.5.1 Roman Padlocks

Padlocks are the logical extension of fixed mechanisms and provide a connecting link between primitive devices and the beginnings of the development of the modern lock.

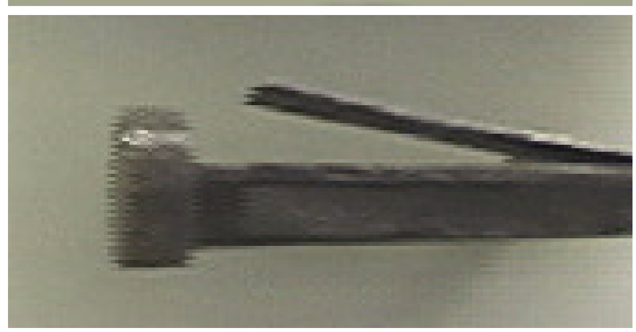





Figure LSS+105. Examples of early Roman and African padlocks.



Figure LSS+106. An example of an early European padlock.

Although the Chinese and Near East peoples developed the padlock, the Romans are credited with having popularized it. They made it a practical device, even going so far as to produce the key as a part of a finger ring for convenience in carrying by the owner. The fact that the Romans had no pockets in their togas may have inspired their locksmiths to devise keys that were small and inconspicuous.

1_1.5.2 Warded Locks



Figure LSS+107. An early warded lock, showing the obstructions to rotation of the key.



Figure LSS+108. This mock-up of a warded lock demonstrates its principle of operation. The key is allowed to rotate the bolt only when the obstructions are cleared. This and the following illustration were produced by the Science Museum, London.

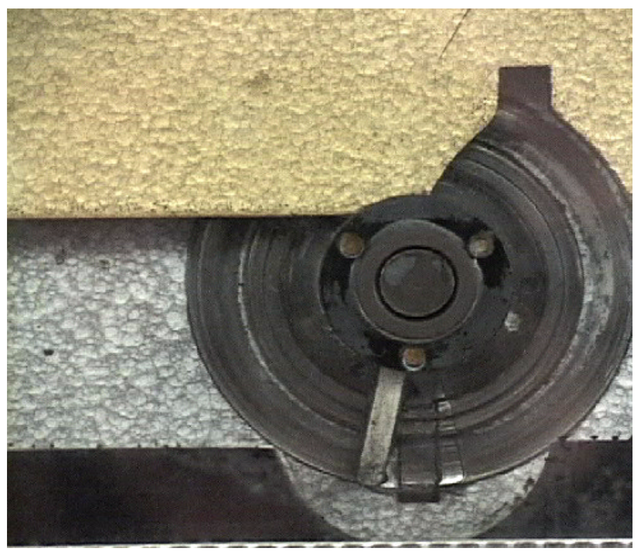


Figure LSS+108 This working model of a warded lock shows the circular wards and how they interact with a key.

While Roman artisans knew that their locks provided greater security, they continued to seek refinements in the mechanisms to frustrate the conventional forms of bypass. The answer came in

the form of **wards** that were incorporated within the lock design. The origin of the warded lock is obscure. It is likely to have been invented by the Etruscans in northern Italy, although recent evidence indicates that the Greeks also knew of the concept. Regardless of its origin, the warded mechanism was perfected by Roman artisans and was to remain the most popular design until the middle of the nineteenth century. It is still found in wide use today.

Wards were a logical extension of the primitive alteration of the shape of a key to frustrate entry into a lock. Some ingenious lock maker discovered that he could place a series of obstructions in the path of a turning key and thus make the lock secure. Only the correct key with the same spaces on its body could pass the obstructions. Thus, the essential principle of the warded lock was to provide one or more internal obstructions to block entrance and rotation of all but the correct key. The incorporation of wards added a completely new dimension to security against picking and led the way for the production of many different shapes and sizes of locks.

Craftsmen continued to improve upon the mechanism, making the keyway and ward pattern more intricate. Then, when this was not enough, they began to use multiple locks for greater security. As an example, it was reported that in 1415, Queen Isabelle of Bavaria called her locksmith to secure the apartment where the ladies-in-waiting were quartered. The doors were fitted with locks that required five different keys to gain access.

1_1.6 Lock Design during the Middle Ages and Renaissance

The Middle Ages followed the fall of the Roman Empire. While scientific achievements were few, locksmithing flourished during this period in history. Warded locks were now not only complex mechanisms but became works of art. Prestige and respect was accorded those with the most intricate locks.

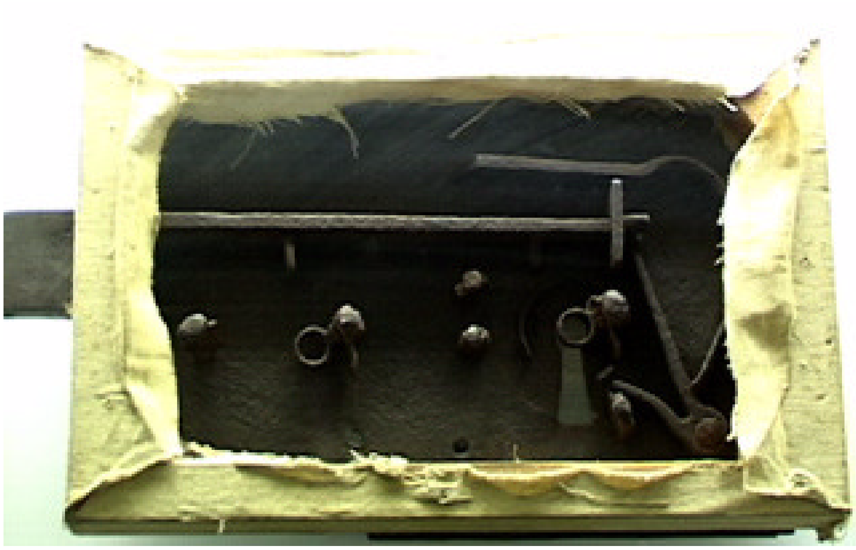
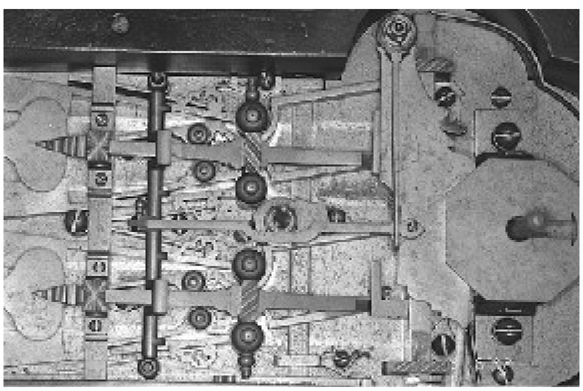


Figure LSS+109. This is a warded lock that was produced between the fifteenth and eighteenth century. Note that multiple keys were required.

These were the days of castles and knights, of robber barons, and of monasteries containing books and manuscripts of great learning from ancient days. Security took on new and more urgent dimensions.





The warded lock had been designed to perfection, and yet it was not secure enough. The demand for more security increased to match the accumulation of wealth. The late eighteenth century produced the next significant refinement of locking mechanisms: the **lever** concept.

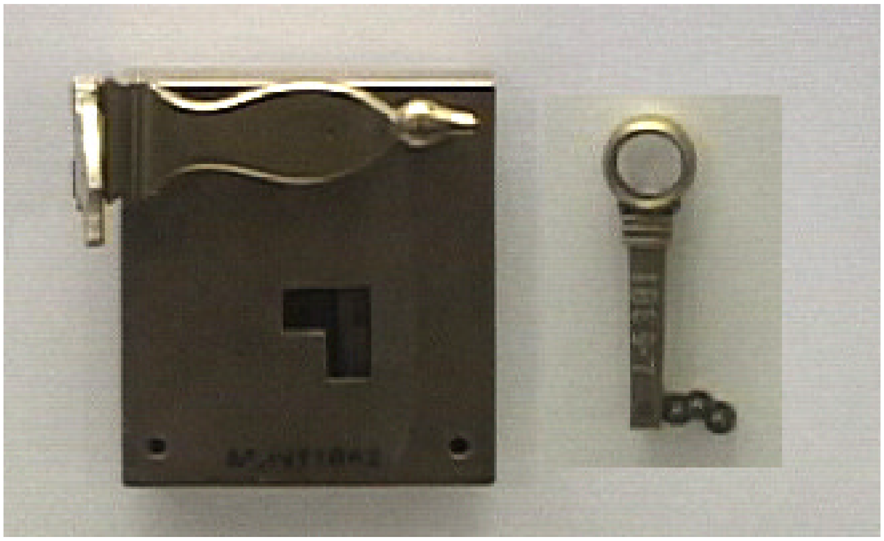


Figure LSS+110. This replica is made from a lock preserved in Pompeii after the eruption of Mt. Vesuvius in in A.D. 79. It closes with a hasp.



Figure LSS+111. Early warded door lock.

1_2.0 Origins of Modern Locking Concepts

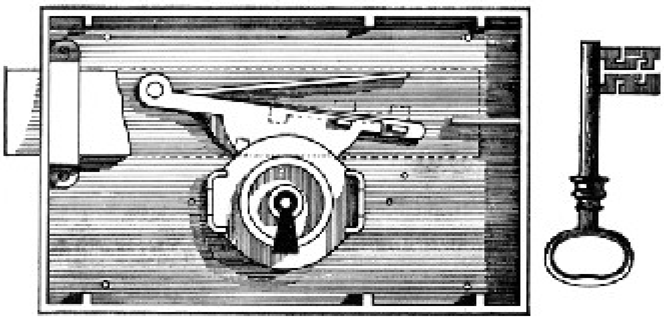
Most of the significant achievements in modern lock designs find their basis in developments of the past two hundred years. From the time of the Romans until the end of the eighteenth century, security was based upon fixed obstructions and elaborate keyholes, fine slits, perforations, and intricate keys. Falling pins, invented by the Egyptians, were forgotten. No other methods had been invented to put more security into the locks.

Towards the end of the seventeenth century, traditional sliding and pushing of keys gave way to the concept of **turning**. Keys would rotate around a pin or slide through a keyway. As developments progressed, many different key designs emerged, incorporating both art and utility.

In 1778, **Robert Barron** developed a new and radically different locking mechanism. Over the next two hundred years, many modifications to the Barron lock would be introduced, as well as completely new and fundamentally unique designs. Because of the many different advances since 1778, a chronological summary of important inventions, beginning with Robert Barron, is presented in the remaining portion of this chapter. A detailed treatment, examining the significance of each of these major developments, will be found at the beginning of the chapter relating to the corresponding basic locking mechanism. This format will allow the reader to logically trace and understand the changes made to each type of lock and how various designs evolved.

1_2.1 Barron Lock: 1778

With the exception of the Egyptian pin tumbler design, most locks had relied upon wards prior to the lever principle. The Barron lock, first introduced in England, was based on a completely new locking theory: the **double-acting lever tumbler**. It was probably the most significant development since that of the ancient Egyptians. Through many refinements and modifications, the lever lock would become one of the most popular mechanisms in the world to this day.



Originally, the lever was a form of catch. Until raised by a key, it would normally hold the bolt in a fixed, immovable position. In the first lever locks, the key merely had to **lift** a single spring from a notch in the bolt and then force the bolt forward. The height of the lift was not important, provided that the notch was cleared. The **Banbury** wooden locks employ this principle.

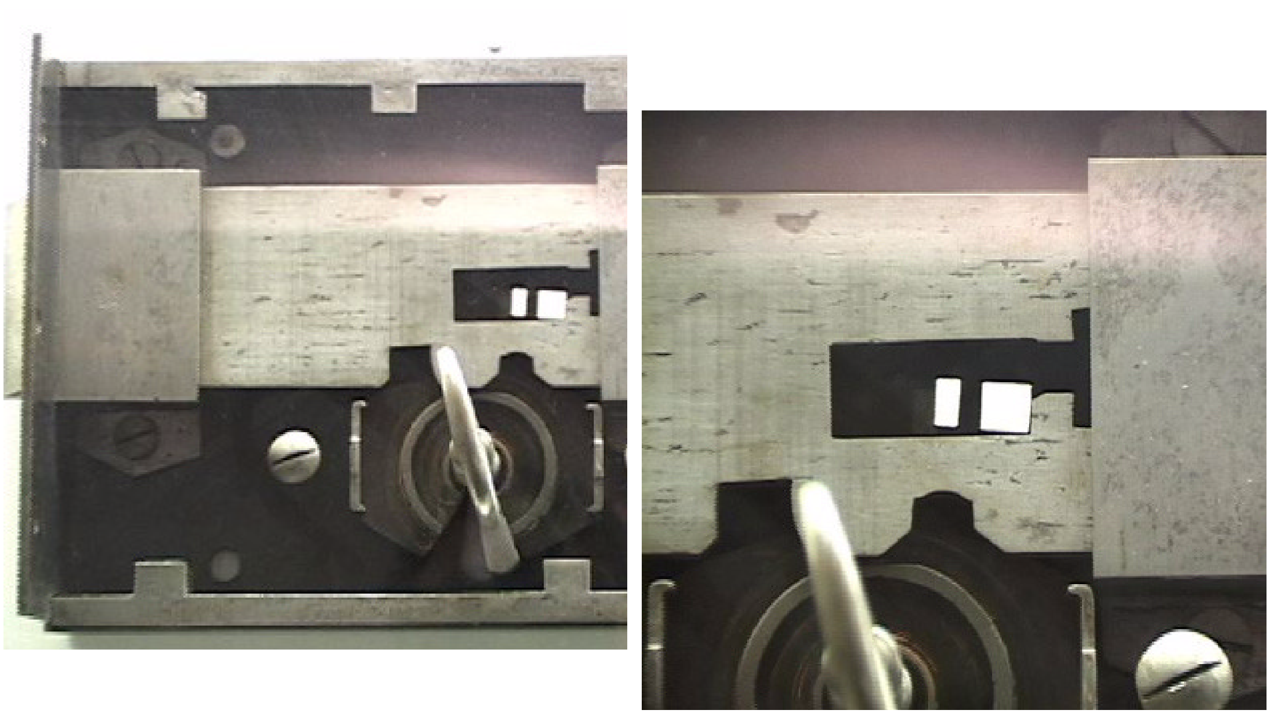


Figure LSS+112. A replica of the original Barron lock, showing the action of the key and levers.

The bolt of the Barron lock had a square-cut notch, called a **gate.** Stumps, formed as part of the levers, would project into

the gate, thereby preventing them from moving. The key would lift all the levers until the stumps cleared the gates, allowing the bolt to slide into a locked or unlocked position. If any of the stumps were raised too high or not high enough, the bolt could not move. The lever principle was a great improvement over wards, because it was believed that wax could not be used to determine precise details of the mechanism. This was true, at least for a few years.

Levers offered the first real security against picking because the lever not only was used to hold the bolt but to block its movement until the correct key was used. Several levers were employed, thus eliminating the use of skeleton keys that had defeated all security in the earlier warded lock.

Essentially, all lever locks for the next two hundred years would adopt a design based upon the original Barron concept. Each were based upon the idea that a moveable, pivoting lever should have a square gate cut into its end opposite the pivot point. When lifted to precisely the correct height, it would allow a stump to enter the gate, and thus permit the bolt to laterally move. Today, locks of seven or move levers can provide extremely high-security against picking and other forms of bypass.

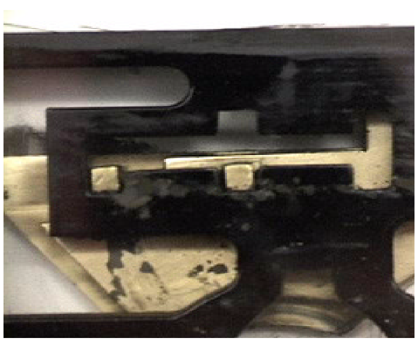


Figure LSS+113. The three photographs depict the movement of the bolt in the Barron lock, as



In this photograph, the levers have been raised to clear the gate, and the bolt has been



In this figure, the bolt has been moved to the locked position; the levers are again at

the key raises the levers to the proper height and allows the bolt to be slid to the locked or unlocked position. In this exhibit, the levers are a rest; the bolt is locked in position and is blocked from movement.

partially moved. Note the stump is floating between the gates.

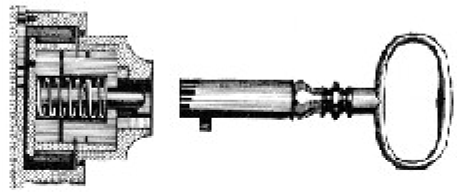
rest.

1_2.2 Bramah Lock: 1784



Figure LSS+114. The Queen of England recognized Bramah for its excellence in the manufacture of locks.

In 1784, **Joseph Bramah** was the first to receive a patent for a lock in which the key did not actually reach or make direct contact with the bolt. Rather, it acted through an intermediate and intricate slider mechanism. This design allowed the lock to be physically small, yet secure.

The Bramah key was a tube with narrow longitudinal slots cut in the end. Depressing the key into the lock would cause a number of sliders to align at a shear line. The Bramah design resembles, in some respects, the modern axial pin tumbler of Chicago Lock Company and others. Interestingly, Bramah's invention initially found no commercial acceptance. For many years, the pickproof lock, on display in the window of the Bramah Lock Company at 124 Piccadilly, in London, remained unopened; the reward for picking this lock uncollected. Seventy-five years later, a subsequent version of this lock was to become the focus of a contest at London's **Great Exhibition** of 1851 and a catalyst for competition in the development of pickproof locks.

1_2.3   The House of Chubb: English Lock Makers

For almost two hundred years, the name **Chubb** has been associated with quality lock manufacturing, design innovation, and many revolutionary patents, including the Detector lock. Chubb was the name of a famous inventor who originally founded the company in 1818, after the immediate commercial success of his **Detector Lever Lock.** Charles Chubb and his younger brother, Jeremiah were born in England in 1779 and 1793 respectively. The Chubb's originally worked as iron mongers in Portsea, England, building ships. In 1818 Jeremiah patented the Detector lock, which was an immediate success. The brothers then opened a lock factory in Wolverhampton the same year to produce and market the product. Since that time, the company has grown to be one of the most highly respected lock and safe makers in the world.



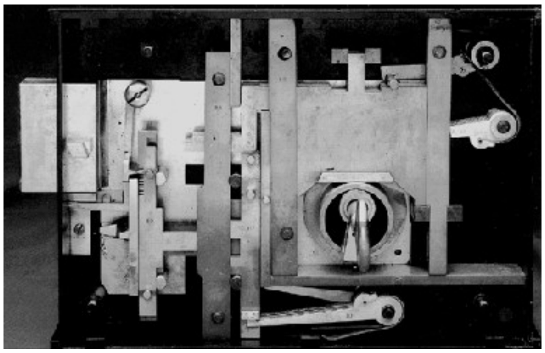
Figure LSS+117 Map of England

At the end of the nineteenth century, their products were so respected that in the Chinese colonies the natives would refer to "Chubby pot of jam" or "Chubby pair of trousers," meaning that they were of the highest quality. The Chubb Safe Company, still headquartered in **Wolverhampton(50)**, today has offices throughout the world. The firm manufactures a broad range of security products, including safes, lever locks, and electronic alarm systems. They have received numerous awards for design and production excellence, including recognition by the Queen of England for their contributions. Innovation, based upon research and development, has been the hallmark of the company. Chubb, for example, recently was the first to receive a patent for an all-plastic fire and burglary-resistant safe, called the "Planet." The reader is directed to **Chapter 33**, for detailed information on unique Chubb products.

1_2.3.1 Chubb Detector Lever Lock: 1818

The Detector introduced a totally new concept to lever lock design. Its commercial success provided the foundation for the future growth of the Chubb Safe Company. The Detector was a

mechanism with a slightly different lever design than found in the earlier Barron lock. Chubb conceived of a different configuration, wherein the ***gates*** formed part of each lever, in contrast with the Barron lock, where the gate was actually part of the bolt. This significant enhancement remains in use to this day.



The essential element of the Detector lock was its ability to show if any attempt had been made to pick open the mechanism. This feature, coupled with the capability of completely disabling the operation of the levers once an unauthorized attempt to pick or use an improper key was made, provided a high level of security and confidence to the owner. Chubb made many improvements in the design of the lever lock, including the introduction of a curtain that surrounded the keyhole internally. This enhancement would revolve with the key, making picking impossible.

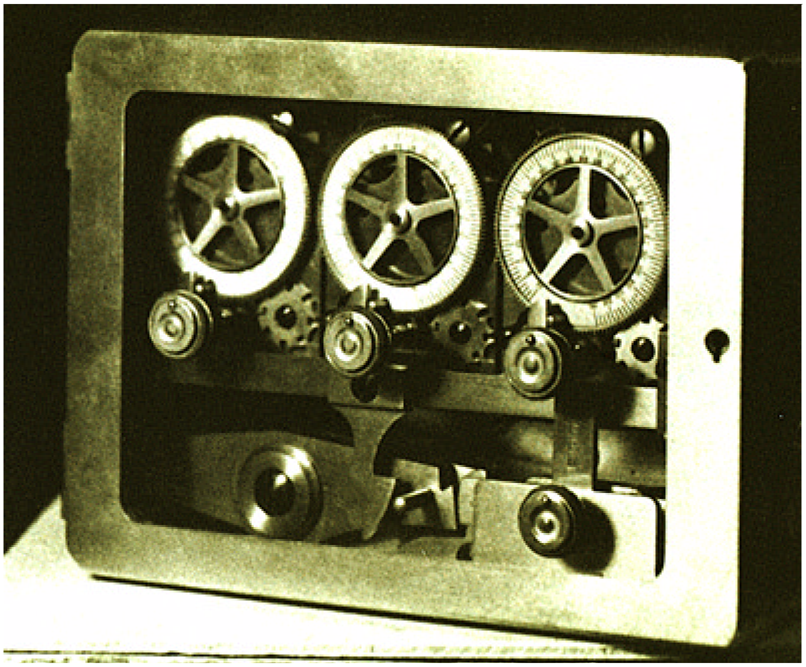
1_2.4 Time Lock: 1831

While refinements in the lever lock were being made, there were also efforts to increase the security of the combination lock (sometimes called letter, number, or permutation locks). These made their appearance during various stages of the world's history, dating back thousands of years to early China. Their application was usually confined to padlock designs and offered very little security against opening by "feel" or manipulation. They were never popularly accepted as secure locking devices until modern machine methods achieved high tolerances. In fact, until the middle of the nineteenth century, they were mainly looked upon as locks of convenience only. Although combination locks were used on safes and vaults prior to the introduction of the time lock mechanism, they did not provide security against robbery. Criminals, especially in America, determined that the simplest way to obtain the contents from the bank vault was to

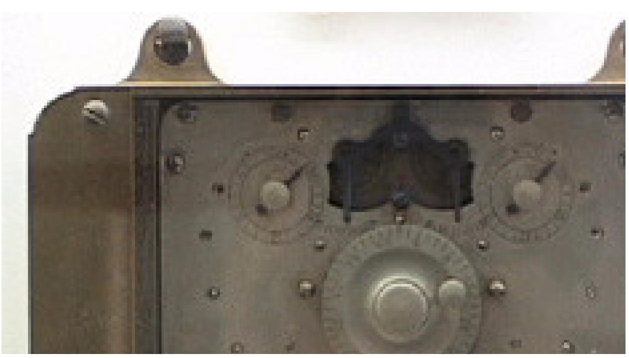
kidnap the cashier or bank manager and force him to open the safe.



A Scottish inventor, William Rutherford, developed a combination lock utilizing a disc with a notch cut in the side, to be driven by a clock. Rutherford placed a circular stop-plate at the rear of the lock. This prevented the operation of the bolt until the plate had rotated to a certain position, which was controlled by the timing mechanism. The modern version is simply a variation of this design.



The introduction of the time lock revolutionized the security of safes and vaults. The original Rutherford invention did not receive much attention until an American, James Sargent, of Rochester, New York, improved upon the design in 1865. Sargent made the use of these locks practical. Because of the introduction of the Sargent design, combination locks gained wide acceptance in the United States during the second half of the nineteenth century.





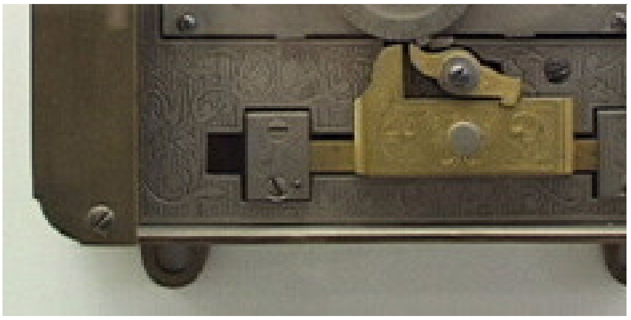
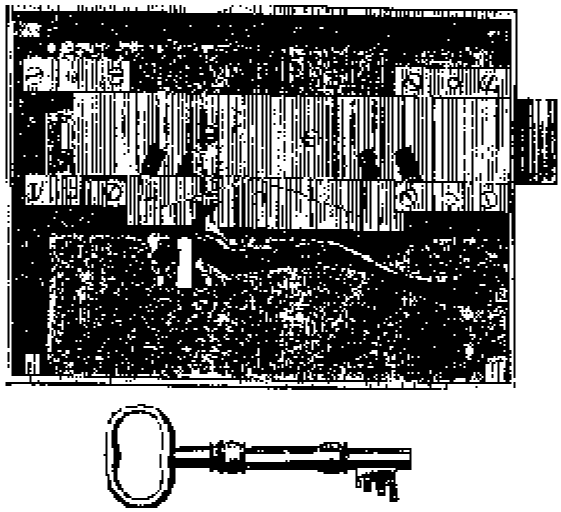




Figure LSS+115. An early example of another time lock developed by Pillard.

1_2.5 Parsons Balanced-Lever Lock: 1832



The **Parsons** balanced-lever lock was significant because of the change in design of the levers. These were set to **pivot in the middle**, rather than at one end. The lock was designed so that if any lever were raised too high, as with a false key, it would hook into the bolt, thereby becoming immobilized. This lock was produced with seven levers and provided an innovative design.

1_2.6 Newell Parautoptic Lock: 1841

The Newell Parautoptic lock was shown at the Great Exhibition in 1851. It was invented by Robert S. Newell of New York and manufactured by the Day and Newell Company. The word **parautoptic**, taken from the Greek, means **concealed from view.** The lock was designed so that it was almost impossible to reach the working parts from the keyhole. By utilizing a double set of lever tumblers, one acting in sequence upon the other, and a rotating plate that would block the tumblers from inspection, the lock was virtually impossible to pick.

In a further innovation, the combination of the lock could be changed at will by altering the relative positions of the parts of the key bit. The key is comprised of fifteen separate segments that are interchangeable and which controlled the derivation of the combination. This design provided the idea for instant rekeying systems, which would become popular a century

later.

1_2.7 Hobbs Protector Lock: 1851

The Hobbs **"Protector"** was introduced the same year as the Crystal Palace Great Exhibition. This was a simple four-lever lock, following the original Chubb design, with some modification. Alfred Charles Hobbs, an American locksmith, is also credited with being the first to pick the world-famous Bramah lock. His achievement attracted so much publicity that he remained in England to found a lock manufacturing company called **Hobbs & Company**, later to become **Hobbs, Hart & Company.** Chubb would later acquire Hobbs & Hart.



Figure LSS+116 The lever lock developed by Hobbs and Hart.

1_2.8 Tucker and Reeves Safe-Guard Lock: 1853

A variation of the Chubb lock was introduced in 1853 which featured four levers formed in the shape of a wheel, mounted on a central pin and enclosed in a moveable barrel. The barrel formed the true keyhole that was offset from the key. The design made it impossible to insert a picking tool to reach the levers. To increase its pick resistance, the inventors also required that the key turn the moveable barrel before the stump on the bolt could enter the gate.

1_3.0 The Race for Security: The Great Exhibition of 1851

Until the eighteenth century, lock designers appeared to be more concerned with creating works of art than of security. Eventually, true craftsmen and scientists applied their talents

to raising the security of locking devices rather than appearance. Chubb, Bramah, Newell, Parsons, and many others improved upon designs and received patents for concepts that can be found in use today. A public rivalry developed between inventors, in a constant quest for greater security against picking. Public contests were held as new inventions were introduced. The masters pitted their lock-picking skills against one another in an attempt to defeat each new innovation. This intense competition was responsible for many of the significant improvements in certain lock designs which previously had not changed in three thousand years. The most famous of these contests was held at the London Exhibition in 1851.



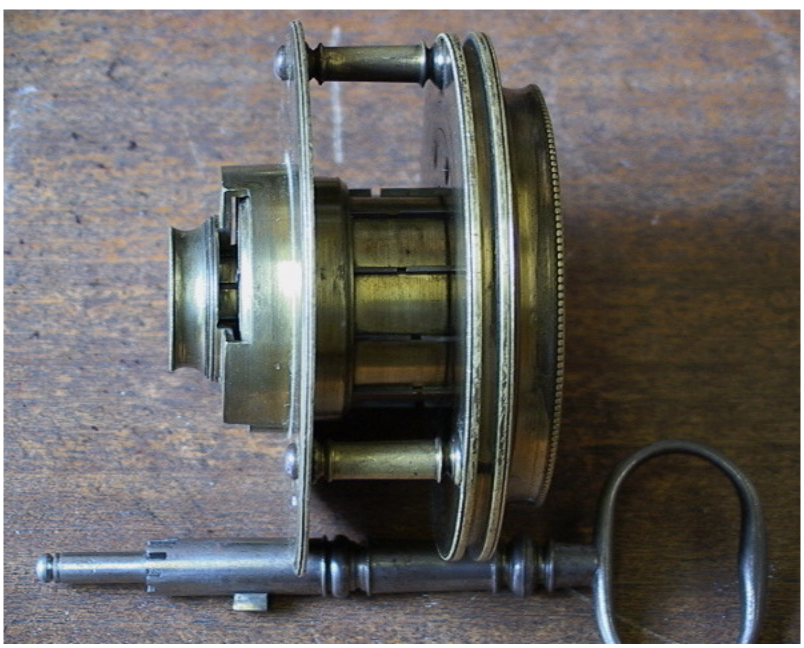
Figure LSS+118 The Bramah lock that was successfully opened by Alfred Hobbs.

The London Exhibition occurred at the peak of British industrial power. Because Britain was noted as the "workshop of the world," the English decided that they needed a chance to show their products and technology. This was an effort to bolster trade and to demonstrate that their varied technology ranked favorably with their foreign competitors. The exhibition was an epic event. Its catalog, running hundreds of pages, described commodities and technologies, with diversity that included steel furnaces, pottery, firearms, and locks. Locomotives, steam hammers, sewing machines, musical instruments, photographic equipment, and every other significant product and process available was on display. In the context of locks and keys, the exhibition was a great

success. Public confidence in the locks of the day was high, especially as each new improvement was introduced, and the difficulties of defeating these inventions was demonstrated to the public. The exhibition gave lock makers a chance to offer rewards to anyone who could pick their wares, and thus, they were able to show the security of their devices.

Alfred Hobbs was able to bypass the Bramah lock. Courtesy of Hans Mejlshede.

The high point of the exhibition was the offer of two hundred pounds by the Bramah Company to the person who could successfully open their pickproof lock. It will be remembered that this lock, originally developed some fifty years before, had remained one of the most secure in the world; nobody had succeeded in manipulating it open. Then Alfred Charles Hobbs arrived from America. Hobbs announced that he could easily pick the most difficult of lever locks, the one made by Bramah. Of course, he was scoffed. But he persisted. The Bramah Company finally set up an impartial panel of judges, gave him a sample of their lock, many blank keys, a place to work, and thirty days in which to crack the invincible device. While the two hundred pound reward was a great deal of money, the company believed that they had nothing to lose, since no one had been able to break the lock.



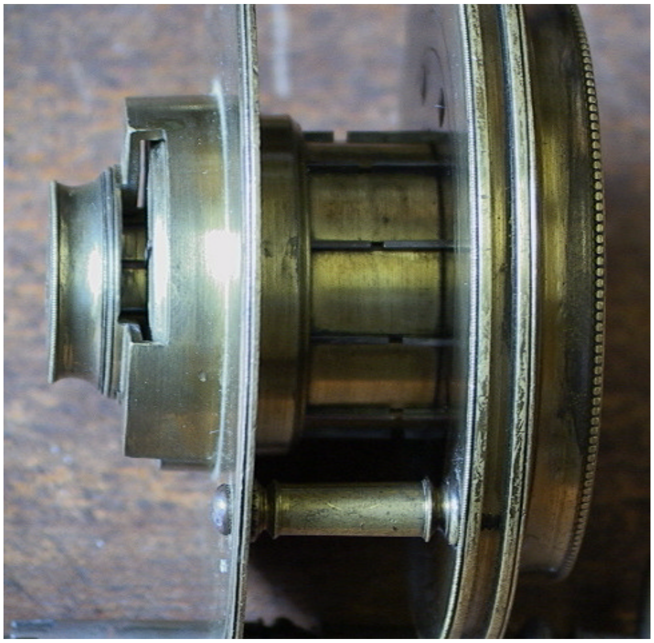


Figure LSS+119 The Bramah lock utilized a series of sliders that were depressed and aligned with two fixed curved "fences." The sliders that are shown were moved forward by the key so that all of their gates fell directly under the fixed fence, which resembled two arc rings that prevented the lock from rotating until the sliders were in the correct position. The "fence" had multiple slots corresponding with the position of each slider..

Hobbs diligently worked at his task. One day he would spend many hours at his workbench, another only minutes. At the end of twenty-four days, he summoned the judges. With his observers watching, Hobbs confidently took the key he had made, inserted it into the lock, and unlocked the mechanism. The judges were incredulous. The lock makers claimed that it was a trick or that it was just luck. So he relocked the lock, opened it, and again relocked it, all very easily. Nevertheless, said the manufacturer, the mechanism is surely damaged. Not so, Hobbs claimed. To the chagrin of Bramah, the most secure lock of the time had been defeated. The task was clear: a new, more secure device had to be developed. Both American and English locksmiths took up the challenge. In 1861, the answer came in the form of the Yale pin tumbler, which today is used throughout the world. Its development revolutionized the lock-making industry as the lever lock had done a hundred years before.

LSS101: Interview with Jeremy Bramah

It is interesting to note that Hobbs never disclosed to the Bramah Company precisely how he was able to open the lock. In an interview with the author, Jeremy Bramah, (a direct descendent of

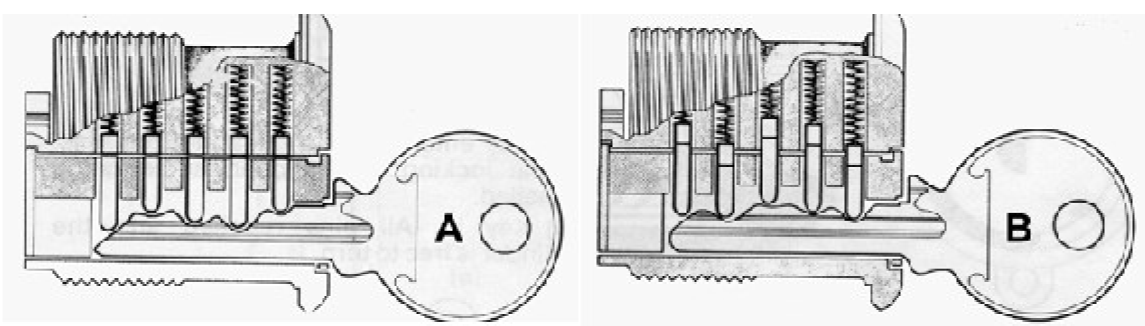
Joseph Bramah and present owner of the company) indicated that Joseph Bramah had died several years before his lock was bypassed by Hobbs, and so was not available to analyze just how Hobbs performed his feat. The company felt that Hobbs had used some form of trick to open the lock, and that the competition was unfair.

After a careful examination of the original lock, it is the author's conclusion that Hobbs decoded the slider position in much the same fashion that John Falle constructed his pin and cam system to read minute tolerance variations. It would have been relatively easy for Hobbs to determine the play between the gate within each slider, and the barrier that formed a fence, and then to construct a key.

The Chicago Tubar lock and many other variations of the sidebar mechanism can be viewed as an offshoot of the original Bramah lock. In the case of the Tubar, the sliders were replaced with two rows of four pins with gates cut into the lateral area of the pin. In the Bramah lock, the "sidebar" is comprised of two fixed rings that block the movement of the sliders. In the Tubar, the sidebars are moveable; however, they perform the same function. See the accompanying video of the interview with Jeremy Bramah.

1_4.0 Yale Pin Tumbler Lock: 1861

Linus Yale, Sr., was born in Middletown, Connecticut, in 1797. He was an ingenious and successful inventor and manufacturer of bank locks. His son Linus Yale, Jr. was born in 1821; he began his career as an artist. First developed by Yale in 1844, the pin tumbler mechanism was refined and presented to the public by Yale, Jr., in 1861. Between 1860 and 1868, Yale, Jr., conceived and produced the now familiar cylinder and incorporated most of the refinements which exist today.



The lock worked on the same basic principle as its ancient

Egyptian predecessor, using several small pins to block the movement of the bolt. A small key provided greater security while at the same time offering many thousands of combinations. The major difference between this lock and that of the Egyptians was that the Yale device was smaller and was manufactured to close tolerances. In addition, the lock utilized a small, flat steel key, cut with several grooves. These grooves would line up with the internal pins. The Yale lock had a number of spring-biased pin tumblers, each in two parts or segments that were set in line with the key. Once inserted, its serrated upper edge would raise each pin to the correct height, so that the plug could be turned. Tolerances were such that a difference of .02" in pin length would be sufficient to prevent rotation.

Linus Yale, Jr., is credited with actually making the modern pin tumbler lock available to the public. Although he was never in partnership with his father, he followed in his father's tradition, designing and making locks in his own factory. He succeeded at improving his father's original design, ultimately allowing it to be mass produced. For the first time in history, Yale's lock made possible large-scale use of a secure locking device at a modest price. It was produced in many forms and allowed complex keying systems to be introduced. Today's locks are but a refinement of the original Yale pin tumbler design.

In 1868, Linus Yale, Sr., died. In the same year, his son took on as an associate, Henry Towne. As a young engineer, he had worked in Port Richmond Ironworks during the Civil War, then went to Paris to study at the Sorbonne. In 1883, the Yale Lock Manufacturing Company became the **Yale and Towne Manufacturing Company**. It is now known as Eaton, Yale, and Towne, Inc.

1_5.0 Disc Tumbler Lock: 1890

The modern disc or flat-tumbler lock was originally introduced in England in 1890 and was later refined in the United States. It has wide acceptance today in many low to medium security applications, ranging from vending machines, to desk locks, to key switch locks.

1_6.0 Knobset Locks: 1919

W.R. Schlage introduced the Knobset in England in 1919. It provided the basic design for the key-in-knob lock, found today in most homes and offices. Ultimately, Schlage would found one

of the largest manufacturing facilities in the world.

1_7.0 Sidebar Lock: 1935

Briggs and Stratton introduced the sidebar in 1935 for use in the automobile. The design of this lock was a radical departure in mechanisms employing wafer tumblers and remained impervious to bypass for almost fifty years. The sidebar design has been incorporated into pin tumbler and other types of locks, to provide a high level of security against picking.

1_8.0 Lock Developments of the Past Fifty Years

Improvements in designs, combinations of technologies, introduction of electronics, sophisticated metals and production techniques have occurred within the past fifty years. These improvements are surveyed in **Chapter 2**.

1_8.1 From Blacksmith to Locksmith: The Development of the Locksmithing Profession

Locksmithing is one of the oldest handicrafts known to civilized man. Long before the great Pyramids were built, blacksmiths plied their trade in Egypt, Babylon, Assyria and China. For four thousand years, their primary mission has been to design and construct locks that would make picking and bypass difficult.

1_8.1.1 Guilds in Europe

The traditions and customs of locksmithing, as it is known today, are derived from the great medieval **guilds** of locksmiths which had their formation during the Middle Ages. The guild was the all-powerful force. It regulated everything from the terms of apprenticeship, the rules and conduct for journeymen, and the techniques of the masters, to prices, and the number of rivets that could be placed in a lock. The guild was the supreme master over the craft; the penalty for defiance was expulsion and the loss of the right to earn a living as a locksmith.

Of course, in the earlier days, the strictness of the guild masters helped maintain the integrity of the locksmith's trade.

Like all autocratic and dictatorial organizations, however, guilds became overbearing, jealous of power, and unwilling to advance. The locksmith trade became a father-to-son enterprise and remained so until the end of the eighteenth century. This is one of the reasons that lock design did not progress much beyond the creation of intricate artistic patterns while the guild was so active. Lock making would have to wait until the Industrial Revolution before utility designs and mass production techniques were employed.

The Renaissance was a humanistic revival of learning that originated in Italy in the fourteenth century and marked the transition from medieval to modern times. While the rest of the world awakened to the wonders of science, art, and engineering during this period, locksmiths amused themselves and their customers with trick locks and fancy designs. For hundreds of years, the locksmith's stock in trade consisted of false keyholes, false wards and many "gingerbread" designs. Chests that cut off fingers, fired shots, ejected murderous knives, or other exotic devices were the order of the day.

As has been previously described, only one notable improvement was added to locks during the Renaissance: the lever tumbler was introduced. Amazingly, the lever principle was never fully appreciated by Renaissance locksmiths, who simply handed it down to their more skillful heirs of the nineteenth century.

1_8.1.2 American Locksmiths

In America, old-guild traditions and customs did not fetter locksmithing. Rather, they took full advantage of the advanced mechanical knowledge of the day and produced masterpieces of precision and security. As has been noted, the two primary contributors to nineteenth-century American lock technology were Yale and Sargent. As mass-production methods were introduced, the locksmithing craft broke into two distinct groups: lock makers and lock repairmen. The manufacturing end of the business became a highly technical and complex function, leading to the creation of multimillion dollar giant manufacturing organizations. The term "locksmith" now refers to the repairman rather than the manufacturer of locks.

Several inventions increased the scope and efficiency of locksmiths. The first of these, the **key duplicating machine**, was invented by Henry Gussman in 1909. his machine ended the drudgery of hand filing and made accurate reproduction of keys within a

matter of minutes a practical reality. The next significant advance was the development of the **code machine** in 1926 by the engineers of the Independent Lock Company. This device created new opportunities for locksmiths, because it enabled them to make keys according to the "serial number" of the lock.

Many inventions and devices designed to make locksmithing more lucrative and technically advanced have been introduced in recent years. The trade will be forever indebted to men like H. Hoffman and Jerry Hoffman, Ted Johnstone, Eli Epstein, Nick Gartner, Harry and Clayton Miller, S.A. McClean, the Chubb Group in England, and scores of others. Their tools, devices and methods have become standard in the locksmith industry. Locksmithing in America is a vital, growing field. The industry has formed significant international trade associations. These include the Associated Locksmiths of America **ALOA**, Safe and Vault Technicians Association **SAVTA**, and National Safemans Organization **NSO**. They all have raised the level of proficiency of the entire profession by offering educational and certification programs to insure the competence of the industry.

Specialized schools in the United States provide excellent technical manuals and on-site training for locksmiths of all skill levels. The **HPC Learning Center** in Chicago, as well as **MBA and Lockmasters**, both in Lexington, Kentucky, lead the industry in their educational programs for the professional lock and safe technician. With modern techniques, scientific tools, and continuing education, the locksmith profession has progressed from a small handcraft to a flourishing service industry.

Locksmith training in Denmark, in comparison to the United States. Courtesy of Hans Mejlshede.

CHAPTER TWO: RECENT DEVELOPMENTS

The Last Twenty-Five Years

2_1.0 Advances in Security

The first edition of ***Locks, Safes, and Security*** was written in 1970. At that time, there were really only two "new technology" high-security cylinders available in the U.S. market: the Keso dimple lock and the Medeco sidebar rotating tumbler lock. Twenty-five years ago, the market for locks in the United States

was primarily supplied and supported by American manufactured products. Simply stated, locks sold in America were made in America. Today, the market for locks is international, with U.S. companies manufacturing and selling their products throughout the world. More importantly, vendors from many countries produce or offer their wares to the U.S. consumer. Security requirements and standards are now formulated and adopted on an international basis.

When the first edition of this book was published, automatic teller machines were just beginning to appear. Magnetic stripes on credit cards had recently been developed, and the use of computerized access control systems and high-security locks were not yet popular. Neither Corporate America, nor the general public was as security conscious as today. But then, the problems of international terrorism, theft, sabotage, and issues relating to overall security were not as serious, either. There were no personal computers (PCs), nor hackers or high-tech thieves. Modems and fax machines were not prevalent, and cellular was still in the minds of Bell Laboratory engineers. Medeco had introduced the most sophisticated lock in the late 1960s, based upon a patent granted for the innovative rotating tumbler and sidebar. This lock set the standard for high-security mechanisms and retains its superiority to this day.

During the past quarter century, many developments have dramatically affected the lock and security industry. Optics, magnetics, RF and induced fields, electronics, tiny microprocessors, and sophisticated mechanical designs utilizing new alloys and materials have emerged to become standard implements in the arsenal of security hardware. These devices, including locks and safes, enable government, commercial, and the private consumer to reap the benefits of technology in their quest for security. The integrated circuit, surface mount technology, and many spin-offs from the space program offer manufacturers the option to design and produce any desired product.

Perhaps the greatest advance has been in the integration of computers with mechanical locking devices. The use of microprocessors has made possible an incredible array of security features that are now required in the modern work environment. Options such as multiple levels of access control based upon security clearance, location, time of day, and direction of entry or exit, can all be provided simply and economically. Detailed audit functions, supervisory control, and remote authentication

are standard items.

Security and sophistication of master key systems has been greatly enhanced. The use of computer-based control can allow an infinite number of key combinations, without cross-keying problems associated with earlier and less complex systems. It is not unusual for a large physical facility to have 100,000 or more master keyed cylinders with incredibly complex keying requirements, without any loss of security that was typical in older systems. In today's market, one may find low-priced to highly sophisticated and expensive locks, alarms, and enclosures. There is a product to meet virtually every need and budget. If a desired product cannot be found in America, then it surely can be obtained in Europe or the Orient. Security requirements are now universal, and manufacturers from every part of the globe are scrambling for the business.

The author has observed certain design trends since the original edition of this book was published, the most significant of which are outlined below. Harry Miller, the genius behind the Sargent & Greenleaf Company for over thirty years, recognized early in his career that very few entirely new inventions were conceived. Rather, **new combinations** of old ideas were what drove most industries, especially the security industry. Today, one may find ideas incorporated in products that were originally introduced many years ago. Their application in new devices attests to the soundness of the original concept and to the sophistication and diversity of the marketplace.

The sidebar lock is a prime example. Originally developed by Briggs and Stratton in 1935 for use in cars, it has not only remained the standard for the automotive industry, but several high-security cylinder manufacturers have adopted the basic idea. Thus, the original premise is now the basis of designs by General Motors and Ford, as well as by Medeco, Assa, Schlage, Ikon, and others. Sidebar locks provide extremely high-security, if designed correctly. Many variations of the original principle can be found that offer sophisticated keying and pick resistance. They have become popular in government and commercial installations, where key control, resistance to physical attack, and other criteria are important.

Other major innovations have occurred in both pin tumbler and wafer locks. Dimple locks, first introduced and patented by Keso in a high-security configuration, have become extremely popular and are presently manufactured by many vendors throughout the

world. Mul-T-Lock of Israel, Keso of Switzerland, DOM of Germany, and others have improved upon the original design introduced twenty-five years ago. Now, for example, telescoping tumblers are utilized for increased pick resistance. These locks, utilizing from four to twelve or more pins, can be very difficult to pick, although some may be impressioned.

Magnetic locks have become prevalent within the past twenty years as an adjunct or alternative to the pin tumbler principle. Although there are a number of different schemes employed, the basic theory is the same in all such devices: like poles repel and opposite poles attract. The magnetic locking principle has been applied in conventional as well as high-security cylinders. Probably the most clever and unique cylinder design was developed by Evva in Austria and produced under license by Ikon in Berlin, Germany. This lock utilizes two rows of four round, freely rotating disc magnets which control two sidebars. Corresponding embedded magnets within the proper key will cause individual rotation of the discs within the lock, so that they align properly to allow sidebars to engage.

The magnetic locking principle has also been applied to card locks both for access control and higher-security applications. A pioneer in the industry, Corkey of Hong Kong devised and patented a lock that utilized up to 42 magnetic pins. These had to be lifted by corresponding magnetized spots in a barium-ferrite vinyl card inserted into the lock. The security of this, and similar mechanisms, is based upon the location and polarity of each of the magnets. Card locks utilizing magnetic pins as in the Corkey and magnetic stripes such as found on credit cards have become popular, especially in the hotel industry. Hoteliers have recognized increased security needs, stemming from losses by their hotel guests that have translated into large money judgments against the hotel. The flood of litigation has forced the industry to install specialized locking systems, even in the smallest inn.

Hotels throughout the world now utilize a wide array of locking systems, all designed to provide access control, security, and ease of key change. As noted later in this text, many of these systems provide key control but not security. The hotel guest will find locks that utilize magnetic stripes on credit cards, cards with magnetic spots hidden throughout the card surface, and cards with holes punched in various locations. Door locks in these hotels will read cards utilizing infrared optics, magnetic readers, magnetic pins, or other technologies that did not even

exist twenty-five years ago.

Instant rekey locks, such as offered by Winfield, are also popular. Introduced in the late 1970s, they allow maintenance staff to instantly rekey a cylinder, either to a different guest key or to a different master key.

Electronic access control systems have become extremely popular. Keypads are utilized at entry points and allow secure control of mechanical locks and strikes. There are many systems to choose from, both domestically and in Europe.

Developments by Medeco, LaGard, Hirsch, Mas-Hamilton, Evva, Keso, DOM, Ikon, S&G, Ford, GM, and a host of other companies throughout the world have provided the industry with innovative approaches to access control utilizing microprocessors and transducers embedded in keys. These electronic systems offer excellent flexibility, allowing customers to define exactly who, when, where, and how an employee shall gain access.

Locks based upon RF induced fields have also become popular in access control and automotive applications. These devices sense proximity through the use of passive transponders that receive a coded signal, then rebroadcast that signal at a different frequency back to the initiating station. Transponders are now built into keys, credit cards, and other similar wafer-sized devices.

In the realm of safes and vaults, three dramatic advancements and innovations have occurred within the past ten years. In 1987, Chubb Research and Development, in Wolverhampton, England, developed and patented a process and materials that would allow the company to offer an all-plastic fire and burglary-resistant safe. The product, called the "Planet", will protect the contents for one hour, at 1800°F. In addition, the special plastic resin is extremely resistant to most forms of penetration. This is the only fire and burglary-resistant safe available in the world as of 1993. The materials utilized by Chubb may be poured into any configuration and are already being utilized in certain other specialized applications.

The electronic combination lock patented in 1991 by the Mas-Hamilton Group, in Lexington, Kentucky, is the second major development to occur involving safes. The X-07, in the view of the author, is perhaps the most innovative enhancement within the safe and vault industry since the time lock was introduced over

one hundred and fifty years ago. The product was originally conceived and developed by an award-winning team of designers, including Clayton Miller and Jerry Dawson, and has set the world standard for a computer-controlled lock. Clayton Miller, who ran Lockmasters school in Nicholasville, Kentucky, is an internationally recognized expert in the field of safes and vaults. His father, Harry Miller, is regarded as the dean of the combination lock industry in the last half century. No doubt, Harry Miller's influence contributed to the design of the X-07.

What Miller, Dawson, and others accomplished in their design would completely revolutionize mechanical-based three and four-wheel combination locks. The configuration relies upon an on-board computer, powered by three generators, driven by the dial as it is turned. Thus, no batteries are required. One million actual combinations are available without compromise of security. The lock allows for a number of audit and control functions and will surely set the standard in the industry for the next hundred years. To date, eleven United States government agencies have evaluated the lock and concluded that it cannot be manipulated or compromised. It is the only lock to receive DoD approval, to date, as a Group 1 rated device for top security enclosures.

The third major development in the safe and vault industry is a direct result of the introduction of the Mas-Hamilton X-07 lock. Computerized robot dialers and manipulation devices have become available within the past five years. These are typically comprised of a sophisticated computer-based portable servo stepper-motor that is attached to the dial. They will test every possible combination within preset parameters, in forty-five minutes to eighty hours, for a three-wheel lock. The electronic combination lock was developed as a response to these devices and cannot be manipulated or auto-dialed like conventional mechanical locks. Mas-Hamilton is developing its own manipulation robot, which may be capable of opening both Group 1 and Group 2 locks, utilizing advanced optical computer links to sense sound and dial rotation.

A number of very sophisticated picking, impressioning, and decoding tools have appeared within the past twenty years, introduced by HPC, MBA, John Falle, Lockmasters, Jeff Cookson, and other vendors. Although many companies offer such tools worldwide, the leaders in the industry are undoubtedly HPC for the commercial sector and John Falle for government applications. Jerry Hoffman, at HPC, is well known in the trade. He has

developed an extensive product line that is marketed throughout the world. His company, which was originally begun in the 1930s by his father, is recognized for their innovative approach to serve the locksmith industry.

Today, a rich diversity of complex tools is offered to the professional locksmith to decode, pick, and impression almost any lock. They are described in detail throughout this text. HPC, ILCO, and Silca of Italy have lead the industry in the development of sophisticated, computer-based key-cutting machines, since 1965. These companies produce machines to read and duplicate virtually any type of key, including the three-sided "laser" or "sidewinder" used on certain foreign automobiles. Silca has even developed an attachment to one of their machines to laser-read a key and reproduce it to original factory code standard. HPC, in conjunction with LaGard, has introduced a number of key cutters and decoders that have become invaluable aids to the industry and have allowed code cutting to become the preferred method of reproducing keys. The HPC 1200 and Codemax are perhaps the best-known code machines in the world and most accepted by the American locksmithing industry.

A number of tools, chemicals, and techniques have become available within the last twenty-five years for use in forced-entry applications involving safes, vaults, and buildings. Probably the best known of these is the thermic lance. Initially developed for underwater applications in shipbuilding and repair, a lance will generate up to 10,000°F, which can be delivered without danger to the operator. A thermic lance manufactured by Broco, in Rialto, California can be handheld and can precisely cut, pierce, or gouge to or through virtually any material. The lance will cut 2″ steel in a matter of a few seconds, effortlessly. They are equally effective at penetrating concrete and cinder block to gain access to buildings.

Advances in explosives have also been made since the first edition of this book. Many varieties of plastique and flexible placed charges are now available to cut precise holes in almost any material. Advances in microcircuits brought about by the requirements of NASA, has allowed alarm technology to take a quantum leap forward during the past two decades. Sophisticated motion detectors, utilizing microwave and infrared technology, have become common, as have a host of other alarm-sensing devices, based upon on-board microprocessors.

Since 1970, sophisticated new penetration techniques, based upon

the use of computers, robots, radioscopic imaging, fiber optics, ultrasonic, and highly sensitive sensing equipment, have been developed for looking into containers and locks and for compromising them.

Since the last printing of this book, the professional locksmith trade has become a craft of highly skilled technicians, requiring a diverse amount of knowledge to properly service and open the myriad of locks and containers in use today. Continuing education is a requirement in order to remain competent in this rapidly changing field. A skilled locksmith must now have an understanding of electronics, mechanics, and manipulation and bypass techniques for many types of locking mechanisms, if he is to perform properly in today's environment.

The professional locksmiths of the world are today required to be college graduates and businessmen. They must be specially schooled in the trade, educated regarding complicated products and capabilities, and able to evaluate, recommend, install, and service a great many different products and needs. Locksmiths are now security technicians. International locksmith organizations and schools have developed special programs over the past twenty-five years to meet the needs of the profession and insure that its technicians have available the latest information regarding new products and techniques. ALOA, HPC, MBA, and Lockmasters, as well as many manufacturers have been driving forces in providing such technical support.

Finally, international standards in security hardware are being proposed and adopted. Major organizations throughout the world are agreeing upon criteria for the testing of materials, security, bypass, manipulation, forced-entry, and other requirements for locks and enclosures. Underwriters Laboratories (UL), the British Standards Institute (BSI), the International Standards Organization (ISO), American National Standards Institute (ANSI), American Society for the Testing of Materials (ASTM), and many other organizations have all contributed to the development of accepted standards for manufacturers. This book will detail both the history and current state-of-the-art in locks, safes, and security.

CHAPTER THREE: TERMINOLOGY

Definition of Terms

Master Exhibit Summary

3_1.0 Definitions

The lock, safe, and security industry has developed jargon to describe and define its products and product-component parts. Although there is some difference in terminology throughout the world, there is general agreement regarding the major elements within most of the primary locking systems. In order to assist the reader in understanding the materials presented throughout this text, a basic definition of general terms is presented in this chapter. Specialized definitions applicable to materials within a specific chapter are presented within that chapter. A clearer understanding of detailed material can be achieved using this format. If you are searching for a definition or

identification of a component that is not explained in this chapter, check the Index and perform an advanced search query. The etymology of certain terms is presented within the definition where relevant.

Ace Lock: A term often used to describe an axial pin tumbler or tubular lock. Ace is a registered trademark of Chicago Lock Company, the first to introduce the mechanism.



LSS+301 An axial pin tumbler lock

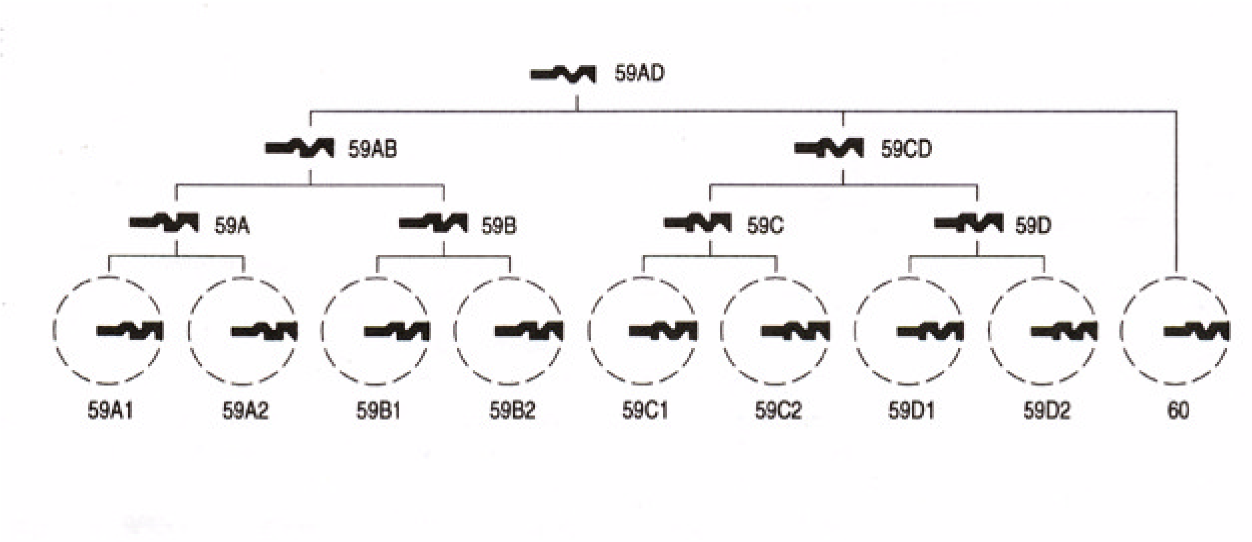
Actuator: A device or extension that is usually connected to the movable component of a cylinder or lock that in turn causes a mechanical locking component to activate or deactivate. Such can be a tailpiece, cam, bolt or other linkage.

Adjustable Mortise Cylinder: Certain mortise cylinders can be physically adjusted to compensate and precisely fit doors of varying thickness. A **flexible head mortise cylinder** can be extended against spring pressure to make it slightly longer.

AFTE: Association of Firearms and Toolmark Examiners. This is the professional group of technicians, criminalists, and scientists that perform forensic examinations in crime laboratories.

AHC: Architectural Hardware Consultant, as certified by the Door and Hardware **Institute.**

All-Section Key Blank: That portion of the blank that enters all keyways within a multiplex key system. In the diagram, keyway 59AD will enter all subsections.



ALOA(51): Associated Locksmiths of America. This is the largest locksmith trade group in the United States.

Angularly-Bitted Key: A key in which one or more bitting angles are not cut in a parallel plane, but rather at different degrees of rotation from a perpendicular angle.

ANSI: American National Standards Institute

Arc Ring: A ring that is also called a circlip, with open ends that can be sprung into place to retain a plug within the shell of a lock.

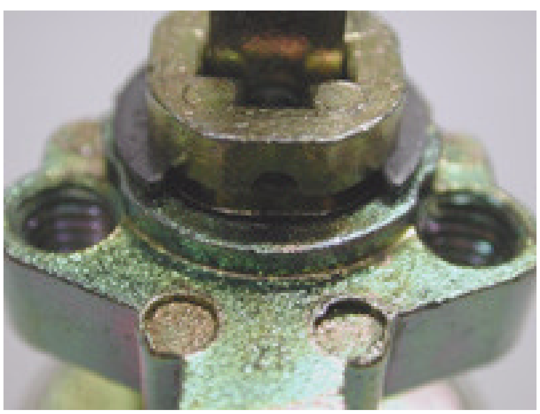


Figure LSS+302 An arc ring retains the core.

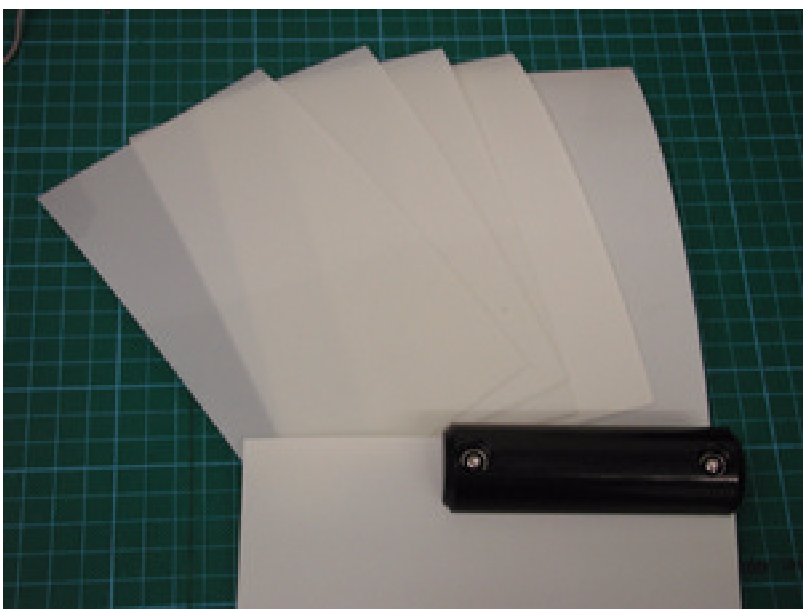
ASIS: American Society for Industrial Security. This is the largest professional security organization in the world.

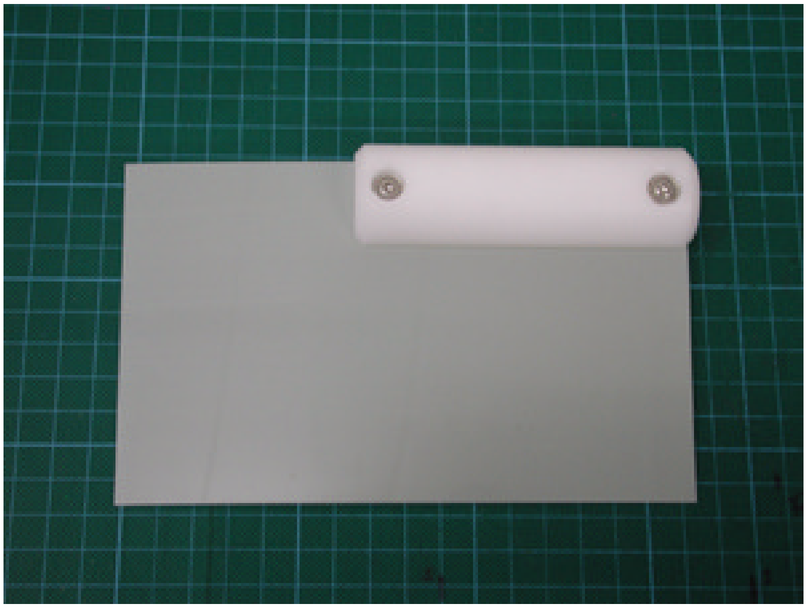
ASTM: American Society for Testing and Materials.

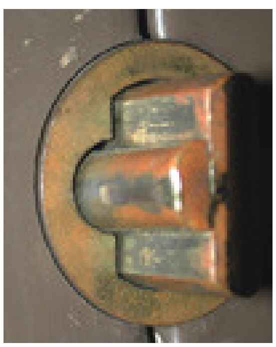
Astragal: A molding that is used to cover the space between two doors that meet at a common closing point.

Auxiliary Deadlock Latch Bolt: An additional bolt is provided that is depressed by the strike when the door is closed to automatically deadlock the bolt against end pressure. The diagram shows the two states (left) fully extended in the unlocked position, and (right) secondary bolt depressed to block retraction of the primary bolt. A loid, such as produced by MSC and shown below, can be utilized to force the bolt to retract in the absence of a secondary bolt. A demonstration of the MSC loid is provided in LSS203.

LSS203: Demonstration of the use of a loid, by MSC









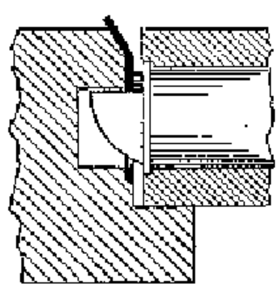


Figure LSS+303 An auxiliary deadlock latchbolt provides secondary protection against loiding. A plastic loid, produced by MSC (Germany) is shown above.

Backset: The lateral distance from the outside edge of the strike plate or face plate on the door, and the center of the keyway.

Ball Bearing: A metal ball that is placed in the pin stack in

some locks for specialized keying systems such as hotel or construction, or as a portion of the bottom pin stack in one or more chambers.

Balanced Driver: A top pin length that is varried for each chamber, and which is based upon the total length of the bottom pins. The function of the balanced driver, also referred to as **compensation driver** or **graduated driver**, is to make the overall pinstack length constant between chambers. Best locks, for example, require that the overall pinstack length for each chamber be 23 depths.

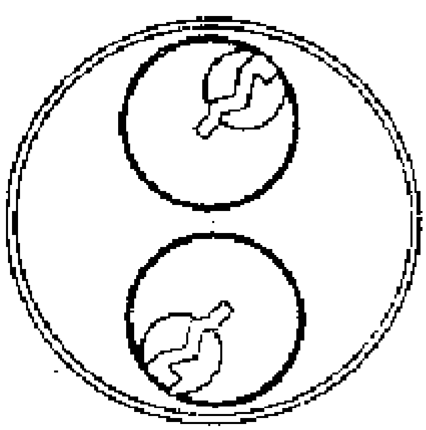
Barrel bolt: A locking bolt that is surface mounted on the door.

Bell-type Key: A key with longitudinal grooves that often run the entire length of the key. See also **Lasertrack** and **sidewinder** keys.

BHMA: Builders Hardware Manufacturers Association

Bible: That portion of the lock that contains the pin chambers.

Bicentric Cylinder: A cylinder containing two separate plugs, generally with two different keyways.



Bi-directional Cylinder: A cylinder that allows operation by rotating the plug in both directions.

Binary Cut Key: A key that allow for only two bitting depths for each position: cut or no-cut. The Winfield lock and the Schlage

wafer lock, described elsewhere in this text, are two examples. Such keys are used in **binary cylinders** or locks.

Bit or Bitting: That portion of the key that contains depth cuts corresponding to the tumblers in the lock. It can also be defined as the blade portion of the key, usually in a warded or lever lock.

Bitting: It is those portions of the key that contains depth and space information that corresponds to wards, wafers, levers, or pin tumblers. The bitting interacts with the internal locking components and is contained within the blade of the key. The term can also refer to the numbers that represent the physical dimensions of the actual cuts, or describe the combination of the key.

Bitting Depth: The depth of a cut made in the bitting, or blade of a key.

Bitting Position: The location of a key cut, with reference to the shoulder or tip of the key.

Blade of Key: That portion of the key that contains the bitting surface. The **bottom** of the blade is opposite to that surface which is cut, and the **top** of the blade is the surface upon which cuts are made. Almost any part of the blade can form a portion of the bitting area, although bitting is generally confined to the upper half of the blade, as shown in the exhibit below. Measurement of the depth of a cut is made from the root to the bottom of the blade, although in some instances a manufacturer may choose to compute from the root to a register groove.

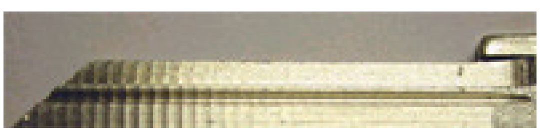
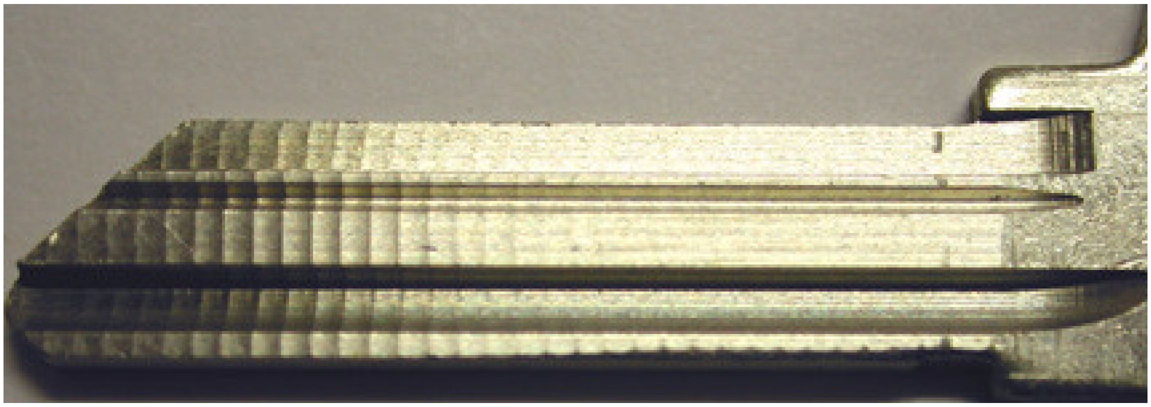


Figure LSS+304 The bitting surface of a blank key is known as the blade.

Blank or Blank Key: A key that has not been cut.


Figure LSS+305 A blank key. All of the material constitutes the blade.

Blind Code: See **indirect code.** This is a code that is unrelated to the direct code of the key.

Bolt: The active external locking component of a lock that secures the moving member to which it is affixed. A **flush mounted** bolt is one that is designed to be equal with the surface of the door and not protruding from it. A **mortised** bolt is one that is installed within the door.

Bogus Key Blank: A non-original knock-off, or bootleg key blank.

Bottom of Blade: In a single bitted key, it is the portion of the blade that is opposite to the cut edge.

Bottom Pin: Any form of tumbler that makes physical contact with the bitting. Its shape may be cylindrical, conical, ball or chisel-pointed at the contact end.

Bow and Bow Stop: The bow is the portion of the key that is held for control and serves as a handle. The bow stop is located near the bow to prevent further forward movement.

Broach: This is a hard steel die that is used to cut the keyway into a plug. The term can also be a verb, indicating the process of cutting, and is described more fully in later chapters.

Bypass Key: A key that operates a cylinder that overrides normal operation.

Cam: The tail-piece, thrower piece, or tongue that is attached to the end of the rotating plug, and is used as the actuator for the locking mechanism. A wafer lock is shown, with cam attached.



Figure LSS+306 The cam transmits rotational energy and forms the locking bolt.

Cam Lock: (shown above) A cam lock comprises the complete locking system, whereby the cam constitutes the locking bolt or mechanism.

Cap: This term has two definitions. It is that part which links and retains the plug to the shell and acts as an actuator. It can also be the spring cover for a single pin chamber.

Case Ward: Within a warded lock, the ward or obstruction that is formed as part of the case. Note the circular bands around the keyhole. Corresponding removal of material from the bitting surface of the key will allow rotation.

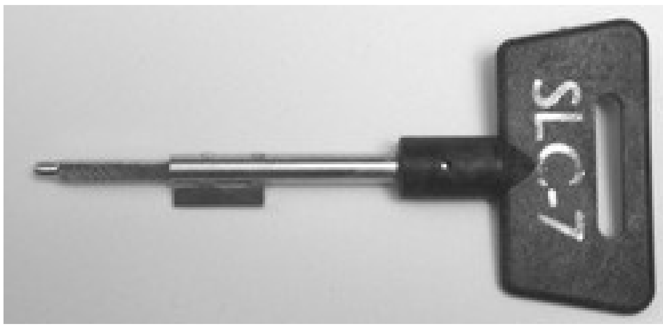


Figure LSS+307 A case ward is integral to the lock body.

Chamber: Any opening, hole, or cavity within the shell or plug of a lock that contains tumblers.

Change Key: The lowest individual level of keying. A lock may

have a change key and several levels of master keys. The term also refers to a special/ key used with combination locks to alter the relationship between the gates and drive pins in each disc within the wheel pack.



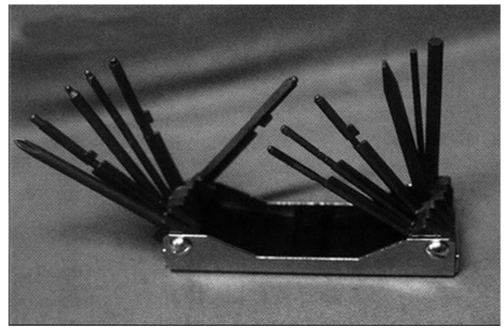


Figure LSS+308 A change key for a combination lock. Complete sets(52) are also available.

Changeable Bit Key: A key that allows for the interchange of the bitting surfaces in order to alter or rearrange its combination.

Chubb: The name of a famous English lock maker who founded a company in 1818 that still exists today. The name Chubb is identified with many revolutionary patents, including the Detector lock.

CK: Symbol for change key or control key.

Clevis: A metal link that is utilized to join a chain to a padlock.

CMK: Construction master key.

Code: A record of the bitting corresponding to a particular key. A "code cut key" is one made from such information, rather than from a physical copy.

Code Original Key: A code cut key that conforms to the lock manufacturer's specifications. Note that the factory direct reading code appears on the key head, and correlates to the depths of each cut, from front to shoulder.

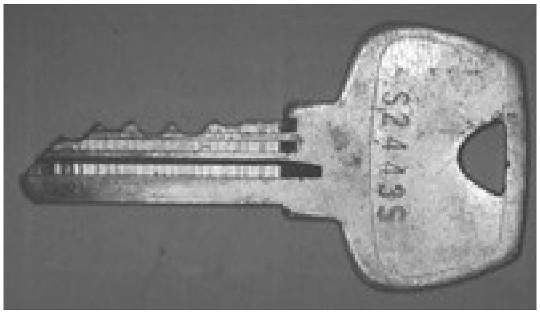


Figure LSS+309 A factory original with a direct reading code.

Combinate or Combination of Lock: The group of bitting which form the various tumbler positions within a lock. Combinating a lock means to set a specific combination. An uncombinated lock is one that is supplied without keys, tumblers, or springs.

Combination or Permutation Lock: The name for a keyless lock utilizing numbers, letters, or symbols. These will correlate to the internal location of gates, the precise alignment of which will allow the lock to open.

Combination Pins: The lower pins within a pin tumbler lock that are utilized to set the individual bitting pattern for a specific lock.

Combination Wafer: A binary disc tumbler that is used in certain key-in-knob wafer locks, such as Schlage.

Compensation Drivers: See also balanced drivers and graduated drivers.

Complementary Keyway: A keyway within a wafer lock that has been master keyed. The design will allow different key sections to make contacts with different areas of the disc.

Composite Keyway: An enlarged keyway that has been designed to accept more than one key section. The keyway may allow sections from several manufacturers to pass the wards.

Compound Bitted Key or Cut: A complex bitting that contains a cut within or overlaid upon another cut.

Concealed Shell Cylinder: Generally a mortise cylinder wherein only the plug face is visible or accesible when properly installed.

Connecting Bar: A bar, rod, or other linkage that transmits motion from the rear of the lock plug to the bolt, latch, or other opening mechanism.

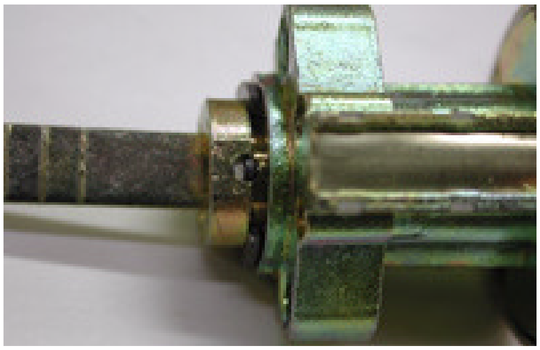


Figure LSS+310 A connecting bar transmits rotational energy to the bolt.

Construction Master Key CMK: A special key that is utilized during the time a building is under construction. Once a building has been completed, such keys will be rendered inoperative. A **construction core**, often keyed alike, may be utilized for this purpose, then removed after the project has been completed.

Control Key: A key that is used for the sole purpose of installation or removal of an interchangeable or removable core from the shell of a lock. The bitting of the key that releases the **control lug** (and the core) is referred to as the **control cut(s)**.

Core: See **Plug**. A core can also consist of all components in the lock (plug, shell, all pins, plug retainer and springs). The core in an interchangeable lock may take the form of a figure eight.

Corrugated Key: A key having longitudinal striations or corrugations corresponding to the locks keyway. These keys are used in warded padlocks.

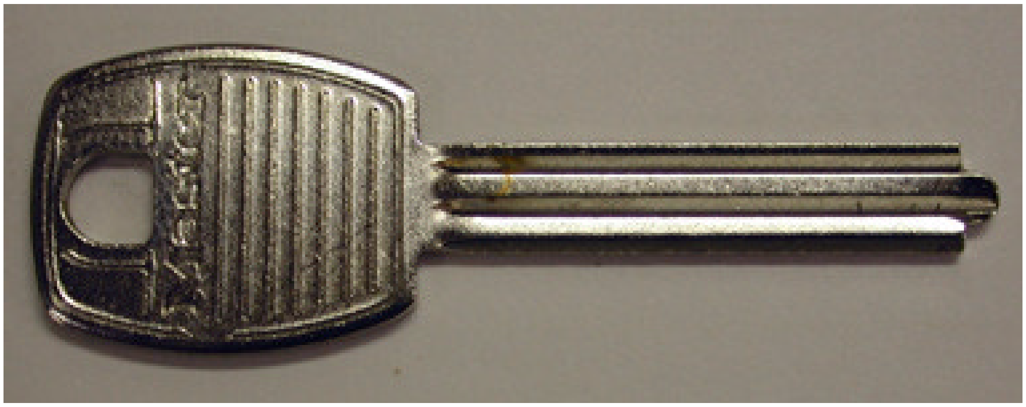


Figure LSS+311 A corrugated key is used primarily in warded padlocks.

CPL: Certified Professional Locksmith (by ALOA.

CPP: Certified Protection Professional (by ASIS.

Cross-Keying: Cross-keying can be described both as intentional (controlled or intended) or as a system keying error (uncontrolled cross-keying) that is caused or created by setting the combination of a master keyed cylinder so as to create one or more virtual shear lines to allow more than one key to operate the lock. Uncontrolled cross-keys may allow unintended or unauthorized keys to open one or more locks, and can also permit two or more different keys that are grouped under higher level keys to operate one cylinder. When a lock is master keyed, many virtual shear lines are created as the result of multiple pins being placed in each pin stack. Each added pin creates another shear line. In a six pin lock with a lower pin and master pin, there would be a total of 64 (2^6) combinations created.

Cruciform Key: A special key bitting design, or keyway that takes the form of a + or X.

CSI: Construction Specifiers Institute.

Cut: An indention, depression, or notch made in the bitting of a key.

Cut Angle: The measurement, expressed in degrees, of the combined angles created by making a cut in a key.

Cut Edge: That area of the key blade that contains the cuts.

Cut Key: A key that contains bittings.

Cut Root: The base or bottom of a key cut. The photograph shows an individual cut of a key for a pin tumbler lock. **"A"** represents the cut angle; **"B"** shows the root or base of the cut. The shape denotes a key that was cut by code.

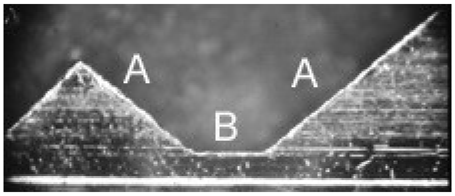


Figure LSS+312 The root of one cut from a pin tumbler key.

Cut Root Shape: The shape of the bottom of a key cut. In the case of a lever tumbler lock, the cut root shape will be flat, having 90° corners. In the **pin tumbler** lock, the shape will usually be curved or angled, as shown in the photograph above (cut root). The root has a specific dimension that may be flat, radiused, or be a perfect "v".

Cutter: The active portion of a key machine that creates bittings. This may also be described as a cutting wheel.

Cylinder: A self-contained lock assembly that consists of the plug, shell, tumblers, springs, plug retainer and tailpiece.

Cylinder Clip: Certain cylinders are secured in place by a spring steel mechanism.

Cylinder Collar: A protective ring, often hardened, that fits around the lock cylinder on the outside of the door on mortise and rim locks. Their function is to provide a mounting surface and protection for the cylinder.

Cylinder Guard: A protective device that forms part of the mounting hardware. It may also be referred to as the **security collar**.

Cylinder Key: A general term that denotes the key for pin and disc tumbler locks.

Cylinder setscrew: The retaining screw that is utilized on a mortise cylinder to secure it in place, and to prevent its rotation and removal.

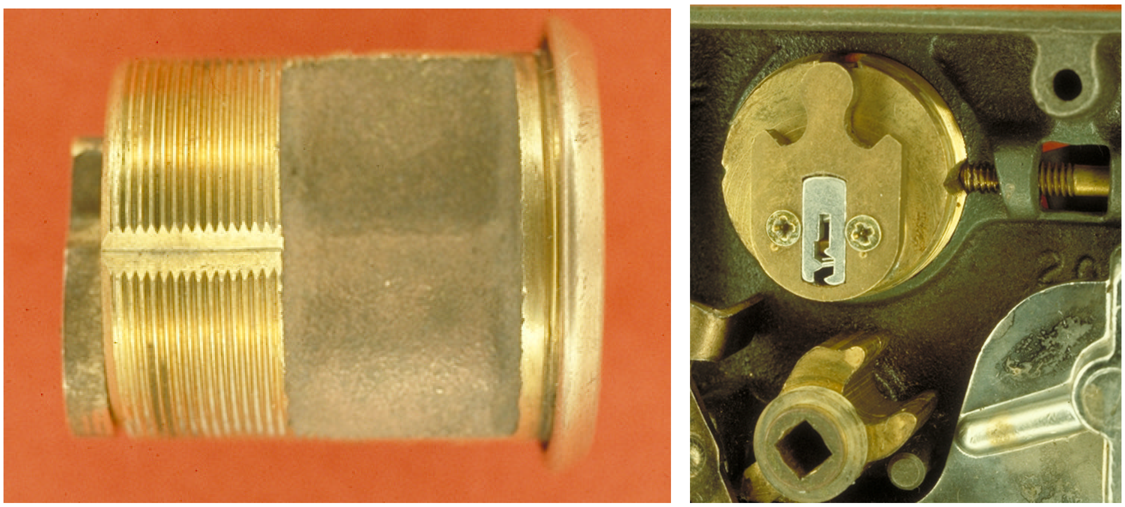


Figure LSS+328 (ISP 49-2963 left, and 50, right). A standard mortise cylinder showing its mounting and retention by setscrew.

Dead bolt: A square-shaped bolt that extends into the strike or recess of the door frame in such a way as to be locked into place, and incapable of retraction as the result of end pressure. In the photograph, a dead bolt that extends three inches is shown.

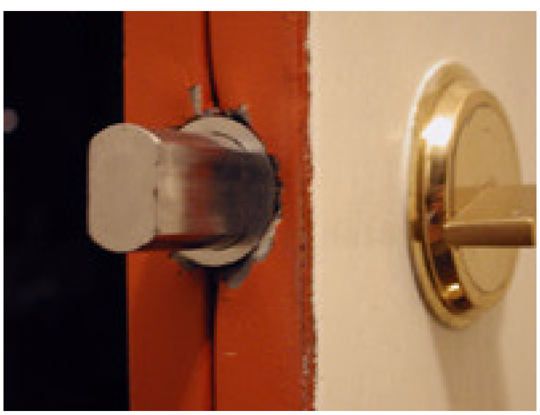


Figure LSS+313 A dead bolt can extend horizontally or vertically from the door.

Declining Step Key: A bitting pattern that contains cuts that progress from shallow to deep from bow to tip. A stair step pattern. It is also referred to as a shedding key.

Decode: To ascertain the bitting or combination of a key or keys that fit a lock by physical measurement, or extrapolation through the use of specialized tools or procedures.

Degree of Rotation: Certain high security locks such as Medeco provide for the rotation of cuts made into the key blade. The degree of rotation specifies the angle of the cut and is referenced from the perpendicular. Medeco defines three angles: right (R or 2), left (L or 1), and center (perpendicular or C).

Depth Key Set: A set of reference keys made for a specific lock that provide complete depth and spacing measurements. A key can be duplicated from such a reference. Each key within the set is cut so that all bitting positions are the same, with the proper spacing between positions. One key is cut for each depth.

Derived Series: A series of indirect or blind codes that represent bittings that are directly related to those contained in another bitting list.

DHI: Door and Hardware Institute.

Differs and Differing: The term "differing" originated in England and refers to the designated change key that fits a lock. It also describes the number of different possible combinations and numbers of change keys that can theoretically open the same lock. The number of wards, levers, pins, discs, design of the keyway, and tolerances determine "differs". Although the number is mathematically based, it is not absolute. Differing is also affected by the method of cutting a key. The number of combinations may be increased by complex lock design, utilizing for example, magnetic and mechanical locking action, or standard pin tumbler combined with a sidebar. The author prefers the term "differs" for use in this text to denote possible combinations, although other terms are accepted. The **theoretical number of key changes** or combinations may greatly exceed the actual number of useable differs.

Dimple Key: A key in which the cuts are produced by drilling holes and removing material from the bitting surface. In the photograph, a Sargent Keso key that is cut on three surfaces. The depressions are called "dimples."

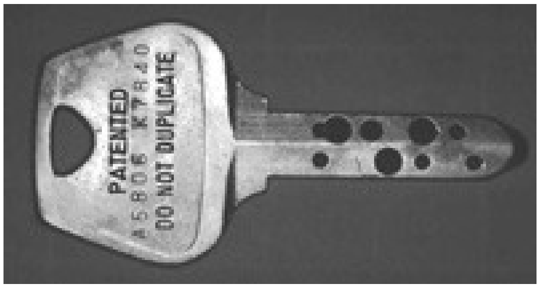


Figure LSS+314 A Sargent Keso dimple lock requires a key with three active surfaces.

Direct Code: See **code.** A direct code corresponds precisely to the bitting patern of the key. The code designates a bitting depth for each chamber that correlates directly with the measurement of each pin.

Disc Tumbler: A flat metal tumbler utilized in a variety of cam locks to retain the plug in a fixed position until the proper key is inserted. The term can also refer to a tumbler, usually flat and rectangular, that contains a gate that must be aligned to one or more sidebars by the proper key.

Double-Bitted Key: A key that is cut on two surfaces, usually opposite each other. These surfaces meet the internal mechanism of the lock.

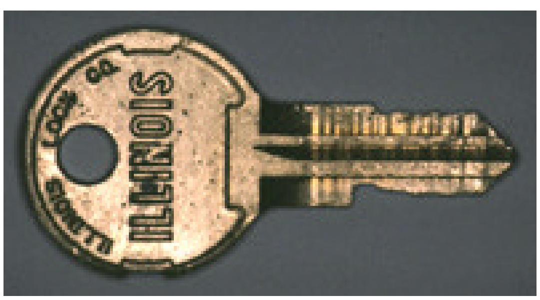


Figure LSS+315 A double-bitted key. Note bitting on both vertical surfaces.

Double Pin: When two or more master pins or wafers are placed within one chamber, the lock is said to be double-pinned.

Driver Pin: A driver pin provides the top portion of the pin stack and is biased directly by the spring (driver spring). In a chamber with only two pins, it provides for double detainer locking of the plug. The preferred nomenclature today is **top pin.**

Effective Plug Diameter: This term applies to pin tumbler locks and is the actual diameter of the plug. It is computed by adding the length of the bottom pin to the position in the root of the cut where the tumbler actually rests, thereby establishing a perfect shear line. The effective diameter may be slightly greater than the actual diameter of an empty plug.

Ejector Holes: Within certain interchangeable core locks, there is a hole at the bottom and under each chamber. It provides a path for the ejector pin, which uses a tool to drive all of the elements of a chamber out of the lock, to aid in rekeying.

Emergency Key: A key that can bypass a lock (often in a hotel) or privacy feature. It may also be referred to as an emergency key (abbreviated EMK), and is used to open every lock within a hotel.

Escutcheon Plate: A protective or ornamental plate that provides an outer protective cover for locks and related components when mounted on a door.

Extractor: A tool that is used to remove a broken key from a keyway. It is usually made of fine saw-teeth.

Factory Original Key: This is the key provided by the manufacturer for a specific lock. It is referred to in this text as the **Source Key**.

Feel Picking: This is a method of lock bypass requiring that each individual tumbler, wafer, or lever be manipulated or raised by a curved or similar pick tool. Feel picking is the traditional method of lock picking, and is contrasted with rake picking and other methods described throughout this text.

Fence: Generally in lever locks, but the term can be applicable to sidebar, combination and other locks. It denotes a projection on the bolt that is designed to prevent movement of the bolt unless proper alignment occurs between a corresponding gate.

Firemans Key: A key that is used to bypass or override normal operation of elevators in an emergency, usually fire.

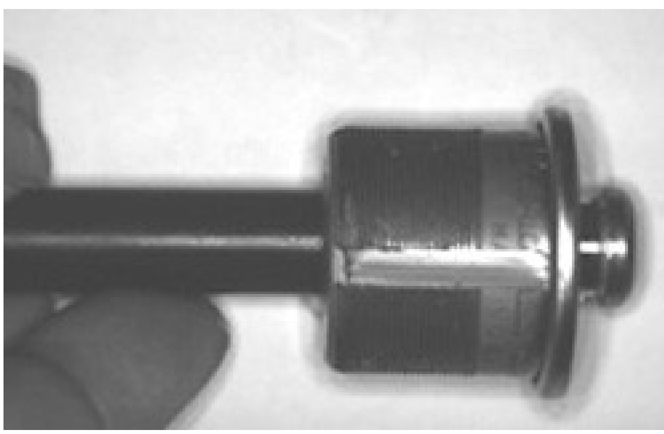
First Generation Duplicate or Copy: A key that is reproduced directly from a factory original or code-cut key. This is contrasted with a "first key" that is generated other than by copying of a source key.

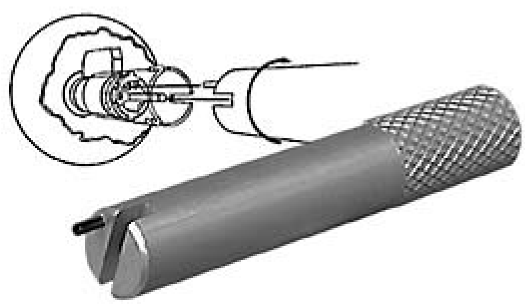
Flat Key: A key made from sheet metal, without grooves or keyway, used in warded or lever locks. Most safe-deposit locks utilize flat keys.



Figure LSS+316 A flat steel key, usually made of brass or steel. This key fits a safe-deposit lock.

Following Tool or Follower: A round tool utilized when disassembling a pin tumbler lock. A follower resembles a dowel or round metal tube and has the same diameter as the plug it replaces. In the photograph, a follower is partially replacing the plug, shown at the front of the lock. The tool will "follow" the plug through the shell, until the plug can be completely removed. The follower will replace the plug, maintaining the top pins and springs within the shell. A segmented follower is a special tool that is divided into sections and is utilized in profile cylinders.





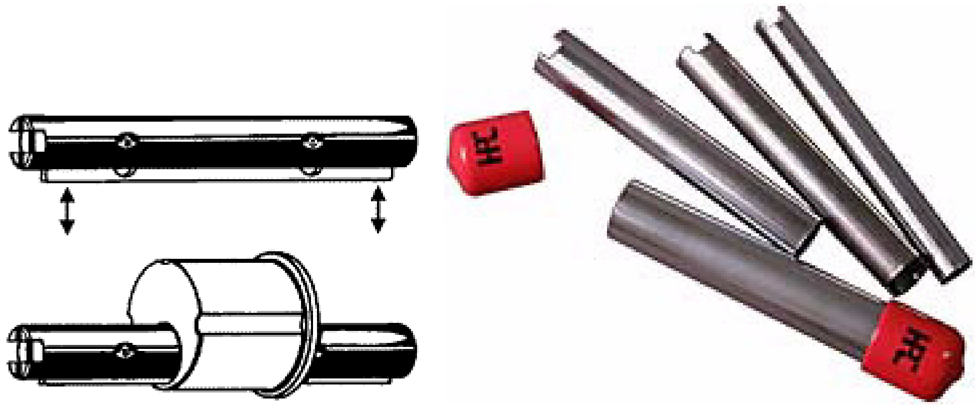


Figure LSS+317 A variety of following tools are available to fit virtually any plug diameter. Shown are a fixed diameter, and a spring-loaded tool produced by HPC to adjust to different plug sizes. Also shown is the HPC hollow follower set for several different plug diameters.

Gate: A notch or indent that is cut into the tumbler edge to correspond with and accept a fence or sidebar protrusion.

Graduated Driver: See balanced driver. These constitute top pins of different lengths that are used to compensate for the overall length of the pin stack, so as to make the total length of the pin stack constant.

Grand Master Key: A key that operates locks in several series, all of which have their own group master key.

Guard Key: A safe deposit box lock, generally of lever design, usually requires that two keys be used in concert to accomplish an opening. One key is utilized by the "guard" or bank; the other by the renter. A **prep key** is a form of guard key that is used in locks with only one keyway. It must be turned once and withdrawn before the renter's key can operate the lock.

Hand of Door: The orientation of the lock, determined from the hinge position on the door. Thus, "right hand" means that the hinges are on the right side of the door.

Hand of Lock: This term primarily applies to combination locks, and indicates the mounting orientation with respect to the bolt. Handing is specified as vertical up (VU), vertical down (VD), right hand (RH), or left hand (LH).

Hardware Schedule:(53) This is a specification that details the door hardware to be utilized on a job.

Hasp: A fastening arrangement comprised of a fixed staple and corresponding slotted hinged member (hasp).

Heel: This term refers to the moveable locking portion of a padlock shackle that is not removed from the body when unlocked.

High-Security Lock: A lock designed to offer a greater degree of resistance to surreptitious and forced-entry methods, including picking, impressioning, key duplication, drilling, and other forms of entry.

Hold-Open Cylinder: A locking mechanism that has a special cam that will retain the latch bolt in the open or retracted position when so set by the key.

Holding Fixture: An apparatus that is designed to hold or retain cylinders, plugs, and other lock parts to facilitate their installation and maintenance. A setup tray can also be considered as a holding fixture.

Hollow Driver: A top pin that is reamed or hollowed out to allow insertion of the spring into the body of the pin. This is especially useful where there is limited clearance within pin chambers.

Housing: The part of the lock that holds the plug. See **shell.**

Impression System: A technique to produce keys for certain types of locks without taking apart the mechanism. The process is used to determine the position and depth of cuts corresponding to the tumblers. Another form of impressioning involves the **copying of keys** through the use of wax, clay, or metal impressions. An "impression" refers to the mark left by the tumbler on the key.

Increment: The measured difference between depths of the bitting of a key. These differences are usually uniform (for example, .015") and will correspond to changes in the length of bottom pins (in a pin tumbler lock).

Indirect Code: A reference number that can be correlated to the actual bitting of a specific lock or key through an independent reference. This may also be called a **blind code.**

Interchangeable Core: A locking system that allows the rapid interchange of the entire locking assembly is referred to as an interchangeable core. All of the components (plug, shell, pins,

springs, retainer) are self-contained within the core, which can be easily removed through the use of a control key. The term "removable core" can also describe this mechanism.

Interlocking Pin Tumbler: A system wherein all pin segments within a chamber are interlinked when the plug is in the locked position. See **section 17_4.4.**

Jamb: The vertical portion of a door or window frame.

Jimmy-resistant Rim Lock: A type of rim lock that resists prying of the door from the jamb to bypass the bolt. A vertical movement prevents the bolt from being withdrawn.

Jumbo Cylinder: A large mortise cylinder that may measure 1 1/2" in diameter. See **section 23_2.4.**

K: The symbol for Key.

KA: The symbol for Key Alike.

KBA: The symbol for **key bitting array.** It is a graphic matrix of all of the possible bitting for change keys and subgroup master keys within a master key system.

KD: The symbol for Keyed Differently.

Key: There are many different kinds of keys. A key is a device that can be carried by its owner. It is inserted into a particular lock or group of locks to cause the internal mechanism to align, thereby allowing an opening. The modern spelling dates from 1632. Before that time, other spellings can be found. The reader may be interested to know how the word is spelled in different languages: clef (French), schlussel (German), llave (Spanish), chiave (Italian), sleuted (Dutch), lukke (Norwegian), nyckel (Swedish), clavis (Latin), and cleis, (Greek).

Key Alike: A system of keying where all locks are fit to the same key-bitting pattern or combination. Locks that are keyed alike may or may not be part of a keying system. Locks may also be **keyed different**, which would be the opposite of keyed alike.

Key bitting array: A matrix of useable depth codes that is used to define a master key system. The KBA shows all depths that form the basis of keying progressions for all master keying and change key levels. It is derived after the code for the top level master

key is specified. The KBA is more fully described in **chapter 11.**

Key Bitting Specifications: The mechanical information provided by each manufacturer so as to allow the bitting of key blanks for one or more locks, or groups of locks.

Key Blank: See **blank.**

Key Changeable: A lock or cylinder whose combination can be changed without disassembly through the use of a key is said to be "key changeable." In combination locks, described in later chapters, a special change key tool may be required to reset the wheel pack.

Key Control: Procedures established to limit or restrict the unauthorized possession, distribution, or duplication of keys. The term now encompasses access control issues, as well as the location, organization, and inventory of keys. **Visual key control** is the process that requires the stamping of standard keying symbols on all locks and keys.

Key Cuts: The portion of the bitting that remains after a key is created.

Key Cut Profile: The shape of the key bitting, which takes into account the root shape and cut angle.

Key Changes: See **Differs.** This refers to the number of different bitting combinations available within a given lock.

Key Gauge: A mechanical device that can measure the individual depths of a bitting pattern and provide precise information as to depth coding or length. A key micrometer, HPC HKD-75 or similar device is used for this function.

Key Head: The portion of the key that extends past the shoulder and provides a gripping surface for the user is referred to as a key head. Its design is unique to a specific manufacturer, and often carriers information that allows identification of the lock, keyway, and code. The photographs show a Sargent LE series blank, a Schlage generic head, and a Schlage 923E blank, with a factory original key code of 33699. This code is direct reading, allowing the key to be precisely reproduced from this number. The key fits a five tumbler lock.



Figure LSS+318 Key heads provide identification of the manufacturer and specific blank.

Key Picking: A lock may be jiggled open by moving a key back and forth across the tumblers, much like a rake pick. Maison-keyed locks are especially vulnerable to the practice of key picking because of the multiple virtual shear lines that must be created to allow access to all tenants.

Key Records: Records that are maintained by a facility to manage its locks. The information should include:

- **Key system schematic;**
- **Number of keys and cylinders that have been issued and comprise the system inventory;**
- **User list with keys issued to them for which locks or keying levels;**
- **Hardware and keying schedule;**
- **Bitting list**
- **KBA**

Key Retaining: This term often refers to a lock that is designed so that it must be in the locked position before the key can be withdraw, or reqiure the use of a second key or tool to allow the key to be removed.

Key Section: The precise configuration of a key blade as viewed from bow to tip and laterally.

Key Symbol: The designation utilized to identify any key within a standard key coding system. A full list of symbols is provided in chapter 11.

Keyed: How a lock is combinated.

Keyed Random: One or more cylinders that are chosen from a group of cylinders that may or may not have any relationship to each other in terms of combinations. As a result, there may be duplicate bittings in one or more locks.

Keying: How a cylinder is combinated.

Keying Conference: This is a meeting between the locksmith or system vendor and the end user to define keying levels, system requirements, future needs, and security. A **keying schedule** is provided, detailing the specifications of the system. This will identify how all locks are to be combinated, quantities, markings, and delivery instructions of cylinders and keys.

Keying Levels: A master key system is divided into **levels or hierarchies of access(54)**, with standard definitions for each level as provided by the Standard Key Coding System (SKCS).

Keyhole: The opening in a lock that allows the entry of a key. The term can also mean a keyway, but is more generic to a warded lock.

Key Interchange: Usually occurring within master key systems, whereby a key that is designed to open one specific lock will also open one or more unintended locks. This is more fully explained in **chapter 11**, regarding cross-keying.

Key Manipulation: A key designed to open one lock may be manipulated or jiggled to open another. This can occur due to wear of the lock components or key, or result from the use of too thin master pins.

Key Milling: The grooves, wards, or bullets along the side of the key are referred to as milling. The term can also denote the alteration or modification of a key blank to enter a restricted or different keyway than intended by the blank manufacturer.

Key Override: In many electronic, combination, push button, or specialized locking systems that do not ordinarily rely upon the use of a key to open, an override system is provided in case of malfunction. This function, however, can significantly reduce the security of the locking system, especially where master keys are utilized. See chapter 31 for a discussion of a method to compromise conventional master key systems through a process of decoding and extrapolation using the change key. In such instances, the key override function can completely neutralize the associated access control system.

Key Profile: The shape and appearance of a key after being cut, taking into account cut angles and root shape. The term can also refer to the specific keyway.

Key-Pull Position: The vertical or horizontal position where the key can be physically withdrawn from the plug. This may be in one or more orientations, depending upon design of the lock.

Keying Levels: The divisions of a master key system into access hierarchies, beginning with the individual change key. The standard keying levels are:

Individual key
Keyed alike
Keyed different
Master key

Keyway: The opening in a (lock) plug into which the key is inserted. A keyway provides a certain measure of security within most modern locks, based upon the placement of wards to block entrance of all but the correct key. “Keyway” appears to be a relatively modern term; the earlier references appeared to use the word “keyhole.”

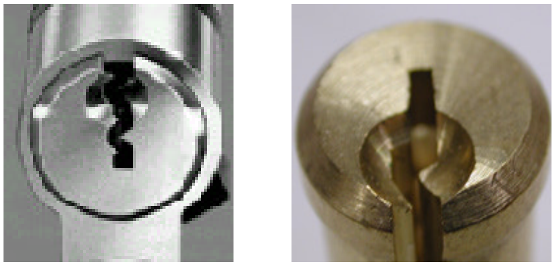


Figure LSS+319 A keyway provides security and indexes the key to the active locking components.

KWY: The symbol for Keyway.

Laminated Padlocks: Padlocks that are constructed with layers of metal plates. The Master Padlock is typical of this method of construction.

Lasertrack Key: See also **sidewinder key** or **bell-type key**.

Latch: A component that secures a moving and non-moving device, but has no locking function.

Layout Tray: A container with compartments to house cylinder parts. It is used for keying and service. It may be similar to a setup tray to hold pins, springs, and plug.

Lazy Cam or Tailpiece: A lock may be designed so that the cam is somewhat free-floating in certain positions, so that it remains in one position while the plug is partially turned.

Levels of Keying. See Keying Levels.

Lever Tumbler Lock: A lock mechanism operating with flat metal tumblers with a gate. The levers are actuated by the bitting of the key, and are aligned to a certain height to allow the bolt to be actuated.

Loading tool: A device that is used to facilitate the installation of components into the shell of the lock.

Lock: In its simplest form, a lock consists of a case containing a bolt that is fastened to, and employed to retain a moveable object such as a door. The bolt is normally actuated with a key. The term lock, as currently spelled, appeared between 1300 and 1400 A.D. Prior to that time, the English spelling of the word

took the form of **loke** or **locke**, until the seventeenth or eighteenth century. The word "lock" seems to have many derivations. Thus, it appears as **serrure** (French), **schloss** (German), **cerradura**, (Spanish), **serratura** (Italian), **slot** (Dutch), **las** (Norwegian and Swedish), **sera** (Latin), and **kleihron** (Greek).

Lockout: A condition wherein the normal functioning of a lock is not possible.

Lockout Key: A system whereby a key is formed in two separate parts to block access to a lock. One portion of the key is inserted into the keyway to prevent any other key from entry. A second mating piece (removal key) is used to withdraw the portion residing within the keyway. This technique has been utilized in construction keying systems, and may also be referred to as a **construction breakout key**.

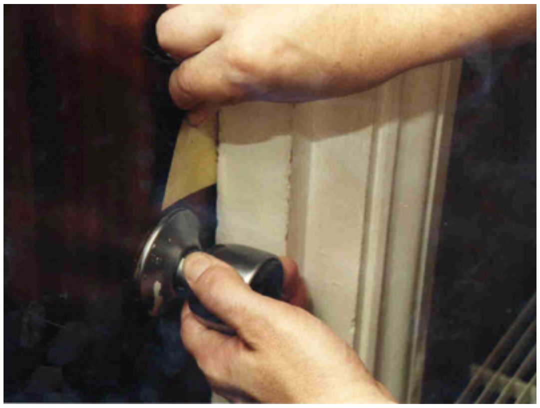
LOCKMASTERS: A company in Nicholasville, Kentucky, that is known throughout the world for training of locksmiths and government agents regarding locks and safes.

Locksmith: A locksmith is one who is skilled in the art of working with locks and keys. Originally, locksmiths were blacksmiths, until they formed a separate guild and became specialists in their trade. The earliest use of the term may be found as **locksmythe** in 1440. After 1627, the term may be found as two words, **lock smith**, or hyphenated. Sometime after 1841, the term, as we know it today, came into use.

Loiding: A technique to bypass a bolt by inserting a shim or thin flexible material between the moveable locking component and strike or frame.

Loiding a lock, by Harry Sher

LSS203: Demonstration of the use of a loid, by MSC

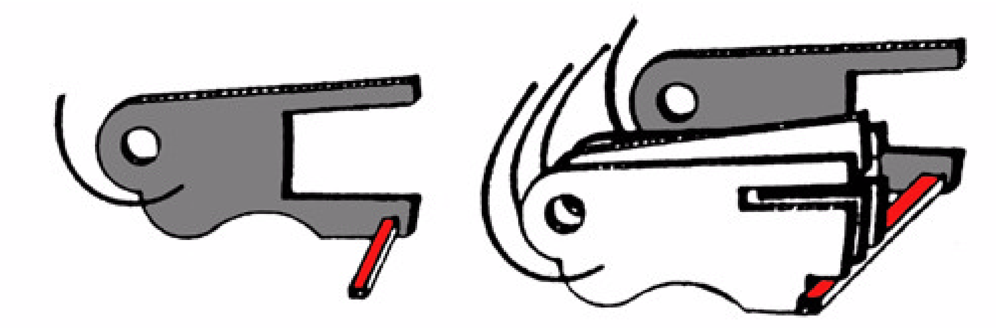


MACS: Maximum adjacent cut specification. This is the maximum allowable depth of cuts in single and double-bitted and dimple locks that can be made without interference to each other. MACS is an integral factor that must be taken into account in a master key system. The MACS specification is defined by each manufacturer and will physically prevent a key from being properly cut.

Manipulation Key: Any key that is designed to be moved within a lock for which it is not intended, and which can effect an opening through vertical and lateral movement of the active locking components. Rocker keys, tryout keys, jiggle keys, variable keys (John Falle system), and computer-generated picks described elsewhere in this text would all be considered as manipulation keys.

Master Key: A key designed to operate two or more locks having different change keys. Simple to complicated **master key systems** can be designed so that one or more master keys can operate one or many groups of cylinders. A system is said to be **"master keyed"** when a group of locks can be operated by individual change keys and one common key. Locks that are **only** combinated to a master key are said to be **master keyed only**.

Master Lever: A master keying scheme for lever locks wherein one lever tumbler is designed to to align some or all of the other gates of the levers within the lock to the fence. This technique is most common in locker locks, and is more fully explained in chapter 11.



Master Pin: Originally, this was referred to as a master pin. It is the build-up pin that is used to create a different virtual shear line within a master key system, and is fully discussed in **chapter 11.**

Master Ring: In certain locks, a sleeve or tube is placed over the plug to form a second physical shear line. All master pins are aligned to this higher shear line to prevent unintended cross-keys from opening the lock.

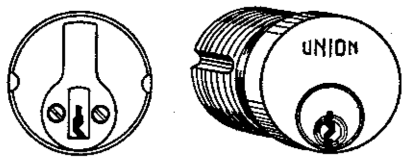
Master Pin: See **master pin.**

Maximum Opposing Cut Specification (MOCS): This specification can be likened to MACS , but is relevant in dimple pin tumbler locks. It defines the maximum allowable depth for any dimple to prevent penetration of the key blade to the other side, thereby interfering with opposing cuts.

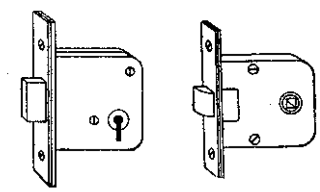
Milling of Key Blank: The longitudinal grooves machined into the key that makes up the keyway.

Mogul Cylinder: A large size pin tumbler lock that is primarily used in prisons. All components are increased in scale from a standard mortise cylinder.

Mortised Cylinder: A cylinder that is affixed to a locking assembly which has been inset into a door. The cylinder is generally screwed into the assembly, and held in position by a setscrew.



Mortised Lockset: A mortised lockset is inset into the door. In the accompanying diagrams, a dead bolt (left) and spring latch (right) is shown.



Multi-section Blank: A key blank that is milled to allow entry into more than one keyways within a **multiplex** keying system. This blank will not enter all keyways, however. A **multiplex keying system** is one that integrates a series of different key sections to allow for expansion of the master key system. Bittings can be repeated with locks having different keyway sections without compromise in security. However, the negative ramifications of the use of such systems is that if a locksmith or key duplicating vendor utilizes the wrong keying level blank, then the system can be compromised by allowing a key designed to fit one lock from opening another.

Mushroom Tumbler: A security driver pin or top pin that is designed to resist picking attempts. A **spool pin** is a form of mushroom tumbler. The **step pin** takes the form of a spool or mushroom tumbler, but has a portion of its end milled to a lesser diameter than the opposing end.

Negative Locking: See also **"Positive Locking"** below. Negative locking relies upon springs, gravity, magnetism, or force other than the key directly moving a detainer to block rotation of the plug. It is an indirect method of locking. An example would be a key with a cut that is too deep and which does not allow the plug to turn because the pin has not been raised to shear line. Positive and negative locking theory are employed in master key systems to deter the use of keys between systems.

Non-Key Retaining: A lock that does not prevent removal of the

key in either the locked or unlocked position. This is the opposite condition to **key retaining**.

Non-Original Key: Any key blank that is not factory original or provided by an OEM.

One-Bitted: A cylinder which has its bitting referenced to the number one bitting of the manufacturer. In contrast, a **zero-bitted** cylinder is one that is combinated to a manufacturers reference of zero bitting.

Operating Key: Any key that will operate a lock, and which is not a control or reset key. An operating key may be a change key or master key.

Operating Shear Line: The physical shear line within a standard plug to which all tumblers must be aligned to permit rotation.

Padlock: A portable lock used to fasten two objects together. The padlock has existed for thousands of years, with the original meaning of the term uncertain. **Pad** meant rubber in the seventeenth century. Prior to that time, pad and lock were hyphenated or appeared as two words, becoming one in 1663.

Paracentric Keyway: This term is used generally to describe the keyway within a pin tumbler lock. It refers to wards on either side of a keyway that protrude past the centerline of the plug. The key must be so milled to allow passage of the wards.



Figure LSS+320 An Ikon paracentric keyway.

Pattern Key: Any original key that is utilized as a reference in making duplicates of that key.

Peanut Cylinder: A mortise cylinder that measures 3/4" in diameter.

Picking: The process of opening a lock through manipulation of the internal components, simulating the use of the correct key. A **pick** is the implement utilized to manipulate active locking components.

Pick Key: A key that has been modified to allow manipulation of locking components and operation of the lock.

Pin: (verb) To pin or repin a lock means to install active locking components (pins, springs) in order to set the combination. The noun refers to a pin tumbler.

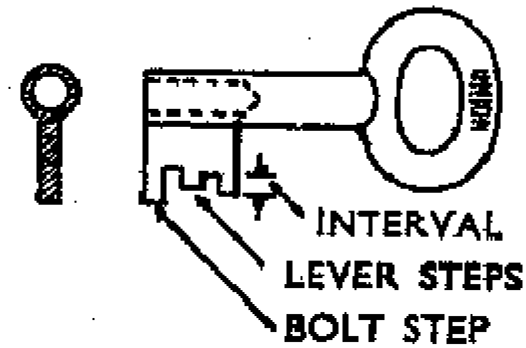
Pinning Chart: A diagram detailing and graphically showing how each lock within a system is combinated.

Pinning Block: An apparatus to facilitate the loading of tumblers into a cylinder.

Pin-Stack: All of the tumblers within one chamber. The pin stack height is the total length of all pins within one chamber, expressed as depth increments or an actual measurement in inches or milimeters.

Pin Tumbler Lock: A lock, originally invented by the Egyptians, that utilizes moving pins to prevent the rotation of a round plug by all but the correct key.

Pipe Key: Keys for warded and lever locks may be configured with pipes or posts, depending upon the design of the mechanism and how the key is anchored. The pipe is hollow, as shown in the diagram.



Plug: The round, central part of a lock that contains the keyway and is rotated to operate the mechanism. It is sometimes called a core. The preferred term is **plug**, which will be used throughout this book.

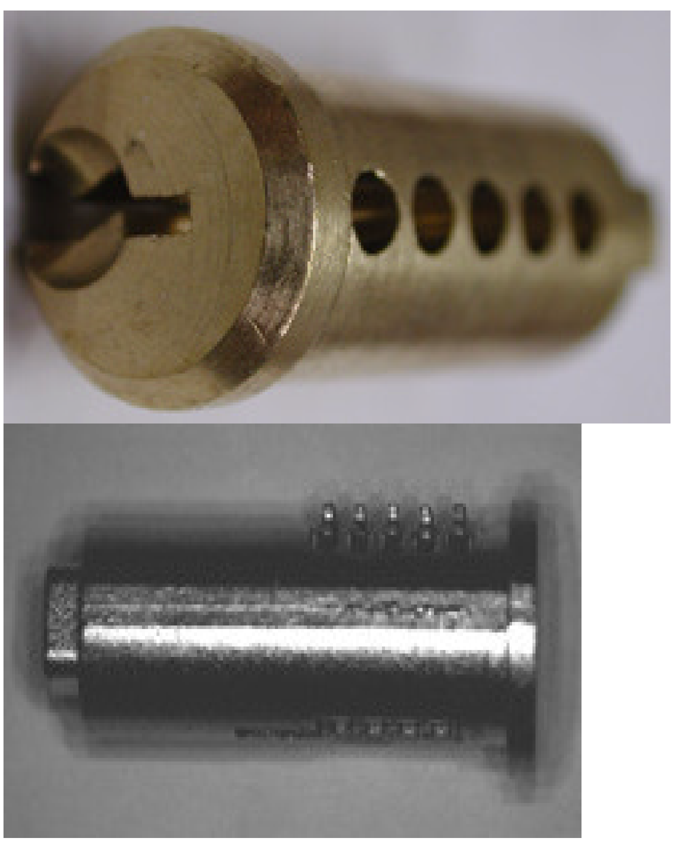


Figure LSS+321 A pin tumbler lock plug (left) and wafer plug (right).

Plug Follower: See **Follower**.

Plug Retainer: The mechanical component that secures the plug to the shell and prevents its release when the correct key is inserted.

Positive Locking: Within a double-detainer locking mechanism, the action of lifting a tumbler, wafer, or other form of detainer from the plug into the shell is called positive locking. A direct obstruction to the movement of the plug is created through the action of metal against metal. Thus, an incorrect depth on the bitting surface of a pin tumbler key will cause a pin to extend above shear line. It is the reverse of **"negative locking"** defined above. A cut on a key that raises its corresponding pin tumbler above shear line would positively lock the plug.

Practical Key Changes: The useable number of differs or combinations for a specified cylinder and manufacturer. This number will be different than theoretical differs which do not take into account tolerance issues, key design, depth and spacing, and MACS.

Privacy Key: A special key that operates a cylinder that is not on the master key system. It is an override key.

Profile Cylinder: A form of mortise cylinder that is not prevalent in the United States, but is mounted in similar fashion. The shape of a profile cylinder is quite different than the traditional mortised cylinder found in the U.S.

Proprietary Keyway: A keyway that is designated by the manufacturer for one customer, locksmith, or region.

Radiused Blade Bottom: The bottom portion of the key blade that is rounded to precisely conform with the base curvature of the plug in order to provide for a more uniform plug diameter and roundness.

Rap or Rapping of a Lock: A process to cause a lock to be opened by applying directed energy to a key or lock. This may occur by applying tension and shock to a specially prepared key (999 key) or to the lock body or shackle release mechanism of a padlock.

Recombinate: To change the combination of a lock or key. This may also be referred to as **rekeying**.

Recore: To change the combination of a lock by exchanging the core.

Register Groove: A reference point established at a certain position on the blade from which a manufacturer can define bitting depths.

Removable Core Cylinder: A complete locking assembly that is designed to be removed and replaced with the use of a control key. See **interchangeable core.**

Renter's Key: A key that must be used in conjunction with a guard key or prep key (or electronic release) to unlock a safe deposit box.

Reset Key: Some cylinders can be recombinated through the use of a special key. In certain cases, special tools and the new key are also required. See the discussion of **Winfield** locks for an example.

Restricted Keyway: A special profile that has been designed for limited use by one or more customers.

Reversible Key: A symmetrical key that can be inserted into the keyway in either vertical orientation to operate the lock.

Rim Cylinder: A cylinder that is utilized with a surface mounted rim lock.

RL: Registered Locksmith ALOA.

Root Depth: The dimension from the bottom of a key cut to the bottom of the blade.

Rose: An escutcheon that is usually circular in shape.

Rotary Tumbler: A pin tumbler with one or more vertical grooves or gates milled into its side. The key bitting angle causes the pin to rotate to the correct position to align with a sidebar or fence. Medeco received the original patent for this technology.

SAVTA: Safe and Vault Technicians Association.

Scalp: The thin outer skin of the front of the cylinder. It is usually crimped or spun, and may also serve to retain the plug.

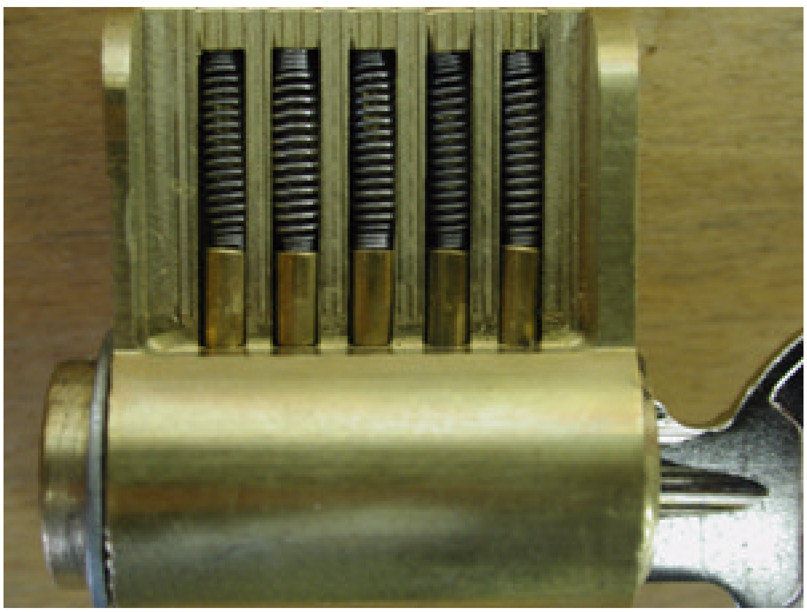
Second Generation Duplicate: An original copy from the first

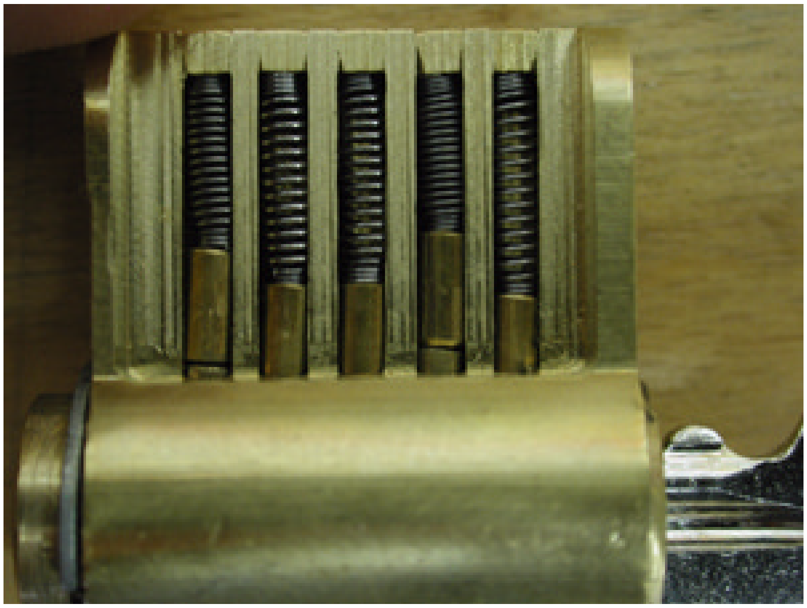
generation duplicate.

Set-up Plug: A type of follower that contains individual chambers to correspond with those in a lock. These chambers are loaded with springs and top pins, which are then forced into the shall of the lock.

Set-up Tray: A fixture that is used to hold pins and springs and plug during lock disassembly or pinning.

Shear Line: The space between the plug and shell of a lock that creates the ability for active locking components to secure or release rotation or movement of the plug. The photograph shows all pin tumblers at shear line (left), thereby allowing the plug to rotate freely. The plug cannot turn (right) because it is blocked by pins above and below shear line.





Shedding Key: See **declining step key.**

Shell: The non-moving part of a cylinder lock containing all the internal moving parts. It is also referred to as the cylinder. In the left photograph, a cylinder is shown without the spring retaining strip. The springs, drivers, and lower tumblers have been removed. In the right photograph, a profile shell contains springs and drivers. The portion of the lock that holds the plug or core may also be referred to as the **housing.**

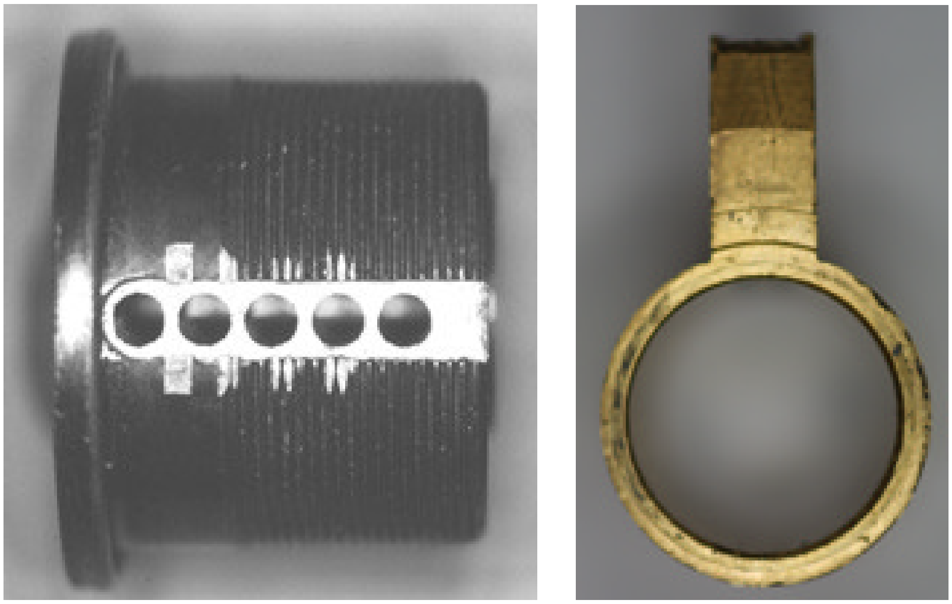


Figure LSS+322 The shell contains driver pins and springs.

Shim: A very thin, flat piece of metal, generally .002" to .005" in thickness.

Shoulder of key or **Stop of Key:** The shoulder prevents the key from entering the keyway past a certain point, and provides a method of registration for the bitting to correspond with the precise position of the tumblers. Some keys do not have shoulders. In such cases, a small **tip stop** is provided. Best Lock Company keys do not have shoulders.



Figure LSS+323 The shoulder of a key provides a stop and indexes the blade to the chambers.

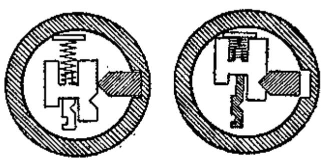
Shouldered Pin: A bottom pin that has a larger diameter on its top or flat side. This will limit penetration into a

counter-bored cylinder.

Shove Knife: A tool that is employed in conjunction with a setup plug to load pins and springs into the shell of the lock.

Shutout Key: A special key that is used to block access to a specific lock by all but an emergency key. This is generally found in hotel locks. In such status, the lock is said to be in shutout mode.

Sidebar Lock: A lock incorporating a secondary locking mechanism that appears in both disc and pin tumbler locks. A separate spring-biased projection will block rotation of the plug until all tumblers are properly aligned. The sidebar was originally developed by Briggs and Stratton for automobiles, and was introduced in 1935. The diagram below shows the original sidebar wafer design. The left illustration shows the sidebar extended; in the right drawing, it is retracted, allowing the plug to rotate.



In the left photograph below, the plug from a **Medeco** sidebar cam lock is shown. Note the protrusion on the bottom of the plug. This is the sidebar, in the normally locked position. In order for the plug to rotate, the tumblers must be properly aligned, in order to allow the sidebar to retract. This is a four tumbler lock; each tumbler is rotated by the key to the correct position. Note the three drill-resistant pins near the front of the plug.

In the middle photograph, an EVVA 3KS modular sidebar profile cylinder is shown. Note the sidebar is retracted into the plug, allowing rotation. In the right photograph, the sidebar is extended, blocking plug movement.

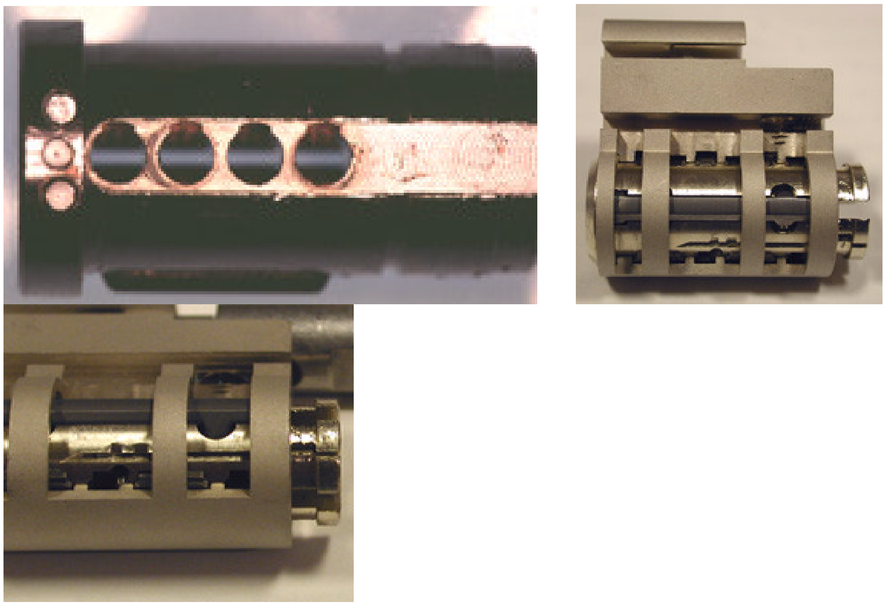


Figure LSS+324 Medeco and Evva sidebar lock designs.

Sidewinder Lock: See also **Lasertrack** lock or key, or **bell-type** key.

SKD: Single Keyed. The symbol indicates a non-master keyed lock. Certain rules apply to single keyed locks:

- **Single keyed combinations are never intended to be used as master keys;**
- **Combinations should never be selected at random, or the result may allow the opening of a master keyed lock;**
- **There can never be key interchange between an SKD and other cylinders in the system that are master keyed or have change keys;**
- **An SKD lock cannot be integrated into the master key system at a later date;**
- **The SKD should be selected from the bitting list and should not be used for any other cylinder in the system;**
- **Within a 1x progression, remove the combination from the system after use. Within a two-step system, the parity may be changed to allow reuse of the combination, althougnb not recommended. • In a rotating constant system, use constants that are not compatible with other system keys. This will assure that there is no interchange;**
- **A forbidden page master may be used as an SKD;**

• A SKD lock is one that has a single combination. In contrast, a NMK (not master keyed) lock is not keyed to any master level but is in the progression for a master key system.

Simplex Key Section: A single key section that is not part of a multiplex key system. This is different than a single key section that **can** be used in a multiplex key system.

Single-acting Lever Tumbler: A lever tumbler with limited or physically restricted vertical travel to allow movement of a bolt, but which cannot be configured to prevent travel of the bolt.

Source Key: See **Factory Original Key.**

Spacing: The distance from the key stop to the center of the first cut, or the dimension between cuts, center-to-center.

Spring retaining strip or Cover: Springs are often retained within a pin tumbler cylinder by means of a brass strip, crimped within a guide slot at the top of the shell. To remove, the strip is slid to the rear of the shell, or peeled back, thereby providing access to the springs, drivers, and lower pins.

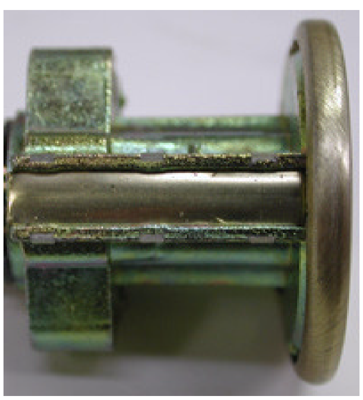


Figure LSS+325 Spring retaining strip.

Standard Key Coding System (SKCS): An industry-standard systemt for defining cylinders, keys, and their function and keying level within a master key system.

Standards: Standards are promulgated by both government and private agencies in almost every industrialized country. For a complete listing, see **security.org**, or National Resources for

Global Standards.

Stepped Tumbler: A wafer tumbler that is utilized in master keying systems must utilize two contact surfaces so that keys with different blade orientation can be utilized.

Strike: The metal plate that are installed as part of the doorjamb to allow receipt of the bolt. A **strike box** can be utilized as an enclosure formed by the strike to surround and protect the bolt.

Tail Piece or Connecting Bar: See **Connecting Bar.** It is a component of the rim lock or key-in-knob lock that is utilized to transmit rotational motion to the bolt.

Talon: The gap in the bolt of a lock, curved to the radius of a key, which has some resemblance in shape to the talon or claw of a bird of prey. A fly talon allows a small key to give a long throw to the bolt.

Theoretical Key Change: The total possible number of individual key combinations for a particular lock.

Throw of Bolt: The lateral distance that a bolt projects from the edge of the door or moving component.

Tip: That portion of the key that enters the keyway first.

Tolerance: The deviation or variance from an actual dimension or standard. In the context of lock manufacturing, it specifies the difference between a theoretical specification and the actual measurement. Chamber bores, for example, are theoretically all drilled in a straight line. In reality, there is a slight variance in each of their position, due to drill fatigue, movement, and wear. In this text, the term "high tolerance" refers to an extremely small deviation between theoretical and actual measurement. Tolerance error contribute to the ability to pick a lock. See the discussion in **chapter 11** and **chapter 29.**

Top Pin: Also known as the driver pin. This is the pin that is directly biased by the spring and which abuts against master pins or lower pins to form the pin stack.

Triple-Bit Key: A conventional key that is cut on three sides or surfaces. It appears that the original patent for a triple bitted

lock was granted to George Full in 1936 (**2030837(55)**).

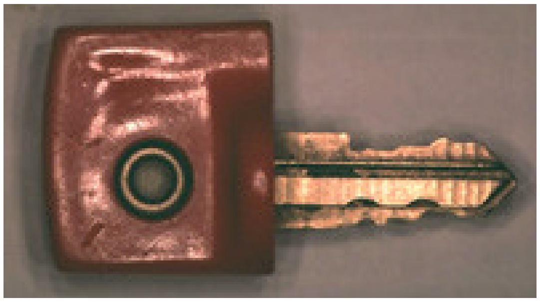


Figure LSS+326 A Dudley triple bitted key. Note the bitting on three surfaces.

Tryout Key: One or more keys that is designed to manipulate the tumblers, wafers, discs or levers in order to open the lock. Tryout keys generally depend upon tolerance errors, and are often cut between normal depth codes.

Tubular Key: See axial key. A key in which the bitting is cut into the end of the bitting surface around its circumference, rather than laterally across the blade.

Tumbler: See also pin tumbler. An active locking component that can also be described as a disc, wafer, or lever. It is used to block rotation of a plug or movement of a bolt, and is the mechanical portion of the lock that comes into contact with the key.

UL: Underwriters Laboratory.

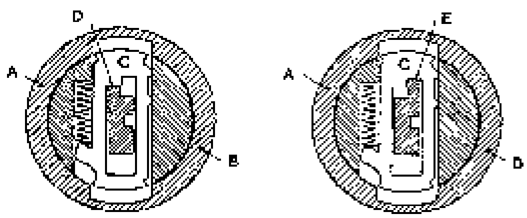
Unidirectional Cylinder: A cylinder that can only be activated in one directon. Complete rotation of the plug may be blocked.

Virtual Shear Line: A shear line that is created by the insertion within a chamber of more than one bottom pin. When the pin stack is raised by the bitting, the pins "break" at more than one position with respect to the physical shear line. In contrast, interchangeable core and master ring locks contain two physical shear lines.

Wafer Lock: A locking mechanism that employs flat metal wafer tumblers. The linked **diagrams** show the positions of the tumblers in locked (**C**) and unlocked position (**A**). (**B**) shows the wafer properly raised to shear line, allowing rotation within the shell. As can be seen, the wafers are forced above and below

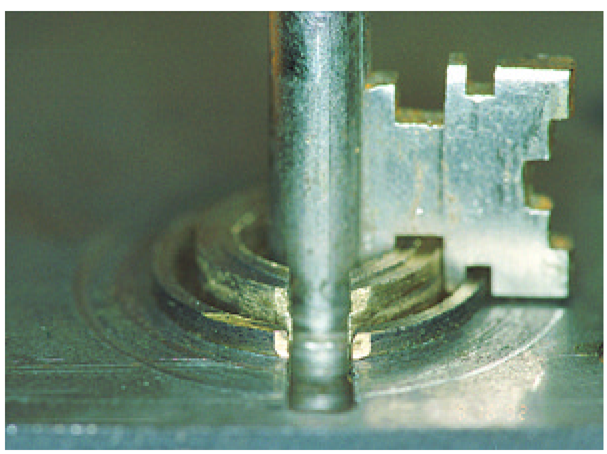
shear line, thereby blocking movement of the plug.

Wafer Lock Master Keying: Wafer locks can be master keyed by utilizing different bitting positions on the key and within the wafer. In the diagram, "A" and "B" represent the shell, "C" shows the wafer, "D" and "E" show the change and master key bitting levels. The keyway for this lock is designed so that the bitting contacts either "D" or "E."



Warded Lock: A minimum security device containing internal obstacles or wards, intended to block the entrance or rotation of all but the correct key. Shown is a simple warded key. Cut bitting is designed to bypass the individual wards within the lock. The photograph shows the circular wards and how they are bypassed by the corresponding cuts i the key. Bitting on the key is referred to as a "ward cut."





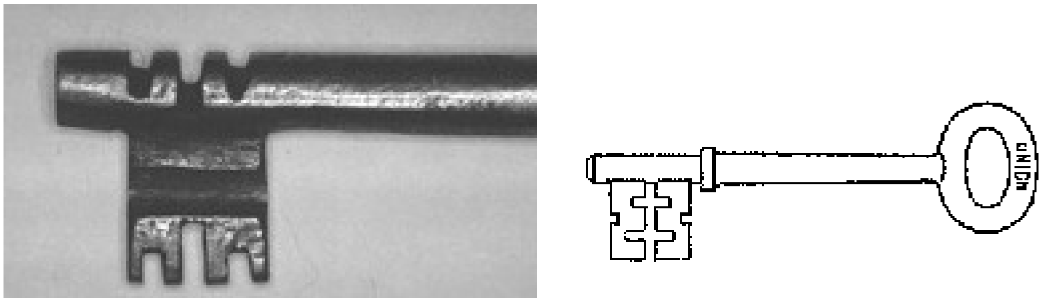


Figure LSS+327 Key for warded lock (left) and bridge ward (right).

CHAPTER FOUR: WORKING MATERIALS

Tools and Supplies

Master Exhibit Summary

Macro lens, Courtesy of Hans Mejlshede.

Data back for documentation of images. Courtesy of Hans Mejlshede.

Photographic equipment requirements. Courtesy of Hans Mejlshede.

Ring strobe is a necessity for forensic photography. Courtesy of Hans Mejlshede.

Forensic marks and their observation with proper lighting. Courtesy of Don Shiles.

LSS204: Brian Chan on lubrication of locks

4_1.0 Introduction

Techniques of disassembly, keying, rekeying, picking, impressioning, decoding, master keying, and forensic analyses of locks are detailed throughout this book. Certain tools and supplies are needed to properly perform those functions and operations. In this chapter, a catalog of primary tools has been compiled. This listing details what the author suggests to be the minimum requirements for both crime laboratory technicians and locksmiths. There are many specialized tools omitted from this chapter; they are covered elsewhere.

Unique tools that are used in the forced-entry of locks are described in **Chapter 32**; tools for the **penetration of safes** in Chapters 34-35; and instruments for non-destructive entry of combination locks and safes are described in **Chapter 36**. Information pertaining to the use of certain of these tools is also presented where appropriate. **Picking**, **impressioning**, and **forced-entry** tools required for such procedures are not listed here but rather discussed in those specific chapters (29-31). All tools and supplies related to work on safes are likewise listed in the pertinent chapters dealing with safes and vaults.

The author, for the past 25 years, has primarily utilized tools produced by **HPC** of Chicago. Although there are a number of other vendors in the United States and Europe who produce comparable items, **HPC** has the most extensive product line specifically geared for the locksmith profession. As noted elsewhere in this text, **John Falle** offers the most sophisticated **lock**-picking, impressioning, and decoding tools specifically and primarily designed for government agencies.

MBA and **Lockmasters**, both in Kentucky, have the most comprehensive collection of tools for the professional **safe** technician. Throughout this book, reference will be made to tools and supplies available through these companies, often with part numbers. Both **HPC** and **Lockmasters** can provide the reader with a convenient, central source for all needed supplies. Contact information, as well as a complete listing of tool vendors can be found at **Security.Org**.

4_2.0 General Tools

A number of small tools and components are required in order to perform routine maintenance and keying operations. These are further classified as small hand tools, specialty tools, and files.

4_2.1 Hand Tools

The following hand tools should be available prior to beginning any work involving disassembly or rekeying.

- **Alligator forceps ;**
- **Allen wrenches;**
- **Bench grinder;**
- **Center punch;**
- **Clip removal tool ;**
- **Dremel tool, battery operated;**
- **Drills;**
- **Follower tool set ;**
- **Hacksaws;**
- **Hook tool;**
- **Ice pick;**
- **Impressioning files: see discussion below;**
- **Magnetic pickup tool;**
- **Mallet: either wooden or rubber, eight ounce is sufficient;**
- **Music wire;**
- **Needle nose pliers;**
- **Pen flashlight;**
- **Retaining-ring pliers (arc ring);**
- **Spanner wrench;**
- **Screwdrivers ;**
- **Small hammer;**
- **Steel wool;**
- **Swiss file set;**
- **Tension wrench assortment;**
- **Tubular hole saw;**
- **Vice: either bench or tabletop. The suction type models are very suitable. A Panavise is also recommended. This special rotating vice allows small parts to be held at any horizontal and vertical position;**
- **Vice grips;**
- **Warding file for safe-deposit keys.**



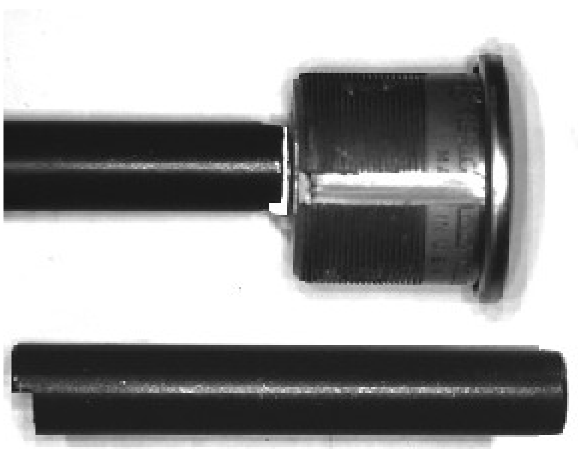
4_2.2 Special Lock Working Tools

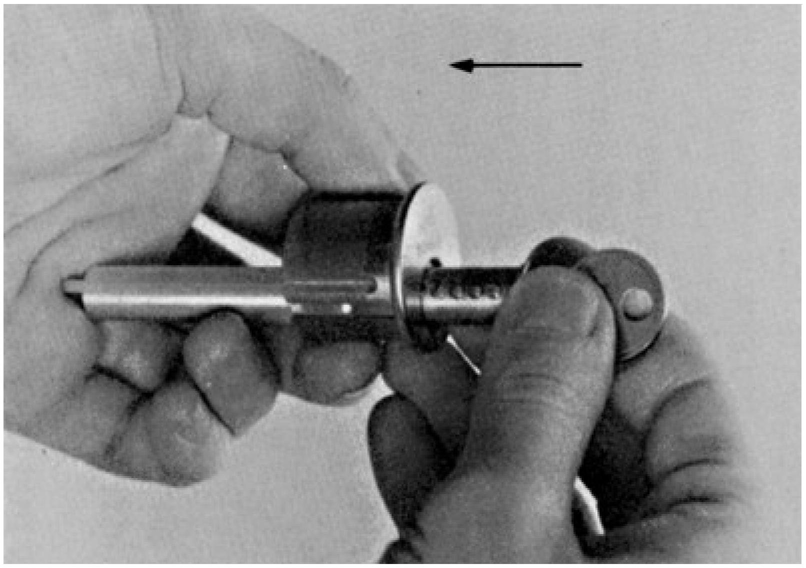
- **Blank keys: as required;**
- **Borescope: various lengths and fields of view;**
- **Broken key extractor: either commercially available, or use a fine-tooth hacksaw blade no more than 1/8″ wide. An extractor has many purposes, including use for removing broken pick ends, broken keys, Kwikset lock release, file cabinet lock bypass, and doorknob release;**

- **Code books: HPC, Silca, Reed;**
- **Dental picks (for broken keys);**
- **Dial calipers: .001″ gradation;**
- **Direct reading micrometer: HPC SKM-20. This device will allow depth and spacing measurements to be made to .001";**
- **Dust cover tool: holds gate open on automobile locks;**
- **Following tools: either made of metal and available from HPC, or wooden dowels may be used. A follower with a diameter of ½″ will replace most standard pin tumbler plugs. Other sizes may be obtained as**

needed;

- **Forceps, alligator;**
- **Impressioning pliers: HPC KIP-1. This is a special set of vice-grips with parallel jaws, having no grooves. The design allows excellent holding strength;**
- **Key decoders: Different HPC models allow the determination of factory depths for most keys, and contain depth and spacing information;**
- **Key gauges: standard and tubular;**
- **Key machine(56): A key machine can be extremely helpful for use in basic lock work;**
- **Lights, flexible;**
- **Mainspring wire: 1/8-1/16" wide, spring steel wire used in watch and clock mainsprings;**
- **Nose puller and door puller kits;**
- **Optivisor: Lockmasters or equivalent product to magnify objects in the work area. A Magni-Focuser, produced by Endroy Products, allows for working at different distances from 4"-20", with diopter adjustment from +2 to -10D. These devices are offered with magnifying powers from 1.5-3.5X;**
- **Ophthalmoscope: A more useful tool than the Otoscope or Optivisor is the ophthalmoscope. This device offers a variable focus from less than one inch, to two feet. It is used by ophthalmologists to look into the eye and is extremely effective for peering into locks and safes;**



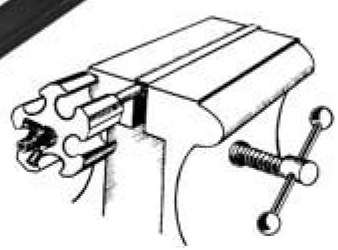


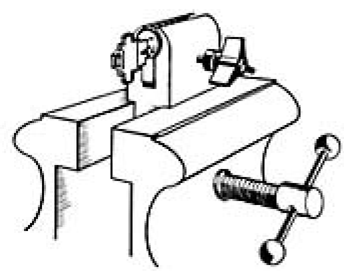
Generally, the ophthalmoscope has a self-contained high-intensity light source. These instruments are produced by Welch Allyn and other companies. They sell for about $300.

- **Otoscope: Useful for visually decoding wafer locks. The device allows magnification of surface areas;**
- **Pick gun (snap type);**
- **Picks: They can be purchased, or made from .032" spring steel stock. A basic set of picks should be available whenever locks are disassembled or rekeyed;**
- **Pick set for lever locks;**
- **Pick set for warded padlocks;**
- **Pin and spring set: HPC Offers a complete assortment of bottom and top color-coded pins and springs;**
- **Plug holder;(57)**
- **Plug spinner: For use when the lock is picked backwards and the plug must be rotated without the necessity of repicking;**
- **Punch: Various lengths;**
- **Safe opening tools: See Chapter 35;**
- **Screwdrivers: flat, Philips, and mini, and holding tool;**
- **Setup(58) (pin) tray: These trays are available from many vendors, including HPC, and can greatly facilitate keying and rekeying of pin tumbler locks;**

- **Shims: various sizes, thickness, and diameter;**
- **Truarc removal tool;**
- **Tweezers(59): Utilize top pin loading type for placing drivers in cylinder, available from HPC. They should be at least 3" in length with non-pointed ends;**
- **Tension wrenches: An assortment is required for any lock work. See Chapter 29;**
- **Ultraviolet light source: Available from Lockmasters for use in impressioning;**
- **Vibrating pick tool;**
- **Weiser shim tool;**

A special key holder and gauge was invented in 1919 by Segal for precisely filing pin tumblers. See (**1307379(60)**). Likewise, a number of plug holders are available from HPC and other vendors.




4_2.3 Cleaning Agents and Lubricants

LSS204: Brian Chan on lubrication of locks

Proper lubrication of internal lock parts is important. There are a number of acceptable wet and dry lubricants that will insure trouble-free performance. Iron and steel parts must be lubricated regularly, especially in damp or moist climates.

Although grease is often applied at the time of manufacture, it may disappear or become inefficient through use of the lock.

Light oil is acceptable for all but pin tumbler locks. Lubricants that thicken or mix with other materials and which tend to clog the parts should never be used. Employ either liquid or powdered graphite to lubricate pin tumbler locks. It should be squirted into the lock or rubbed on the plug, although the old way was to run a lead pencil over the key. Excessive graphite should be avoided, especially in locks such as Medeco.

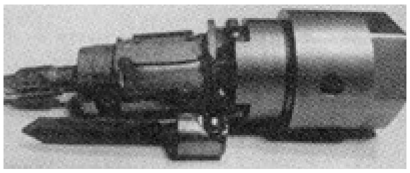
Lubricants should not be used if a lock is to be impressioned; smooth operation of the lock is not desirable and residue can be left on bitting surfaces. If the lock is to be picked, lubricants or cleaners may be of assistance because dirt, grit, or grime makes picking difficult. A non-lubricating spray cleaner may be used to wash keyways and pins. Solvents, carbon tetrachloride, white gasoline, LPS, aerosol cleaners, spray oil, ether, electronic contact cleaner, silicon spray, or automotive cleaners such as GUNK (carburetor cleaner) are all acceptable. Although WD-40 is often used to clean and lubricate a lock, it is not recommended. It has too high a water content, and when mixed with graphite can cause gumming.

4_2.4 Automotive Entry Tools

There are a number of companies that manufacture specialized tools for automobile entry. These are designed to remove ignition locks, door panels, actuate door latching mechanisms, and decode and duplicate vehicle anti-theft key systems. Although not all-inclusive, the following listing of tools is representative of those available to the trade. Many patents have also been issued for such tools, the more significant of which include (**6044672(61)**) Steering wheel lock removing method; (**5701773(62)**) Dual function apparatus for opening and removing automotive sidebar ignition locks; (**4682398(63)**) methods for removing ignition pin type cylinders; (**4638567(64)**) Key decoding device for automobiles; (**4586233(65)**) Method of disabling various types of lock cylinders in General Motors motor vehicles; (**5402661(66)**) Tool and method for turning on Ford sidebar type ignition lock cylinders; (**5454245(67)**) Apparatus and method for removing sidebar automotive ignition locks without damage; (**4868409(68)**) Vehicular anti-theft system; (**4655102**) Locksmith tool for unlocking motorcycling doors; (**4683783**) Car door opening tool and method; (**4608886**) Keyless door unlocking apparatus for

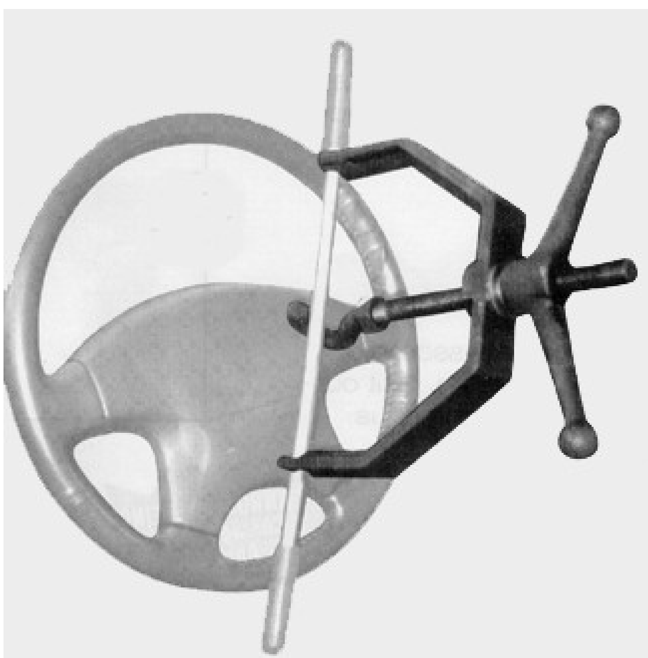
automobiles.

AABLE Locksmiths Quick-On: This is a device for removal of ignition locks.



A-1 Service Kit: This is a picking and decoding system for the new GM-10 cut dash ignitions. The locks can be picked in minutes with this tool.

The Buster: This is an automotive steering wheel lock buster. The tool permits the removal of "the Club" style locks almost instantly. The author has also received a patent (**5277042**) for the modification of the Club in order to make it secure against shims to defeat the ratchet lock.



Determinator Tool System: A key can be generated in under fifteen minutes with this system.

High-Tech Tool System: High Tech Tools Car Opening System will unlock almost every vehicle from 1979-2000. The set includes

forty tools for opening virtually every car.

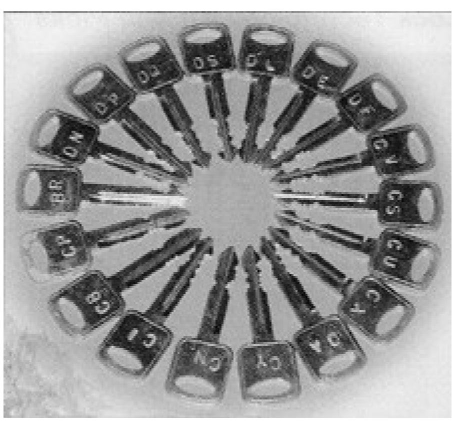
Lockmasters Mercedes Tool: This system is utilized to bypass the ignition bezel, thus gaining access to remove the ignition cylinder.

John Falle Vehicle Decoder Systems: John Falle produces several different sophisticated vehicle decoder systems for Ford Tibbe, Mercedes, Volvo, BMW, Honda, and other high-security locks. See **www.security.org** for a full listing of bypass tools.

PRO-LOCK Window Wiper: This simple tool is designed to clean the bottom portion of the window glass, both inside and outside of the door panel stripping.

Tech-Train Jiffy Jak Vehicle Entry System: This system allows most vehicles to be unlocked quickly and without damage. The tool is made from extremely strong plastic that allows more than eighty percent of all cars and trucks to be opened.

National Locksmith Ford 8-Cut Decoder: This system of 143 tryout keys allows bypass of the Ford 8-cut system.



Strattec DART: DART, or Diagnostic and Reprogramming Tool allows the interrogation of transponder-based security systems and the reprogramming of Daimler-Chrysler vehicles.

Gator MultiFace Cap Tool: Gator Tools Company produces a custom set of pliers that will remove lock caps.

Lock-Our Kits: Lock Technology, HPC, Steck, Z-Tool and other companies produce complete kits for vehicle lock-outs. They contain pick sets and opening tools, as well as comprehensive

instructions on most vehicles.

Slide-Lock Training: The Slide Lock Company provides seminars on the Internet, at **z-tool.com**.

4_2.5 Bypass Tools

As noted elsewhere in this Infobase, there are a number of companies that make a myriad of bypass tools for virtually every generic type of lock. Some of the predominant suppliers are HPC, John Falle, MBA, Lockmasters, PRO-LOCK, Lock Defeat Technology, and Rytan. These companies produce picks, decoders, and impressioning instruments for bypassing, decoding, and producing keys for most locks.

4_2.6 Bypass Tools for Safes and Vaults

There are several companies that manufacture tools specifically for the safe and vault technician. These are thoroughly discussed in **Chapter 35**. They include **MBA**, **Lockmasters**, **HPC**, **Mas-Hamilton**, MDS, Olympus, and Strong-Arm. Tools that are required by the professional safe technician are varied and many. They include drills, drill motors, fixed drill rigs, optical viewing devices, manipulation aids, robot dialers, software-based manipulation systems, and emergency opening tools and components.

4_2.7   Forensic Investigative Tool Set

The forensic investigator or investigative locksmith requires a number of specialized tools, instruments and implements in order to properly evaluate a crime scene, and to gather evidence that is legally admissable. The following items are recommended for field analysis.

HAND TOOLS

- **Hand microscope with lighting, minimum 30X (Lockmasters or similar)**
- **Tweezers: straight, right angle, fine point, broad point**
- **Small aperture Mag flashlight**
- **LED flashlight, high intensity, in white, blue, green**
- **Multibit screwdriver, with insert blades in Philips, flat-head, torx, hex**

- Magnetic pickup tool
- Multi tool, such as Swiss Army knife or Leatherman
- Side cutters
- Vice grips, small, medium, large

OPTICAL AND DOCUMENTATION DEVICES

- Otoscope;
- 35mm SLR camera with 100mm macro lens. The author utilizes a Canon EOS-1 with ring strobe
- Fiber optic light source

Forensic marks and their observation with proper lighting. Courtesy of Don Shiles.

Macro lens, Courtesy of Hans Mejlshede.

Data back for documentation of images. Courtesy of Hans Mejlshede.

Photographic equipment requirements. Courtesy of Hans Mejlshede.

Ring strobe is a necessity for forensic photography. Courtesy of Hans Mejlshede.

- Digital SLR camera with macro lens. The author utilizes a Nikon 990 and a Canon D30 with ring strobe;
- Stereo microscope 10X-40X magnification, with camera adapter;
- Pocket ruler defined in both inches and metric;
- Ruler strips for placement next to items of evidence;
- 50' (minimum) tape measure;
- Ultrasonic or laser measurement device handheld;
- Rare earth magnet for pickup of materials from scene;
- Basic locksmith tool kit for disassembly of locks and locking assemblies;
- Evidence containers, tape, and labels;
- Tape: masking, labeling;
- Latex gloves;
- Telescoping mirror;
- Compass;
- Audio recorder for notes;
- Video recorder;

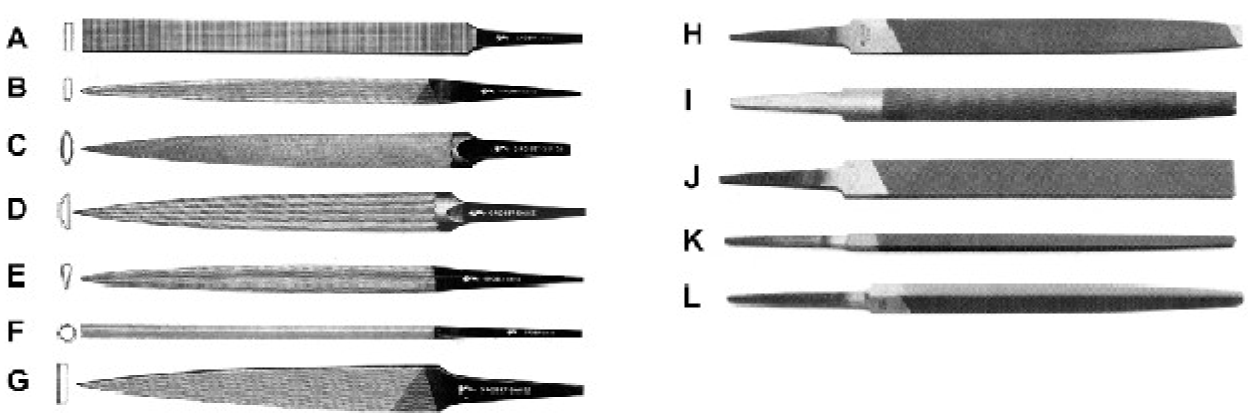
- **Notepad;**
- **Pens: regular, marking;**

4_3.0 Files

4_3.1 Introduction

See **Chapter 30** for a detailed discussion regarding the proper use of files for impressioning. The standardization of Swiss file shapes and cuts began in 1812 when F.L. Grobet went into the file manufacturing business in Switzerland. Today, Grobet files are unsurpassed for their quality, precision, and hardness. Grobet and other fine files are usually made of chrome alloy steel. **Gesswein** is one of the largest producers of high quality files.

Many different kinds of files should be in the technician's inventory. The selection of the proper file is critical to successful key cutting and impressioning. Preliminary criteria are based upon the **shape** and **cut** to be produced. These issues in turn depend upon the type and form of material to be worked, the amount of material to be removed, and the desired finish. Files should not have handles but rather protective covers such as electrical tape, so that an excessive amount of pressure is not applied during use.



4_3.2 Nomenclature

Files are defined by their **shape**, **length**, **tang**, **cut**, and **coarseness**.

4_3.2.1 Shape

Files come in many shapes, including round, half-round, Pippin, flat, square, three-square, and warding.

4_3.2.2 Length

The length of a file will generally vary from 4″-8″. Sometimes, a file that is 8″ in length actually measures 6″, because it has a tang extending the added length. Files may also be tapered, so that their diameter changes over the entire body. Length of the file is measured from where the teeth begin near the tang, to the tip.

4_3.2.3 Tang

The tang is the uncut portion of the file. It enhances control or it is used to attach a handle.

4_3.2.4 File Cuts and Coarseness

There are two worldwide rating systems for file cuts and measurement of coarseness: **Swiss** and **American**. The number of teeth per inch, identified by each system, determines the ability of a file to remove metal. The number will vary, based upon the length of the file and coarseness, and can run from 30 to 295. The Swiss utilize a numbered system, #00 to #6 (00,0,1,2,3,4,5,6) denoting the number of teeth per inch in relative terms. In the Swiss nomenclature, a 00 cut is the coarsest file; the #6 is a fine cutting file.

The American system utilizes the following primary cuts to define how much metal will be removed:

- **Coarse (for fast stock removal)**
- **Bastard (equivalent to Swiss 00, used for shaping and dressing steels and castings)**
- **Second cut (Swiss 0 for hard metals)**
- **Smooth (Swiss #2, for hard metals and as a finishing file).**

Files can have more than one set of cuts, meaning that there are two or more separate sets and angles on the surface. A **single cut** is one series of parallel teeth running diagonally across the

width of the file. This tooth design is used for sharpening tools and saws and for finishing-operations in machine shops.

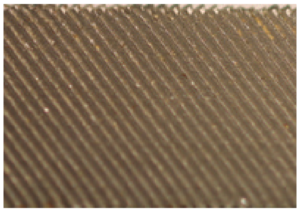
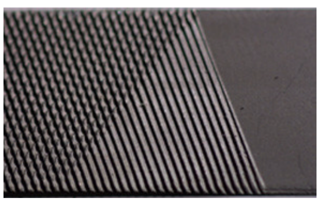


Figure LSS+401 Single and double cut files.

Double cut is two series of parallel teeth running diagonally across the width of the file surface, one series crossing the other. The tooth structure is fast cutting, and well-suited for rapid removal of material.



4_3.3 File Types that are based upon Shape

Standard files for working with keys include Pippin, round, rat-tail, triangle, and warding.

4_3.3.1 Pippin

The Pippin file resembles a teardrop cross section, rounded on one side, with two flat surfaces meeting at a knife-edge on the opposite face. A Pippin allows for the proper contouring of cuts so that a key will not catch on tumblers. Both curved and flat cuts can be easily made with the Pippin shaped file. The sharp side is used to mark tumbler points and spacing, and to make a straight-sided V cut in the bitting of a key. The rounded side is used to cut standard round tumbler cuts, and to open the sides of a key cut or to make the ramps wider. The flat surfaces are used like the flat file to shape the sides of the cuts.

Only a Pippin file should be used with brass, and files should not be used for filing lead keys. Cuts should be made straight down upon the key and not at an angle.

The **Pippin** teardrop shaped #4 Swiss pattern fine slim taper

Nicholson 40524 8" 2-XF) and round file are probably the most popular for use during impressioning. These files taper down to a smaller cross-sectional size towards the tip. It creates a very fine dull finish, and slightly ridged surface on the blade, thereby allowing observation of marks made by the pins. Proper filing continually renews the reflective finish. During impressioning or key duplication, the round file must generally be used in conjunction with a small flat or triangular file for shaping the ramps of the cuts.

4_3.3.2 Rat-tail

A rat-tail file is a long, tapered, round file. The diameter of the file will be greatest toward the middle and will taper toward the ends. Various grades of coarseness should be utilized, depending upon the material to be cut.

4_3.3.3 Warding

A warding file is rectangular, with all edges faced at 90°. It is used for making square cuts in keys, particularly for warded and lever locks.

4_3.4 Recommended File Set

The following files should be included within any maintenance kit for work on locks and keys:

- **Pippin, teardrop shaped, Swiss pattern Nicholson 40524 8" 2-XF), fine slim taper**
- **4" warding files (.045″-.05″ thick)**
- **6" warding file**
- **6" coarse rat-tail file**
- **6" #2 American Swiss rat-tail file**
- **6" #4 American Swiss rat-tail file**
- **Set of jeweler's files**
- **Swiss file set, available from HPC and Lockmasters**
- **4" triangle file**
- **6" triangle file**



Figure LSS+402 Two file sets produced by HPC.

CHAPTER FIVE: METALLURGY and CHEMISTRY

Materials and Processes

Master Exhibit Summary

Figure 5-11 Drill nomenclature for twist drill
Figure 5-12 Chipping within the drilling process
Figure LSS+501, Periodic table.

5_1.0 Introduction

Except for the early Egyptian and Greek locks, metal can be found in virtually every key, lock, safe and vault which has been crafted or manufactured during the past four thousand years. Although Chubb utilizes certain high-technology polymers in their all-plastic Planet safe, metals will continue to be the favored material.

Metallurgy is the science of metals. Based upon both physics and chemistry, it deals with the methods of extracting and refining metal from ores and the manipulation of it into products. Through metallurgy, the behavior, internal structure, and properties of metals are studied, controlled, and manipulated. Metallurgists seek to learn why metals behave the way they do, and alter that behavior to suit particular needs.

The Romans are credited with producing the first metal locks made of iron. From that time until the Industrial Revolution, there were few metals and processes available for use. They mainly consisted of hot-rolled iron or steel sheets, bars, and forgings. Sand casting in brass and iron was considered as sophisticated. So primitive was the early technology that metals (except gold and silver) could only be produced with rough black surfaces until the end of the nineteenth century.

Now, there are many materials available to the lock maker which can be provided in virtually any finish, size, form, and grade. Metals can be extruded, rolled, drawn, hot-pressed, and stamped to close tolerances. Today, using high-quality steel dies, die-casting in zinc and other alloys is commonplace for many lock components.

Any detailed study of keys, locks, and safes must begin with an examination of the materials and processes employed in their production. Every aspect of the design, manufacture, use, and bypass of locking devices is based upon some form of metallurgy. The fundamental security of any lock or container is premised upon the molecular structure of the metals from which they are produced.

The reader may wonder why a chapter on metallurgy is included

here. When considering metals and the principles of metallurgy, many basic questions come to mind that bear a relationship to locks, keys, safes, and their penetration.

For example, three interrelated and very important fundamental questions must be answered: **Why are metals hard or soft? Which ones are which?** and **How do we gauge their hardness and test for it?** Depending upon the chosen material, the answers will directly affect the security of the lock or safe.

Further questions about hardness: **What is the molecular structure that determines whether a metal is hard or soft? Which alloys are hard?**

Other questions which are pertinent: **What basic changes have occurred during the past two hundred years in metallurgy? What makes a metal ductile or brittle? How do we protect against the effects of heat and cold, relating to fracture and bending? What are the characteristics of the metals used in locks, such as brass, aluminum, steel, zamak, aloxite, and stainless steel?**

Additional questions are raised: **What is and what affects tensile strength, shear resistance, and cutting of metal? Why does carbon make iron into steel? What is hardening and tempering, and what are the negative characteristics of these processes? Why and how does a drill, torch, or thermic lance work?**

Although this chapter is not a detailed treatise or explanation of the complex principles and theories underlying the science of metallurgy, it is intended to answer fundamental questions about metals as they pertain to locks and safes. How metals are formed, altered, produced, shaped, and cut are explored. The production, composition, and penetration of alloy hard plate, so important in the protection of safes and vaults, is detailed. The effects of heating and cooling are explained. The classification of metals by alloy content and the testing of materials for hardness is defined.

Finally, the complexities of drilling hard metals are examined from the perspective of the interaction of physics and chemistry, and the physical properties involved in metal cutting. Special emphasis has been placed on these principles and techniques because of its importance in safe penetration, and the analysis of such techniques in burglary investigations. Covered elsewhere in this book are the practical aspects of drilling and other

forms of penetration of metals. The reader may also wish to review the materials in **Chapter 11** of Alfred Hobbs classic work, regarding the use and working of metals in Wolverhampton and Willenhall, England during the Industrial Revolution.

5_2.0 Production and Use of Iron: A History

Iron, for more than five thousand years, was used for making tools and weapons. Ancient warriors had learned to heat the tips of their iron spears to harden them. This was probably the first **heat treatment** of metals. Iron was the principal metal for making keys, locks, and safes, well into the nineteenth century. Then, processes for the manufacture of steel became economical on a large-scale basis. Our discussion will thus concentrate on the production of iron and steel. For an excellent history of keys, locks, and the use of iron, the reader is directed to **Chapter 20** of the Price text, within this Infobase.

Originally, iron ore was heated with charcoal until it became a sponge-like material; it was then hammered into the desired shape. Very early, the Chinese had developed forms of furnaces, and in the fifteenth century, a technique originally developed by the Egyptians for working in bronze and brass was adopted to the production of iron. During the eighteenth century, this technology was greatly refined. A form of blast furnace was developed that used bellows to blow air across the iron, turning it into a molten state. This allowed it to be poured as a liquid. There was, however, a problem in shaping the hot metal: the liquid iron could not be formed using a hammer, for it would shatter.

The availability of charcoal was also a limiting factor in the early production of iron, and later steel because a great amount was initially utilized in the process. In the early eighteenth century, Abraham Darby was able to smelt iron with coke, making the mass production of steel a reality, at a reduced price. Advances in making cast iron led to the production of wrought iron. This used a more sophisticated procedure, higher temperatures, and required the addition of other materials. The process was called puddling. Wrought iron, a tougher material, would withstand greater stresses. It could be forged or hot rolled into plates and strips and was utilized by safe makers until the middle of the nineteenth century.

Until 1856, steel (a mixture of iron and carbon) was classified as an exotic metal. Then, Henry Bessemer developed a technique that allowed steel to be produced for a fraction of the then current price. The process relied upon blowing air through molten pig iron. It made possible the Industrial Revolution, and mass production of steel at affordable prices.

5_2.1 Iron + Carbon = Steel

There are many interrelated and complex factors occurring during the processes of production, which affect steel as a finished material. These include temperature, carbon and other alloy content, and heat-treating. Steel results from the mixture of carbon with iron. Carbon is the key element that gives steel its strength, up to three times that of iron. The more carbon, the stronger is the steel, until the content exceeds about two percent. With the addition of carbon, however, comes brittleness, coupled with the ability to finely hone the metal. The percentage of carbon, together with other alloys, will determine and control the type, grade, and structural qualities of the steel, as well as its strength and ductility.

Steel can be endowed with many special properties, some of which are produced through the addition of other metallic elements that are called alloy steels. These additions may improve hardness, strength, springiness, resistance to wear, and corrosion. Most well known of the alloys is stainless steel, to which nickel and chromium has been added. The metallurgist is concerned with creating many different grades and alloys of steel, to accomplish different purposes. Every metal can be described by its chemical, electrical, mechanical, and thermal makeup. Cost and weight are also factors to be considered. All of these characteristics contribute to the metals "properties". **Hardness**, **brittleness**, and **strength** are three key properties of metals. They are critical in the design of security devices, and they are of course interrelated.

It is a constant balancing act for the metallurgist to account for the many factors and processes to produce steel having the precise characteristics that are desired without compromising other properties of the metal. For example, one difficulty is how to increase hardness and strength without proportionally increasing the brittleness of the material. The solution to this particular problem is often the addition of alloys that add strength without a like increase in brittleness.

In the world of locks and safes, an example illustrates the difficulties faced by the metallurgist in optimizing strength and hardness without brittleness and fracture. One well-known technique for causing metal failure involves the saturation of critical components with Freon. For example, the application of Freon to a padlock shackle, or certain armor platting on safes, followed by mechanical shock will cause fracture. The metallurgist will alloy the metals to prevent this from occurring.

5_2.2 Classification of the Basic Types of Iron and Steel

Steel is a generic term that describes many variations of the metal. These definitions include low, medium, and high carbon steel, tool steel, and spring steel. Composed of mostly iron, steel is classified based upon its carbon and other alloy content, although it will always contain some carbon. The percentage will determine strength, brittleness, and the basic type of the steel. Carbon content will generally be between .15 and 2 percent.

Steels with low-carbon content (.05%-.35%) are used in bridges, buildings, tanks, and auto bodies. Medium-carbon steel (.35%-.50%) are found in wheels, crankshafts, gears, axles, and other heat-treated applications. High carbon steel (over .50%) is both hard and strong and is used in making tools, dies, knives, and railroad wheels.

5_2.2.1 Cast Iron

Iron with a carbon content between 2 and 4 percent is called cast iron or gray iron. If the carbon content is between 4 and 6 percent, then wrought iron is created (but no longer produced). Iron with over 6 percent carbon is so brittle that it is useless.

Cast iron is steel in which some carbon forms in little flakes or spears. Producing cast iron requires that the ore is first refined. Then, after further treatment in a smaller furnace, the iron may be poured into a sand mold for forming.

Cast iron is an extremely economical and convenient metal. It is used in engine blocks, brake drums, and other applications where high- compression strength is required. It is easily cast and machined and thus is popular for the production of millions of

different lock parts, often having unusual shapes.

5_2.2.2 Wrought Iron

Wrought iron is almost pure iron. It has low strength and hardness, is very ductile, and is corrosion-resistant. Prior to 1860, wrought iron and iron castings were the only ferrous materials available for lock making; thus, wrought iron was the most important structural metal available. It was used in wastewater pipes, sheeting on ships, and gratings.

5_2.2.3 Alloys

Generally, alloy steel has properties that cannot be achieved in carbon steel. Alloys, up to a maximum of 2%, are added to steel for many different and important reasons. Alloying elements most used in alloy steel production are aluminum, chromium, cobalt, columbium, copper (over .6%), manganese (over 1.6%), molybdenum, nickel, silicon (over .6%), titanium, tungsten, vanadium, and zirconium. Alloy content is directly related to the cost of the steel. Alloying metals are added to steel for many reasons. These metals include:

- **Carbon, manganese, and nickel: increase strength in the material;**
- **Chromium and copper: provide corrosion resistance;**
- **Lead or sulfur: added machinability;**
- **Tungsten and molybdenum: steel used at high temperatures;**
- **Cobalt and boron: hardness;**
- **Vanadium: toughness;**
- **Columbium and titanium: elimination of carbide precipitation.**

5_2.2.3.1 Different Alloys

Tool steels have high strength, wear resistance, and dimensional stability. There are eleven categories of tool steel, defined by shock resistance, hardening techniques, high speed, hot working, mold making, and special purpose.

Stainless steel is best known for its corrosion resistance. It contains high quantities of chromium and nickel.

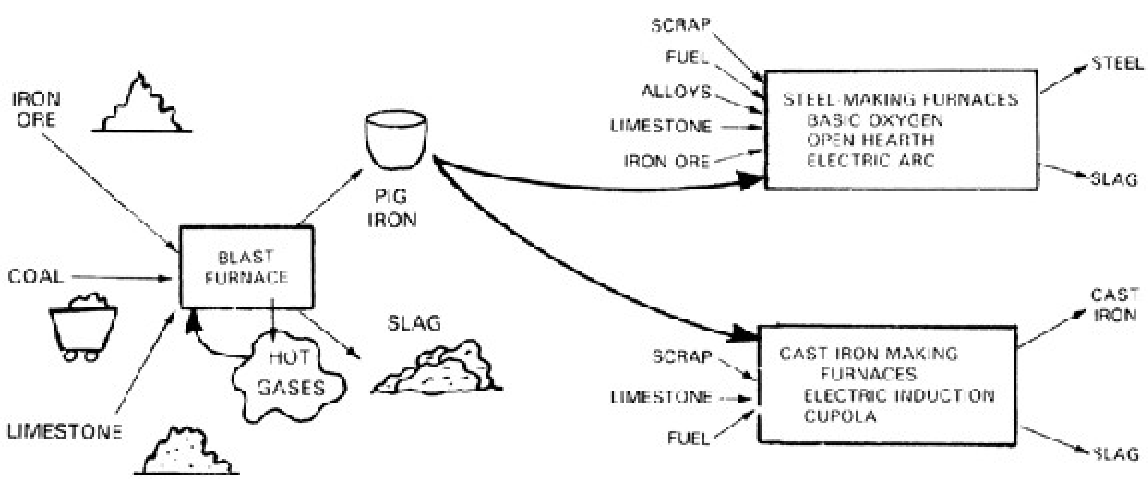
Spring and **special steels** are created for hardness and strength. Their carbon content is between .35-1.4 percent, and will often contain up to .8% manganese, together with chromium, silicon, vanadium, and molybdenum.

5_2.2.3.2 SAE Numbering System

The Society of Automotive Engineers (SAE) has developed a four or five-digit numbering system to designate grades and quality of steel. This system will identify steel by alloy and carbon content. The first two digits of the identifier will indicate the type of steel, the last two give the approximate carbon content in hundredths of a percent (.01%). Thus, for example, an SAE 1030 rating would indicate a plain carbon steel (10) containing up to .3% carbon. Essentially, the higher the number, the harder the metal.

5_2.3 Techniques of Steel Production

Initially, the process of making steel involved the hammering of heated wrought iron. Then, in 1740, a melting process was developed to produce steel more efficiently. Low-carbon mild steel however, was not economically available until the latter half of the nineteenth century when Bessemer and Siemens perfected their process.



Steel is produced in two steps. First the iron ore enters a blast furnace and is mixed with coke, limestone, and hot gasses. This produces pig iron, which is utilized in making cast iron and steel. Once created, it is then transferred to a steel-making furnace in a molten state to make the actual steel.

Carbon is added to iron in amounts from .2-1.5%, depending upon the grade of steel required. The higher the carbon content, the finer is the steel.

5_2.3.1 Types of Furnaces

There are four types of steel-making furnaces: **oxygen**, **open hearth**, **electric arc**, and **Bessemer converter** (no longer used). The pig iron is fed into one of these, together with fuel, alloys, scrap steel, limestone, and small amounts of iron ore, at a temperature of about 3000°F. The molten metal is then brought to a carbon boil in the furnace. Actually, oxygen is combined with the pig iron to form carbon monoxide that bubbles off, then alloys are added.

A **basic oxygen furnace** (**BOF**)(69) utilizes an oxygen lance, which directs the flow of gas at high speed to create an intensely hot reaction for about twenty minutes. The BOF is used for the production of large amounts of steel. An **electric arc furnace(70)** uses electricity, rather than fuel, to create heat. This allows better quality control and is used for the production of special steel, such as stainless, tool, and high alloy. These furnaces process smaller quantities of metal per hour. Once out of the furnace, the molten steel product is first poured into ingots or molds and allowed to solidify. Later, it is uniformly heated and run through a rolling mill to be flattened to a desired thickness.

5_3.0 Basic Principles of Metallurgy

5_3.1 Introduction

Metals have a number of special attributes that are utilized, altered, and always considered in the design, production, analysis, and bypass of locks and safes. Our discussion of metallurgy will become particularly relevant in subsequent chapters relating to forced-entry techniques. In such cases, the unique properties of metals are defeated or exploited using special tools and processes.

5_3.2 From Atoms to Alloys

The earth is made up of over one hundred different individual

basic materials, called **elements.** If the earth were broken down into its most basic parts, it would be comprised of these elements.

5_3.2.1 Elements

An **element(71)** consists of only one material. Regardless of what is done to that substance, whether it is heating, cooling, compression, breaking, or any other process, it will remain the same. Some elements are metals. A metal has several special properties, including the ability to conduct electricity and heat, hardness, heaviness, and opacity. An **atom(72),** which means "cannot be cut", is the smallest particle of these chemical elements that can exist alone or in combination with other elements.

5_3.2.2 Compounds and Mixtures

Compounds and mixtures(73) are comprised of two or more elements but are quite different. The elements within a **compound** are chemically joined and often difficult to separate. A compound may take on entirely different characteristics than those of its individual elements. When elements are chemically joined, their atoms combine to form **molecules(74).** For example, common salt is a mixture of the toxic gas chlorine and a light metal, sodium. In contrast, the elements within a **mixture(75)** can usually be separated through simple processes, such as filtering, and do not completely lose their individual identities. An example is sand in water.

5_3.2.3 Solutions

A mixture in which one substance, the **solute(76),** is completely dissolved within the other, the **solvent(77),** is called a **solution(78).** Usually, a great deal more solvent is required than the solute in order that the dissolving action may occur. A solid solution occurs when both the solvent and solute are solid materials. Although common experience tells us that solids cannot be dissolved within one another, this process will occur at higher temperatures when both materials change to a liquid state at or near their melting points. Iron will dissolve many other elements, and particularly carbon and copper, as well as small amounts of zinc, tin, or nickel. Steel is approximately 99 percent iron, with only about one percent dissolved carbon. This is typical of solid solutions.

5_3.2.4 Alloys

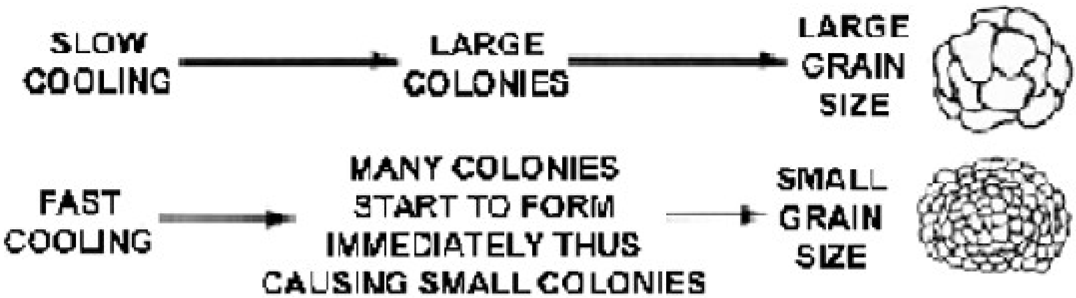
A new material called an **alloy(79)** is created when two or more metals are dissolved together in a solid solution. Thus, steel is an alloy of iron and carbon; bronze is comprised of copper and tin; and brass is made of copper and zinc. The solutes or metals that are dissolved are also called alloys. Thus, alloy actually has two meanings: the dissolved metal material, and the solid solution that is the combination of alloys and solvent.

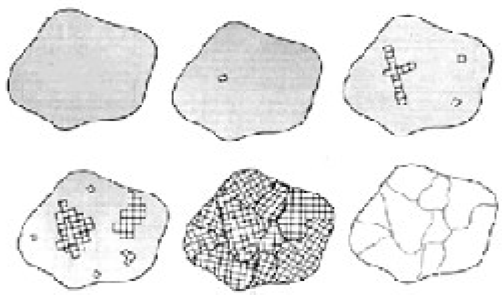
5_3.3 Atoms and Molecules

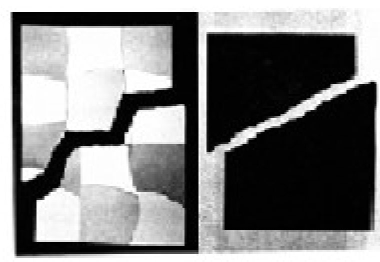
The **atom** is the smallest part of an element, and the molecule is the smallest part of a compound. Just as it requires two or more elements to make a compound, it takes two or more atoms to make a molecule. Molecules are only formed within compounds, not in mixtures or solutions. Within such molecules, atoms are joined chemically through the sharing of electrons from each other. Molecules are not created in alloys or solid solutions. Finally, when a large group of atoms or molecules combine, they form a family, often visible by the naked eye. These families are called **grains** or **crystals(80)**. Within such formations, all of the atoms tend to orient themselves in neat and orderly structures, or **lattice** configurations.

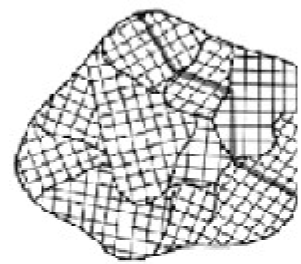
5_3.3.1 Crystals and Molecular Structures of Metals

Metals are actually made of molecules, formed in several different crystal lattice configurations that establish characteristics such as brittleness, hardness, and strength. When, for example, molten metal rapidly cools and changes to a solid state, many small clusters or colonies of crystals form within the material. The size of these crystals and colonies directly affects the properties of strength, brittleness, hardness, and ductility. If there are many very small colonies of crystals, they will be more difficult to fracture and will be less brittle. In contrast, slow cooling allows larger crystal colonies to form.









Crystal structures will also vary, depending upon the metal and its treatment. The rise or fall in temperature and the rate of such change may affect each. The basic types of structures are described as **ferrite**, **pearlite**, **cementite**, and **martensite**. If, for example, steel is quenched or rapidly cooled, it may take on a different molecular structure than if the metal is slowly cooled. In the case of rapid cooling, it is said to go to a **martensite** form. Martensitic iron has a different geometric crystal pattern than other types of structures and is the hardest, strongest, and most brittle of crystal formations.

What does all of this mean? Simply, metals with large colony sizes are easier to tear, break or fracture. A small grain size has a greater resistance to fracture. Thus, the metallurgist goes to great efforts to keep the grain size small, if strength is important. It follows that **barrier material** has a very tight crystal lattice configuration.

5_3.3.2 Hardening of Metals

Hardness of martensite actually results from a restructuring of atoms. This structure appears as needle-like, termed **acicular(81)**. The material is hard because layers of iron atoms are inhibited from slipping over one another by the dispersion among them of smaller carbon atoms. This formation will force the iron atoms out of their traditional cubic structure, locking them into a highly rigid unstable structure. Carbon tool steel

is hardened by heating it to a temperature between 750°C-835°C (cherry-red heat), followed by rapid cooling. An increase in temperature above this range will cause no increase in hardness, but there will be greater brittleness as the crystals grow larger.

5_3.3.2.1 Alloying(82) with W(83), Mo(84), Co(85), C(86), Cr(87), and V(88)

Metal hardness, wear resistance, and other attributes depend not only on the martensite but also upon the size, composition, and distribution of the compounds, especially the carbides. The stability of the matrix at high temperatures is also related to these compounds. Alloying agents are used to produce special and enhanced properties. See the **Periodic table**. Many different elements are utilized for the production of locks and safes, and to **alter the characteristics(89)** of metals, depending upon the required application.

Carbon is required to facilitate bonding of the carbide-forming elements (W, V, Mo) and for martensite hardening. Between 4 and 5% chromium is used to insure the ability to harden, i.e., that the center cools slower than the outside and a consistent martensite structure occurs. Tungsten (W) and molybdenum (Mo) were used for the first high- speed steels. Today, Mo is probably the most popular alloying agent. Vanadium, up to 1%, may also control grain growth. Higher percentages, up to 5%, will produce many hard microscopic particles that will resist wear when cutting abrasive materials. Cobalt, between 5 and 12%, will raise the temperature at which hardness begins to fall.

5_3.4 Specific Attributes of Metals

Metals have certain attributes such as hardness, ductility, strength, and brittleness. In the following discussion, each of these is described.

5_3.4.1 Hardness and Hardness Ratings

Hardness measures a metals resistance to deformation and penetration and results from two factors: the speed of quenching or cooling and the percentage of carbon content. A higher speed of cooling, coupled with more carbon, will provide harder steel.

The best known of the hardened materials is tool steel, which is

used for dies and for cutting other metal. Barrier material (hard plate) is equally tough and is used in safes to protect critical parts. Hardness must be studied together with several other key properties, including strength, brittleness, ductility, machinability, formability, cracking tendencies, and toughness.

5_3.4.1.1 Testing for Hardness

There are two primary criteria for determining the hardness of a material: **penetration** and **scratch** testing. There are nine recognized methods of testing both the surface and internal hardness of a metal, depending upon the type of material and the information required. In penetration testing, hardness can be measured using a number of different machines, but they all essentially do the same thing: they force a penetrator or sharp-pointed probe against the metal sample. The size of the resulting impression or dent is precisely measured and translated to a hardness rating.

There is no universal standard of hardness; each manufacture of hardness-rating equipment has developed its own units of measure. There is a correlation, however, between the different test procedures. There are many different units of measure, such as BHN, DPH, SHORE UNITS, and KNOOP UNITS. The primary and most accepted tests are the **Rockwell** and the **Shore Scleroscopic protocol**.

The MOH testing method was probably the first ever used and dates thousands of years. Ten stones, rated in hardness from one to ten, were first selected. Talc, with a rating of 1, and diamond, with a hardness of 10, was used as the limits of hardness measure. Stones with varying hardness between two to nine were then selected. The questioned sample would be scratched or struck with each test stone, starting with the softest. When a scratch could no longer be made, the test material was said to have that hardness.

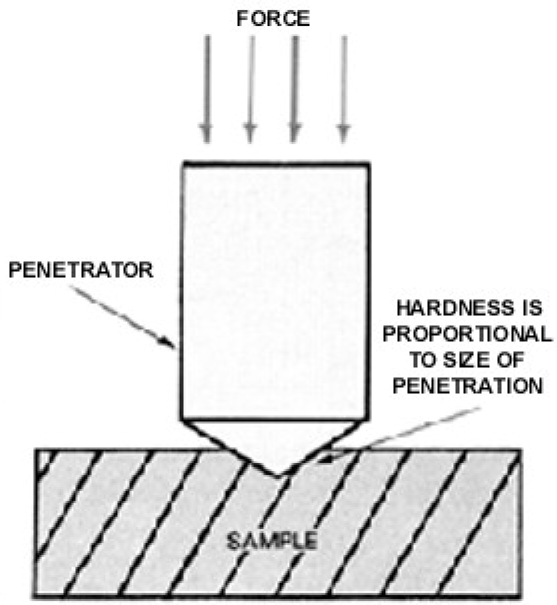
Perhaps the oldest recognized procedure for testing hardness is the Brinell Test. This involves the application of 3,000 kg. load through a steel ball onto a sample. A calibrated microscope measures the resulting depression.

5_3.4.1.1.1 Rockwell Testing Procedure

Rockwell is the most popular method of testing for simplicity in procedures and accuracy. Equally important, localized surface

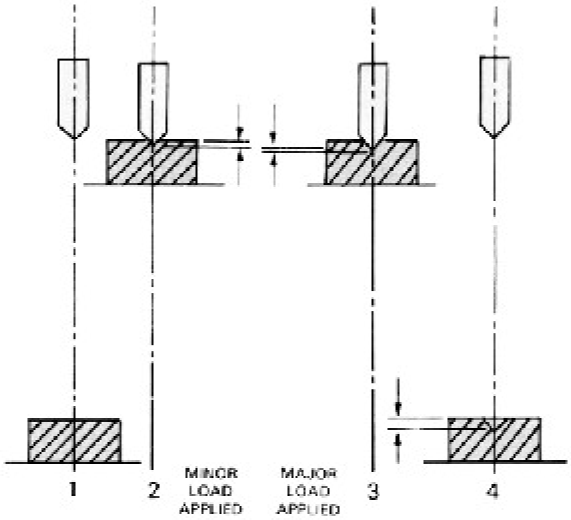
imperfections are taken into account in the process that can skew test results.





After a sample is placed on an anvil, the penetrator is pressed into the material. First, a minor load of 10 kg is utilized. Then the major load of 60 kg, 100 kg, or 150 kg is applied, depending upon the type of test. As the load increases, the point of the penetrator moves deeper into the sample. The measure of hardness is read from a scale located on the testing machine and is directly correlated to the depth of penetration.

Rockwell has nine different testing scales, achieved using three different penetrators with three differing loads. The penetrators are 1/8" or 1/16" diameter tungsten carbide drillpoints and a diamond point.



For the hardest materials, the 150 kg load and a diamond tip penetrator will be used. Identified as the Rockwell C scale, the hardness rating is written as, for example, 85 Rc. It should be noted that Rockwell also makes superficial-hardness test machines that will only test the surface hardness of a metal. They are often used where measurements are to be made with very thin materials or for testing case hardness.



5_3.4.1.1.2 Shore Scleroscopic Test Procedure

The Shore Scleroscopic technique relies on the use of a light

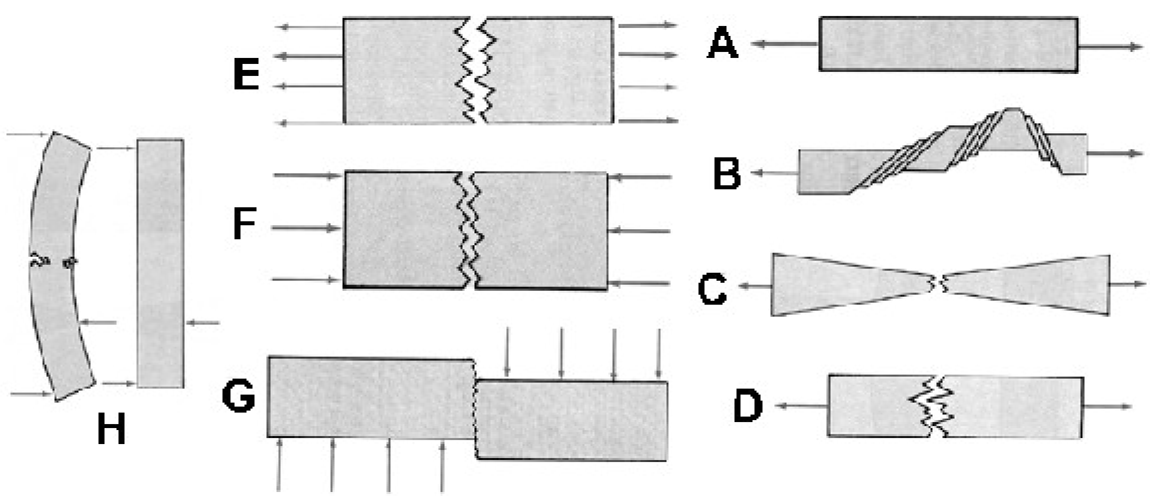
metal ball or hammer that is dropped from a specified height of ten inches, in order to test the "bounce" of the material. The theory is that the hardness of the surface will be proportional to the distance of bounce. In practice, a hammer weighing 40 grains or .001 pound (less than 3 grams), strikes the sample and is caused to rebound. The height of the rebound is measured and translated to "Shore Units." It should be noted that this testing format is not used for evaluating hard plate because it requires a flat, clean horizontal surface.

5_3.4.1.1.3 Sonic Testing

Sonic testing utilizes the resonant frequency of the material, and is quite accurate. A rod of .75 mm diameter is pressed against a sample and electronically vibrated. The resonant frequency of the rod is measured; the higher the frequency, the harder is the material.

5_3.4.2 Strength

The strength of a metal is described and measured in terms of its **tensile(90), stretching or pulling(91), compressive(92), shear(93), fatigue(94), impact(95), flexure or bending(96), and torsion or twisting(97)** qualities. Measurements of these factors are extremely important in the analysis of materials utilized in locks and safes.

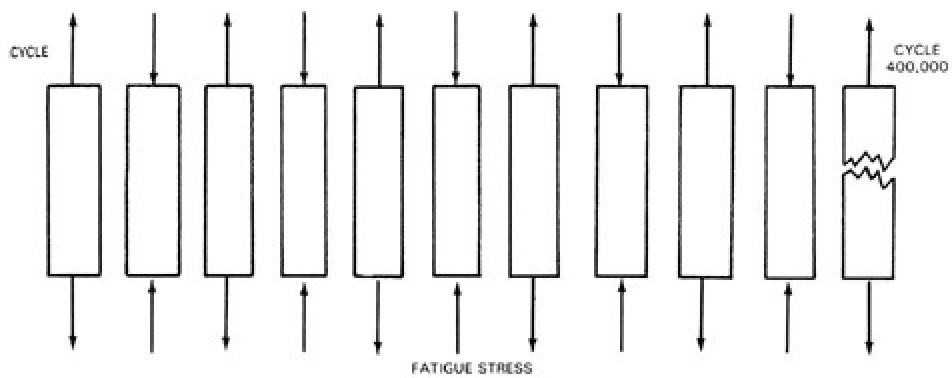


Tensile strength is the measurement of the ability of a material to withstand a "pulling apart" force, or stress in tension, and is the most important measure of the strength of a metal. Steel

has a very high tensile strength. The test is utilized by the ASTM in the analysis of padlocks and is described more fully in **Chapter 32.**

Shear strength is the ability of a metal to resist a "sliding past" type of force. A tearing motion or pressure is applied between two edges like a scissors, in order to perform this test.

Fatigue strength is the ability of a metal to suffer repeated loading without failure.



Compressive strength measures the ability of a material to withstand a pressure or squeezing force.

Toughness and impact strength measure the ability of a metal to resist shock.

Flexure describes bending of a material.

5_3.4.3 Brittleness and Ductility of Metals

These two terms denote somewhat opposing characteristics. A material that stretches before breaking is said to be **ductile(98)**, or has high ductility with a corresponding ability to resist shock. Low-carbon steel, aluminum, and rubber bands are said to be ductile. Alternatively, if the metal does not stretch, it is **brittle(99)** and generally will have a low resistance to shock. Cast iron, glass, and uncooked spaghetti are brittle.

5_3.4.4 Thermal and Other Properties of Metals

Thermal properties, **corrosion resistance**, and **wear resistance** are

also important attributes of metals. **Wear(100)** is the ability of a metal to withstand loss of material by frictional scratching, scuffing, galling, or goring. The "wear factor" is directly affected by hardness; the harder the surface, the greater the resistance.

A metal must be able to resist atmospheric deterioration, called **corrosion.** This occurs from destructive agents in the air, such as acids, alkalis, salts, and smoke. They combine with humidity, heat, and ultra-violet rays from the sun to attack the freshly cut surfaces of most non-precious metals. **Corrosion(101)** produces a film on the surface of the metal that can either protect or destroy the underlying material, based upon its molecular structure. In iron and steel, rust is a form of corrosion, and once begun, it is very difficult to arrest. Copper and its alloys, once exposed to corrosive elements, will form a protective film called **verdigris(102)** that will inhibit further corrosion.

When metals are heated or cooled, their structure changes. If a metal is heated, it grows larger. This property is referred to as the **coefficient of thermal expansion** and is a measure of how quickly the material expands. When a metal is heated to its melting point, it changes from a solid to a liquid. In the case of steel, this occurs at about 3000°F. The molecular structure of the metal allows the heat to travel rapidly across its surface: it is said to have a high **thermal conductivity.** Copper and aluminum are excellent conductors and thus are used to carry heat (from a torch) away from surface materials in safes.

Deformation(103) describes a property of some metals to stretch when tension is applied, just before breaking. The measure of deformation is the increase or decrease in length when a load is applied. A material is ductile if it stretches significantly prior to failure, whereas the metal is brittle if it does not become elongated.

Brittle materials fail with **cleavage(104)**, whereas ductile materials fail during **shear.** Shear failure in ductile materials occurs when atoms slide past each other within the crystals. Shear strength is the ability of a material to resist a “sliding past” type of stress.

Cleavage causes atoms to separate, whereas in shear, atoms slide past each other within the crystals, causing stretch. A shear failure will result in atoms either sliding or twining; the part

will deform and become elongated and thinner. Eventually, a break will occur.

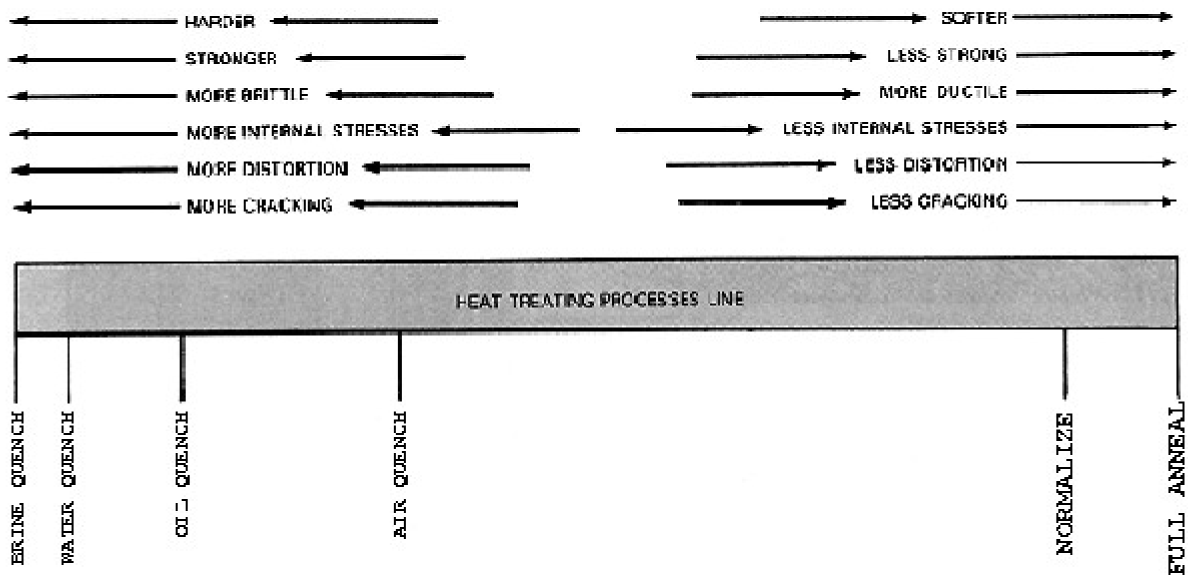
When a material is stretched out of its normal shape, it is often **work- or strain-hardened.** A material that is deformed will work-harden, becoming stronger, harder, and less ductile. Drilling of hard plate, if not done properly, will cause work hardening of the material ahead of the cutting edge, making penetration even more difficult.

5_3.5 Effects of Temperature upon Metals

Any process involving the application of heat and cooling is called heat-treating. This includes **heating**, **quenching(105)**, **annealing(106)**, **normalizing(107)**, **tempering(108)**, and **surface hardening**. Heat-treating affects iron and steel in different ways and depends in part upon the precise quantities of oxygen, carbon, nitrogen, or ammonia that are added, together with the exact duration and temperatures. Heat-treating can both harden and soften a metal.

5_3.5.1 Heat-Treating Techniques

An overview of the various processes relating to the application of temperature to metals can be demonstrated using the example of **tempering** a steel needle. If a needle is heated until it is red-hot then cooled quickly in water, it will break easily but will be extremely hard. If, on the other hand, the needle is heated and cooled slowly, it can be bent like a wire. The needle can be retempered by reheating it to a red-hot state, then rapidly cooling it, then reheating it to a yellow color and then cooling it slowly.



Quenching is a controlled process of cooling that will result in the metal becoming harder. It is achieved by heating the material to a temperature greater than what is called the **temperature transformation region.** Several different quenching methods involve the use of water, air, oil, brine, molten salt, sand, and other materials. Water is the most popular medium for quenching carbon steel, because it can effect rapid cooling. However, water can also cause internal stresses, distortion, and cracking in the metal. Oil, for example, will often be used for cooling critical parts where strength or hardness is not quite so important. Air cooling is used in steel with a high alloy content, such as chromium and molybdenum.

Annealing or normalizing both involve the heating of material to above the critical point, then the subsequent slow cooling of the metal to room temperature. Either process will result in a softer, more ductile, and less distorted material. Annealing occurs even more slowly than the normalizing process and may take several days. There are three methods of annealing: **full**, **process**, and **spheroidizing**. In **full annealing**, the part is heated, then cooled at the rate of 100°F per hour. Annealing will relieve internal stresses without affecting the mechanical strength of the material.

Process annealing is slower and more economical. The part is heated to a lower temperature and cooled more slowly. **Close annealing** requires the exclusion of air to avoid oxidation during the heating and cooling process. Finally, **spheroidizing** is almost

identical to process annealing; the part reaches less critical temperature and has a slower rate of cooling.

Normalizing is almost the same as annealing, with respect to the time required for cooling of the metal. The material, however, is not submersed in a liquid as in standard quenching. The result does not produce as soft a metal as by full annealing. In fact, the metal will be somewhat stronger, harder, and more brittle than would be obtained in the annealing process.

Both annealing and normalizing result overall in a weaker, softer material, which is less brittle and more ductile. The technique also removes internal stresses, thereby lessening the opportunity to distort and crack. These processes are employed to increase the machinability of parts. Often, after annealing or normalizing, the part is then hardened.

Often misunderstood, **tempering** is a process of rehearing steel after it has been hardened so as to increase toughness and ductility. It is used to partially correct the undesired effects which quenching produces: hardness, brittleness, distortion, cracking, and internal stresses, although it will not cure the problems. **Tempering** is similar to annealing but occurs faster and at a lower temperature. The process first involves heating the metal to a temperature that is just high enough to remove internal stresses, then cooling to actually soften the material. It causes less severe changes than annealing or normalizing. Temperatures between 300°F and 1200°F will produce the desired result immediately after quenching. A higher temperature will result in less hardening of the material and an increase in ductility. Tempering of some tool steels between 200°C-350°C is done to protect against accidental damage from mechanical shock.

5_3.5.2 Surface or Case-Hardening

Surface or case-hardening is another form of heat treating that creates a thin, hard, wear-resistant layer or skin on the outer surface of the metal. For historical reference, see **Chapter 3** of Price. **Case** refers to the layer of hardness or higher carbon content mixed within the skin of the metal during the heat-treatment process. The longer the period of heating, the greater the carbon content of the surface. Case-hardening is a critical process; if excessive heating is applied, the metal will become brittle and crack due to the large grain sizes produced.

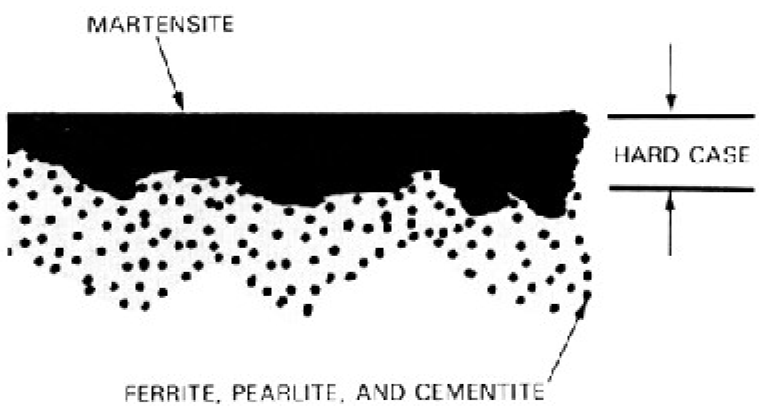
Like an apple, the hard outer layer covers a softer internal

material. The outside layer is generally a martensite crystalline structure, while the underlying material is softer and more ductile and is described as ferrite, pearlite, or cementite structures. Thickness of the "case" may vary from 1/8" to .001".

Case-hardening is particularly important in the manufacture of cutting tools and barrier hard plate. Tools must have an extremely hard exterior cutting surface, yet the material cannot be hard throughout or the tool will fracture. The process dates to ancient times when warriors would harden the tips of their spears, allowing armor to be pierced without cracking the point.

Case-hardening only applies to a surface layer; the process will not harden to the complete thickness of the metal. For example, a 1/4" thick plate may have a case of only .025". Thus, there will be a hardened layer on both sides, measuring .025" thick, but the core material will retain its original characteristics. To drill case-hardened metal, one must penetrate two layers of high hardness, plus the softer core material.

There are three basic methods to achieve case-hardening: **addition of carbon** and/or **nitrogen**, or **localized heating**. These processes are also referred to as carburizing, pack carburizing, gas carburizing, liquid carburizing, nitriding, cyaniding, and carbon nitriding.



5_3.5.2.1 Hardening Using Carbon

When carbon or nitrogen is used, the surface is impregnated and the part is heated and quenched. The now carbon or nitrogen enriched surface becomes hard. In the case of nitrogen, however, the gas combines with the steel and forms an extremely hard

nitride compound. The swords of Roman soldiers were hardened through the **carburizing(109)** technique. When temperatures reach the 1700°F range, most low carbon steel will absorb carbon into its outer skin to about 0.050”.

During p**ack carburizing**, the steel parts are packed into heat-resistant containers filled with a carburizing material. Hardwood charcoal, coke, and barium carbonate are often added to the mixture. These materials are sealed and heated in an environment devoid of oxygen, to between 1500°F-1750°F. The steel is transformed during this process to its **austentite state**, which allows it to absorb large amounts of carbon. The material is then quenched to achieve hardening. **Gas carburizing** involves the injection of propane or natural gas, impregnated with vaporized hydrocarbon liquids. Hardening is achieved at about 1700°F. **Liquid carburizing** involves the use of molten salt baths, into which the parts are dipped at temperatures between 1550°F and 1650°F.

Nitriding has many advantages as compared to other case-hardening processes. Harder surfaces, superior wear resistance, minimal warping and distortion, improved corrosion resistance, high resistance to fatigue, and lower production costs are all achieved in the nitriding process. However, nitriding also has drawbacks. It is a very slow procedure and will adversely affect dimensional accuracy of the part due to swelling. Most importantly, machining of the metal is almost impossible.

Cyaniding(110) involves the dipping of the part in a bath of molten cyanide salt. The process is quicker than most others and produces a case of about .005”. Less than thirty minutes is required to cyanide-harden a part, at 1400°F-1600°F. **Carbonitriding** is also known as dry cyaniding, gas cyanitriding, nicarbing, and nitro-carburizing. Nitrogen gas is introduced during carburizing and assists in insulating the part from oxygen. The nitrogen actually increases hardness and resistance to tempering.

Localized heating is employed for medium to high carbon steel. In practice, high temperature is applied in order to heat only the surface, using techniques of **flame hardening** and **induction hardening**. In flame hardening, no chemicals are used, just heat. A direct flame from an oxyacetylene torch is placed in contact with the surface of the material. As soon as it is heated, it is immediately cooled. This method can produce a deep case, up to about 1/4", with a maximum hardness of 50-60 Rc.

High-frequency electrical current produced through a coil is used in the **induction hardening** process, to cause a magnetic field to be induced around the steel part. This will result in a skin effect, causing eddy currents to pass through the surface of the metal, producing heat.

5_3.6 Special Processes for Treating Metals

Metals can be formed and treated through a number of different processes, many of which are utilized in the production of locks and keys. These do not affect the basic molecular structure or attributes of the metal.

5_3.6.1 Surface Treatments

Anodizing(111): The skin of a metal is anodized to create a thin coating or layer of material that will inhibit corrosion and create a hard and abrasion-resistant surface. The technique utilizes an electrical process and is generally employed with aluminum and its alloys.

Dipping(112): Brass castings are often dipped in an acid bath to clean and remove debris from casting.

Electro-Plating(113): Electroplating, based upon the principle of electrolysis, is a technique used to form a thin metal surface or finish upon another metal. Finishes are created for several reasons, including the protection of the surface, to give the effect of a more precious metal and to improve appearance. The process involves passing an electric current from a source metal (the anode) to the target metal (cathode). Both the source and targets are suspended in separate chemical baths. This allows the molecular structure of one metal to be transferred from the source to the target. Electroplating is used with copper, nickel, zinc, cadmium, tin, brass, bronze, chromium, and other base metals. Copper, for example, may be electroplated onto iron and steel to prevent corrosion.

Galvanizing(114) is another surface treatment for iron and steel for protection against corrosion. **Hot-dip galvanizing** is simply a process for applying zinc, generally in a molten state. The procedure is not suitable for most lock parts, because it is almost impossible to produce and control a precise thickness of the zinc.

Sheradizing also produces a protective layer of zinc upon iron and steel by heating the material for several hours, then rotating the metal in a drum while applying zinc powder. The zinc will impregnate the metal, offering excellent corrosion resistance.

5_4.0 Forming, Shaping, and Cutting Metals

There are many operations available for the forming, shaping, and cutting of metals. Those processes pertaining to the production of keys, locks, and safes are detailed here. Cutting operations can include sawing, reaming, tapping, planing, broaching, boring, threading, and drilling. However, only broaching and drilling is relevant in the context of locks and safes. Drilling is discussed later in this chapter.

5_4.1 Broaching

Some cutting procedures involve simultaneous action on two edges or surfaces. **Broaching(115)** is the process of cutting the keyway in a brass plug during the manufacturing process. A broach, in its simplest form, is actually a pointed, sharp die used to remove layers of metal. In order to form a specific keyway, the plug of a lock must be precisely cut with a broach. Designed as a cutting die, it is formed to create the exact reverse of the key blank.

The **broaching tool** is forced or rammed into a solid block of brass. Its purpose is to shear away metal, thus forming a keyway that has the identical dimensions of the broach. The broach will have all of the grooves, angles, ridges, and bullets of the desired keyway. It will appear exactly as would the key blank, except that its surfaces are extremely sharp. The broach actually removes the metal as it is forced into the plug. See **Chapter 16** for sequential illustrations of the process of producing a plug from a block of brass.

5_4.2 Shaping and Forming of Metals

There are many operations that involve the shaping or forming of metal. These include **casting**, **die-casting**, **extruding(116)**, **forging(117)**, **pressing**, **rolling**, and **stamping**.

Casting: This is a method of producing a part to a required

shape, generally by pouring molten metal into molds of sand or metal.

Die-casting: This process requires a metal die rather than sand for the mold. Zinc, aluminum, and brass can be cast and are very popular for the production of lock parts. It is an economical process that allows intricately shaped components to be formed with a high degree of accuracy. Machining is not required after casting. Metals can also be cut, bent, molded, and formed using dies.

Drop Forging: This is a process of shaping metals while they are hot, using a drop hammer. The machine actually resembles a hammer and anvil, wherein the hammer is raised automatically and falls by gravity.

Drop Stamping: In this operation, a part is shaped using a die while the metal is cold. In contrast, a part may be formed through the process of **hot stamping** or **hot pressing** when the metal is heated.

Extruding: Extruding requires the use of a special die in which metal in a plastic or liquid state is forced through a shaped hole. The material is rapidly cooled to retain the shape given it by the die. Aluminum and brass are very suitable for extruding, and many common parts are formed using this process.

Hot Rolling: Metal, while red-hot, is fed between two steel rollers to form a sheet, bar, or plate of specified dimensions.

5_5.0 Specific Metals Utilized in Keys and Locks

A number of popular metals are utilized in the production of locks and keys and will be discussed here. Materials that are used in the manufacture of safes are covered later in this chapter.

Aluminum and its Alloys: Aluminum and its alloys are very popular for key blanks. One alloy **Avional** is used extensively by Silca to make keys that can be stronger than brass and cheaper to produce. The specification for Avional is: silicon (Si) .4 percent; iron (Fe) .50%; copper (Cu) 1.2-2%; manganese (Mn) less than .3%; magnesium (Mg) 2.1-2.9%; zinc (Zn) 5.1-6.1%; titanium (Ti) less than .2%; zirconium (Zr) .25%; and aluminum (Al)

comprises the remainder of the alloy.

Brass: This is an alloy of copper and zinc, with copper comprising between 60-70 percent. There are other materials added. The melting temperature of brass is approximately 1660°-1710° F. Brass may be sand cast, rolled, extruded, drawn, hot pressed, hot stamped, and die-cast. Almost every part of a lock can be made of brass. Metal content for brass keys is typically: copper (Cu) 57.5-60%; iron (Fe) .45%; nickel (Ni) .3%; zinc (Zn) the remainder of the mixture.

Bronze: Bronze is an alloy of copper and tin, with 90 percent or more copper. This metal can be rolled and drawn.

Copper and Copper Plating: Copper is an alloying agent in certain brasses and bronzes. Copper, with nickel and chromium, is used for plating non-ferrous metals as a primer. Copper also provides an excellent binder for nickel plating.

Gunmetal: This is an alloy of copper and tin. It is a bronze, although lead and zinc may be added. Gunmetal is considered superior to brass in lock making. It is harder and more expensive, resistant to corrosion, and generally is only used in external parts which are subject to environmental conditions.

Malleable Cast Iron: Cast iron may be made ductile through a special process of annealing, described elsewhere in this chapter. Lock bolts and shackles of padlocks have often utilized malleable cast iron because of economy and convenience.

Manganese Bronze: A small amount of manganese can be added to brass to increase strength. It is used for padlock shackles.

Nickel: Nickel is an alloying agent and provides a protective finish when plated to another metal.

Nickel Silver: This is an alloy of nickel, copper, and zinc. It is often mistakenly described as brass, where in actuality, some of the zinc is replaced by nickel, thereby making the alloy tougher than brass. Nickel silver is utilized in many factory original keys for added strength.

Phosphor Bronze: A very small amount of phosphor is added to bronze, which has the effect of making it a very strong, springy material. It is used extensively in making non-rusting springs for pin tumbler locks.

Spring steel: Steel, having a higher than normal carbon content, is used for making springs, lock picks, and other parts.

Stainless Steel: Chromium and nickel are added to iron to produce this corrosion-resistant metal.

Steel used in Keys: Steel is still used for some keys. The metal content for steel keys is typically: (C) carbon .13%; (Mn) manganese .9-1.3%; sulfur (S) .24-0.30%; silicon (Si) >/= .05%; lead (Pb) .04-0.10%; and iron (Fe) the remainder of the alloy. Lead will be eliminated in keys within a few years due to environmental and health concerns.

Tenite: A plastic material used in the production of Mosler dials.

Zamak: Zamak is used for making a variety of lock parts, and is composed primarily of zinc (95.5%), aluminum (4%), copper, lead, tin, magnesium, cobalt, and iron. The material has good casting qualities, good tensile strength, and can be sanded, filled, drilled, and tapped. The melting temperature of zamak is approximately 787° F.

Zinc and its Alloys: Zinc is also the base metal for die-casting alloys. Intricately shaped components can be made using zinc alloys. Zinc has three uses in lock-making: (1) for use in die-casting, (2) as a protective coating of other metals, and (3) as an alloying metal for use with various brasses.

5_6.0 Metallurgy and Safe Development

5_6.1 Introduction

The anti-burglary safe maker faces many difficult problems, both in the selection of materials and in the mechanical design of the safe. In contrast, the fire safe maker must offer minimal resistance to forced-entry while providing protection against the effects of heat upon the contents. Each type of safe has markedly different requirements and demands, from the standpoint of the choice of metals, how they are treated, and what they will guard against.

In the Middle Ages, underground cellars and buried vaults with doors constructed of hardwood with thin iron plates were used for

storing valuables. Then, chests made of iron plates riveted together and secured by iron bands were developed by the Germans and Dutch. Cast and wrought iron, and later steel alloyed with manganese and laminated with copper, was popular. The problem with virtually all of the early safes, whether made of rolled iron, cast iron, or steel, was that they were easily fractured by concussion. Innovations in safe technology would come primarily from England and the United States during the nineteenth century. See **Chapter 33** for a more detailed discussion of the history of safe development.

5_6.2 Early Development of Burglary Safes

Many approaches in the design and use of materials for burglary safes have been tried. The main problem has been finding or creating metals which were hard enough to resist drilling and cutting, yet tough enough not to fracture under percussion or pressure. Chubb, a pioneer in safe development, early on determined that they should make safes out of layers of hard and soft plate, comprised of high carbon steel, welded and rolled between layers of iron and mild steel. The high carbon steel would offer resistance to cutting instruments, while the softer material would add toughness. There were often five or more sandwiched layers.

Other techniques involved the use of cast metals such as speigeleisen, which could be sandwiched between outer and inner layers of other metals within the safe. The cast metals could be solid blocks of chilled iron that were grooved, keyed, or bolted together and were often a foot or more in thickness. Joints were then covered with forged bands. In 1860, Chatwood, an English safe maker, took two sheets of iron, and poured molten metal between them. This produced an extremely hard center that would cause a shattering or flattening of drill bits. This presented a far better solution than obtained from using multiple iron sheets and was successful in resisting cutting and torching; the two most common methods of attack. If copper sheets were then placed between steel plates as a heat sink, the steel would be prevented from reaching its melting point upon the application of heat from a torch.

Later, Chubb, in its high-security safe door, utilized ten layers of metal. The door was comprised of a five-ply drill-resisting steel; three sandwiches of softer steel protected two of these layers. Concrete and hard mineral chips (an anti-blowpipe material) were also used. Siemens steel, copper, and another

five-ply layer of steel, together with proprietary alloy steel, were also employed. Finally, two more layers of Siemens were added. In 1882, it was discovered that steel containing one percent carbon and thirteen percent manganese would effectively deter sawing, drilling, or filing. The metal was heated to about 1900°F, and quenched in water. It was used in the outer shells of safes and in prison bars and was known as manganese hard plate.

5_6.3 Specific Metals Utilized in Safes and Safe Locks

Many materials are utilized in the construction of safes and safe locks, based upon requirements of strength, machinability, cost, wear, and other factors.

5_6.3.1 First Outer Layer

The doors and walls of safes offer a wide divergence in penetration resistance, depending upon whether the safe is rated as **fire** or **burglary**. If burglary, the specific rating, i.e., UL tool (**TL**), torch (**TR**), or explosive (**TX**), will relate to the type and thickness of metals used. Generally, the outer layer of most safes is iron, steel, poured aluminum, concrete, or other materials. Plastics will also become more prevalent as special polymers are developed such as used in the Chubb Planet safe. Typically, ½″ to 5″ of mild steel or other material is utilized as the first barrier against drilling and other forms of forced-entry. Often, a sandwich of hard and soft materials is found, acting as a heat sink and frustrating attacks by drilling, explosives, torches, lances, and other techniques.

5_6.3.2 Hard Plate Barrier Material

Behind this first layer of metal is the real protection for internal locking components. It is called hard plate or simply barrier material and consists of ¼″ or thicker plate that is a specially created and treated metal alloy, having a Rockwell C rating approaching 80. This hard plate protects critical parts and functions and will always be found in front of and covering combination locks and relockers.

5_6.3.3 Internal Moving Parts

Boltwork, locking bars, gears, and other locking surfaces are

generally made of steel, stainless steel, or other hardened materials. Softer metals, which can be machined to high tolerances, are used in all moving components associated with locks and some relockers. Zamak and brass are popular.

5_6.3.4 Internal Lock Parts for Safes

Many different metals are used for internal lock parts, mechanisms, and for special purposes. These will be briefly detailed. Copper is used as a heat sink, generally in sandwiched layers, to frustrate attack by torch. Brass, steel, aluminum, plastic, delrin, acetal, nylon, and celcon are all used in the combination lock wheel pack. These soft materials are chosen for their special characteristics, needed to maintain reliability of the lock. Brass is also utilized for many internal lock parts, including some wheels, casings, cams, levers, relock triggers, and bolts.

Materials are selected based upon the following criteria:

- **Resistance to corrosion and development of micro-organisms and biological growth (green film) in wet climates;**
- **Self-lubricating features;**
- **Resistance to radiographic imaging and penetration;**
- **Impervious to chemicals, oils, grease, or solvents;**
- **Ability to produce to high tolerances;**
- **Does not conduct electricity (not subject to electrolytic action).**

5_7.0 The Penetration of Safes: Barrier Materials and Hard Plate

The following sections describe barrier materials and hard plate in the context of penetration of safes and vaults.

5_7.1 Basic Construction Technique

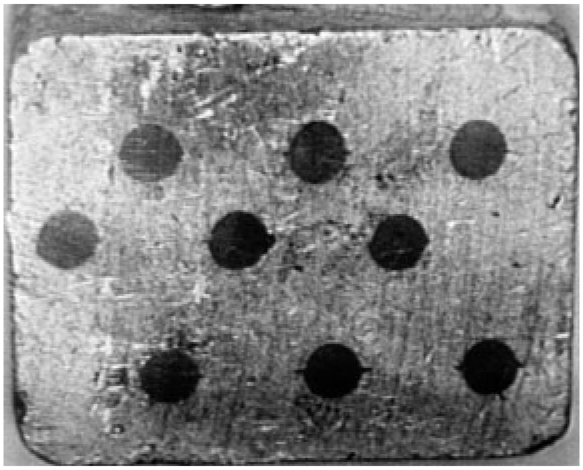
All modern safes follow the same fundamental pattern of construction, although the basic configuration, reduced to its primary elements, is quite constant for most containers. Depending upon the security classification and manufacturer, differences in design can include:

- **More material;**
- **More layers of a given material;**
- **Sandwiched layers of different materials;**
- **Heat sink or ducting materials;**
- **Ball bearings;**
- **Steel pins;**
- **Stone chips;**
- **Specially designed alloys to frustrate penetration.**

Let us first examine the components of a "typical" low to medium rated security safe. The door is made of 1/2" mild steel. Welded behind the door is 1/4" hard plate to protect access to the combination lock, followed by a 1/8" lock mounting plate, upon which the lock body is actually affixed. The mild steel first barrier presents little difficulty for the proper drill rig. In larger, higher security safes, this 1/2" outer skin may be several inches thick. In addition, there may be added copper layers in critical areas to draw heat away from barrier materials. If a copper layer is encountered, it will make attack by torch very difficult.

Regardless of the security rating or the number of layers of metal between the outer surface of the door and the lock mechanism, the principle is the same: **the barrier material is the primary protective shield against penetration.** As will be seen in the chapters dealing with safe construction, there are many sophisticated ways to add penetration resistance. The major safe manufacturers have concentrated their primary research efforts on the barrier material or hard plate, rather than other technologies. Each manufacturer has developed different metallurgy to protect its safes, and thus, each material will differ in its penetration resistance. Hard plate can take many forms from case-hardened steel to laminates and can be any thickness and composition. Generally, all barrier materials will have a Rockwell C rating between 70 and 85 or higher.

5_7.2 Definitions



There are a number of terms associated with barrier materials. These are important to an understanding of their properties and construction techniques.

Carbide chips are welded on the surface of some hard plate (and are placed on the tips of drill bits). They make drilling very difficult because the bit cannot "bite" into the metal without breaking.

Carbide pins or balls are a very popular technique of protecting hard plate from drilling. An anti-drill, closely spaced array is pressed into the plate or is free-floating. Stainless steel rods incorporated within aluminum alloys such as aloxite are equally effective. Chubb has been using this technique for many years.

Hard plate or **alloy Hard plate** is a combination or amalgam of one or more metal plates and particles or other materials. These are sandwiched between the lock body and the safe door to create a hard barrier to resist forced-entry. Depending upon the manufacturer, varying amounts and ratios of chrome, tungsten, carbon, nickel, and other metals will also be used in the production of hard plate.

Hard plate, in its many forms, is metal that has been specially treated and hardened. **Tempered hard plate** will have a smooth surface. Unpainted, there will be traces of discoloration, with reds, blues and greens. Hard plate can be **included** or **non-included.**

Hard plate is generally exposed to 1500°F-1600°F for about four hours, then cooled in oil to obtain a maximum case hardness. The

individual characteristics of the steel being hardened will determine time and temperature applied, for a desired hardness rating.

Inclusion materials are found within alloy hard plate for added drill resistance. Alloy hard plate is known for its "inclusion materials" and is often referred to as **included hard plate.** Generally, included hard plate is high carbon alloy steel. In addition, a layer of bronze, epoxy, ceramic, or other material may be poured over the metal skin. Inclusion composition may contain small chips or pieces of tungsten carbide, carbide chips, carbide dust, ceramics, aluminum oxide nuggets, ball bearings or other materials. These inclusions may also have varying spacing or gaps in materials to make drilling even more difficult.

The combination of surface deposits and inclusion materials within the metal can create a very irregular and rough outer skin, with non-uniform and hard internal layers. Varying surface dimension and materials will wreak havoc with drill bits.

Laminated hard plate is made up of interleaved layers of hard plate, soft steel, copper, and other heat-conducting materials.

5_7.3 Manufacturing Hard Plate

Many manufacturers produce their own patented hard plate or barrier materials; each is given a special name. Thus, there is Maxaloy**tm**, Kimloy**tm**, Lockmasters**tm**, Aloxite**tm**, Alchronite**tm**, and Relsom**tm**. Each manufacturer uses different techniques, including the addition of carbide chips, nuggets, aloxite, concrete, or other materials within the mix or welded to the surface. Layers of plates, iron laced with hard studs, hardened suspended discs which are free to revolve and other techniques may be employed in the production of hard plate. They all have the goal of preventing, delaying, or increasing the danger of penetration by drilling, explosives, thermic lance, and other sophisticated methods. All hard plate is different, even within the same manufacturing batch.

Hard plate can also be poured into a form. Maxaloy, for example, contains coarse cobalt, cemented tungsten, tantalum, and titanium carbide grains in a high-strength matrix. This amalgam is poured into a form, in the shape of a pan. The hardness of this particular material exceeds the top reading of 86.5 on the Rockwell C scale. Mosler pours Relsomite in this same fashion.

The approach Diebold has taken utilizes "envelope" technology, “including” carbide chips within a stainless steel matrix, poured into two pans. When the metal has cooled, the two layers are joined together with ball bearings within a matrix of epoxy. An outer layer of ceramic may also be encountered in drilling certain Diebold products. Chubb utilizes a variety of approaches, including poured aloxite and hardened nuggets, pressed bearings, and other techniques discussed in later chapters. Steel balls, used by Chubb, may be either loose or pressed. If loose, they are suspended in oil.

5_8.0 Metal Cutting Principles

5_8.1 Introduction

This section outlines the principles that apply to metal cutting, with the emphasis on drilling theory of hard plate. The section first details the development of materials used for the production of tools during the twentieth century, including some of the more exotic high-tech compounds. The physics and chemistry of metal cutting are then explored, again with the emphasis on how a drill interacts with the work surface. Special attention is given to the production of chips, how they occur, and why they are so important. Understanding how metal is cut is particularly important for the evidence technician in order to aid in the investigation of the forced-entry of safes and vaults. The discussion is of equal significance for the safe, vault, and container specialist.

5_8.2 Tool Materials in the Twentieth Century

The development of more sophisticated materials can be directly traced to certain periods in the twentieth century and special technical requirements connected with such developments. The following events set the stage for staggering advances in chemistry and metallurgy that have occurred during the second half of this century.

- **The introduction of the automobile around 1910;**
- **World War I and the recognition of the value and subsequent use of aircraft for both military and civilian purposes;**
- **Second World War, with the development of the**

chemical, petrochemical and polymer industries.

Factors, including the birth of the nuclear industry, the need for improved machine tools for use in automated production, jet engine manufacture, the space program, and national defense also contributed to current technology. Finally, environmental concerns, energy costs, and the price of labor and materials have all had a tremendous impact upon technological advances.

5_8.2.1 Cutting Tools

The development of advanced materials for use in the production of cutting tools have resulted from the tremendous demands placed by a highly technical society and the rapid changes which have been brought about. As has been noted previously, the development and refinement of materials used in cutting tools has required the integration of many disciplines, including physics, engineering, metallurgy, and chemistry. Tools are available in hundreds of different alloys and are rated and classified by the following criteria:

- **Structure;**
- **Properties;**
- **Performance;**
- **Composition;**
- **Ability to resist temperatures and stresses;**
- **Interaction of the tool and the work surface.**

A tool is evaluated in terms of initial cost, tool-cutting costs, tool life, cutting speeds and feeds. This is especially important in the case of drills used for penetrating barrier materials. Until the first use of metals, naturally occurring products such as wood, bone, and rock were the only materials available for cutting. Prior to the turn of the twentieth century, copper, iron, and steel were the only metals available.

In terms of a time line of material and tool development, there have been many significant advances after 1900. Before World War II, high-speed steel (1900), cast alloys (1910), super HSS (T-15) (1920), and sintered WC (K-type and P-type) (1940) were developed. Around 1950, M-40 series HSS, ceramic, and synthetic diamonds made their debut. Shortly after 1960, TiC, improved sintered WC, cermets, and coated carbides were introduced. In the seventies, polycrystalline D and CBN and powder metallurgy (P/M) high-speed steels were developed. In the 1980s and 1990s,

extremely complex polymers and ceramics have been patented and are being used for special tools.

5_8.3 Tool Material Classifications

Within the last quarter century, tools have been divided into two major groups: **high-speed steels** and **cemented carbides.** Other groups of materials are **carbon steels**, **cast cobalt-based alloys**, **ceramics**, and **diamond.** Materials are chosen for use in tools depending upon many factors, including operating temperature, feed, speed, and the hardness of the material being cut or drilled. Many metals, such as HSS, will lose their hardness once heated above their tempering temperature. Others, such as tungsten carbide, titanium carbide, cast alloys, ceramics, and cermets will recover their hardness at room temperatures.

5_8.3.1 Primary Measurements for Cutting Materials

Three primary measurements are employed to evaluate cutting tool materials: **high-temperature** physical and chemical **stability** (**HTS**), **abrasive wear resistance** (**AWR**), and **resistance to brittle fracture** (**RBF**). As has been noted earlier in this chapter, rarely can all three criteria be optimized; a compromise is always required. A high HTS material will become more brittle or have a low RBF. If it is made more abrasion resistant or high AWR, it will become more brittle or low RBF. These relationships are true over broad classes of materials, including high-speed steel (HSS), tungsten carbide (WC), and titanium carbide (TiC).

5_8.3.2 Toughness and Hot Hardness

The properties of materials with respect to toughness and hot hardness are inversely proportional. Thus, the following nine material classifications are shown in order of toughness. Carbon steel is the least hard but most tough.

(Most Tough)

- **Carbon steel**
- **High speed steel**
- **Cast alloy**
- **Tungsten carbides**
- **Cermets**
- **Titanium carbides**

- **Ceramic (Al_2O_3)**
- **Polycrystalline diamond and cubic boron nitride**
- **Single crystal diamond**

(Most Hard)

As we move from carbon steel to diamond, the strain or stress required to cause fracture decreases. All of the materials, with the exception of single-crystal diamond (extremely brittle), have a two-phase structure: a softer continuous phase, which separates very hard particles. As a material becomes harder, the space between hard particles becomes less.

5_8.4 Different Tool Materials

Hundreds of materials are utilized in the production of tools that are employed for cutting other metals. These are described below.

5_8.4.1 High-Speed Steel and Alloying Agents

As the Industrial Revolution came into full force in the nineteenth century, carbon steel tools were not cost effective in meeting the increasing demands of factory output. Tools were needed that could cut more steel at lower cost; thus, the introduction of high-speed steels. Robert Mushet of England was the first to use alloying elements to improve cutting tool design in 1868. Prior to that time, lathe tools were forged from steel containing 1% carbon, .2% manganese, and the remainder iron. These had a low hot hardness (hardness at elevated temperatures). The result was that prior to 1868, tools could not be used at high speeds. Production of this material also required water quench that invariably caused fracture.

Mushet introduced 2% carbon steel, with 5.5 percent tungsten, 0.4 percent chromium, and 1.6 percent manganese. One advantage to this mixture was the ability to harden without quenching the metal. It also allowed higher cutting temperatures. This steel was used until about 1900. In 1901, a metal was developed which would double the cutting speed of the Mushet alloy and was to be known as high-speed steel (HSS). HSS did not signal the development of a new metal but rather the introduction of a new heat-treatment for existing steel.

The inventors of HSS, F.W. Taylor, and M. White, noted that if tools were heated quickly to a temperature of 845°C-930°C, just short of the metals melting point prior to quenching, significant improvements in hot hardness would occur. By 1906, the optimum formula (at that time) was determined for high-speed steel tools: C, .67%; W, 18.91%; Cr, 5.47%; Mn, .11%; V, .29%; and Fe, the balance.

Many changes in the composition of HSS occurred, which allowed much higher cutting speeds. In addition, the abrasion resistance of the metal was changed through the addition of vanadium. By 1910, the tungsten content had decreased to 18%, chromium to 4%, and vanadium to 1%. This was the well-known HSS 18-4-1, which would be the standard High Speed Steel for the next forty years. In 1912, cobalt was added to improve the red-hot hardness of the metal.

By 1920, there were three high-speed steels in common use, known as T-1, T-7, and T-4. In 1923, a fourth super high-speed steel was developed, called T-6. Today, the standard M2-HSS, which displaced the original T-1, has the following composition of alloying agents: .8% C, 4% Cr, 2% V, 6% W, 5% Mo. Current HSS will cut up to 120 times faster than the original material. The steel developed by Taylor and White is still popular and is one of the two primary metals used for cutting.

During the 1970s, further advances were made in the development of HSS which created materials with a smaller carbide size and more uniform distribution of carbides. HSS made possible the cutting of steel at approximately four times the rate of carbon steel. The properties result from precipitation hardening within the martensite structure. Toughness and high temperature strength has allowed this steel to survive for almost a century. High-speed steels cannot be used for cutting hardened steels, found in barrier plate within safes. This results from the loss of strength and the changes in the permanent structures when heated above 650°C. The most significant advance in the metallurgy of high-speed steels has been in the development of coatings by CVD and PVD processes.

5_8.4.2 Powder Metal (P/M) High-Speed Steel

High-speed steels can be created through powder metallurgy, which involves a very fine powder stream, produced by atomization of molten steel being broken into tiny droplets. This molten flow solidifies within a fraction of a second to a fine-grained

structure. Through this process, carbide particles are more evenly dispersed than in traditional methods of steel production. Powder metallurgy produces superior structure, resulting in lower failure rates and the ability to manufacture steels with higher alloy contents.

5_8.4.3 Spray Deposition Coated Tools

Like powder metallurgy, a fine spray of molten metal is produced that is then sprayed onto a solid substrate, itself molten. Coating high-speed steel tools involves the formation of hard layers on working surfaces, the primary purpose of which is to reduce friction or wear. Coated carbide tools appeared about 1969. Originally, a thin film of TiC (.0002), TiN, Ti, or HfN was applied to steel-cutting carbides. There are three popular coatings: TiC, Al_2O_3, and TiN. Some tools have several coatings to reduce brittleness inherent with such processes. Two processes, called **chemical vapor deposition (CVD)** and **physical vapor deposition (PVD)**, involve the creation of a very thin layer of metal carbides on the tool surface.

Generally, coated-tools are not suitable for machining high-temperature alloys. They are most useful in high-speed cutting on ferrous alloys of all types, including stainless steel. They can reduce cutting forces, produce greater cutting speeds, and may increase tool life from 2 to 100 times.

5_8.4.4 Cast Alloy Tools

Non-ferrous high-temperature alloys, with significant amounts of cobalt, chromium, and tungsten, were developed about 1915 by Elwood Hayes. The materials were not heat-treated but cast and therefore were known as cast alloy tools. By 1925, they were common. Tools made of cast alloy retain their hardness at high temperatures.

5_8.4.5 Cemented Carbides

Cemented carbides have many unique properties that have led to their use in drills and other cutting tools. Carbides, especially tungsten and molybdenum, are rigid and strongly bonded compounds. Until they reach their melting point, no major structural changes are experienced. Thus, their properties remain stable and unchanged by heat treatment, in contrast to steels that can be softened through annealing and hardened by rapid quenching. Cemented carbides are sometimes included in the

category of ceramics, and thus have often been referred to as **cermets** or ceramic metal.

Although the hardness of carbides will actually drop rapidly as the temperature increases, they remain harder than steel. They are especially well suited as cutting tools because of their stability within a wide range of thermal treatments. Carbide particles and cemented carbide alloys constitute fifty-five to ninety-two percent, by volume of the structure, in contrast to ten to fifteen percent of hard carbide particles in high-speed steels. Cemented carbides are often characterized as brittle materials, almost like glass and ceramics. They are actually capable of a great deal of plastic deformation before they fail.

During the 1960s, there was an increase in the quality of carbide tools; they were made less brittle through improved binding and sintering techniques, coupled with smaller carbide size. These tools are made of milled tungsten carbide powder, mixed with a sintering material and pressed, to provide a homogenous mixture. Traditionally, steel-cutting tools were made in one piece; however, cemented carbides have been produced to form tool tips or small-brazed inserts used for cutting. They are generally less tougher than high-speed steels and require the tool edge to be formed differently. It will be recalled that the rake angle on steel tools is generally as high as +30°. In contrast, the rake angle on carbide tools is rarely greater than +10°, and is often a negative.

5_8.4.5.1 Cemented Tungsten Carbide

Tungsten carbide, with its many alloys, is used extensively in drill bits for the penetration of barrier material. It was originally developed in 1896, when a French chemist mixed iron, charcoal, and sugar with cobalt. The first tungsten carbide tools were brought to the United States from Germany in 1928. These were actually made of finely ground tungsten carbide particles, sintered together with a cobalt binder. With improvements, they became quite popular during World War II.

Drill bits made of WC will withstand higher temperatures than the material being drilled and will generate a great deal of squealing. The chips thus produced are blue-black in color and quite hot. Several bits are generally required to make a hole through most hard-plate material. Note that carbide drills **cut** the material in contrast to diamond tip drills, which **grind** through the metal. There are two types of Tungsten Carbide: one

for machining gray cast iron non-ferrous metals and abrasive non-metals (ISO-K type), and one for machining ferrous metals (ISO-P type).

5_8.4.5.2 Titanium Carbides

Titanium carbide (TiC) tools were introduced in the 1960s in an effort to improve upon tungsten carbide tools. The material is more oxidation resistant, available at lower cost, and quite popular.

5_8.4.6 Ceramic and Cermet Tools

Ceramic cutting tools were first used in England, Germany, and Russia, and were introduced in America in the mid-1950s. This technology uses finely divided aluminum oxide, or alumina that has been sintered, without binders or other additives. These substances have high hardness and melting points. Tool tips consist of fine-grained alumina with high relative density and with less than two percent porosity.

Although the room-temperature hardness of alumina and cemented carbides is about equal, alumina has several advantages, including the retention of hardness and compressive strength at temperatures higher than is available with carbides. They also have lower solubility in steel than any carbide, up to the melting point of the steel. However, toughness and strength under tension are lower than with carbides. Alumina-based tools will cut steel up to four times faster than conventional cemented carbides or TiC-based alloys, yielding greater metal removal rates. Tools made of alumina, however, have not been particularly successful for use in high-speed drills.

In the 1980s, advancements were made in alumina technology, with the addition of up to 25 percent FiC whiskers, one to two micrometers in length, which were randomly distributed in the alumina matrix. This increased the metal's fracture toughness value. Cermet tools are popular for the high-speed machining of hard cast irons and steels, where there is limited mechanical shock encountered. Tools produced with ceramics are more brittle than carbides but also harder.

5_8.4.6.1 Sialon

A special group of ceramics, called **sialons**, has been used since 1976 for cutting tools. This material has high hardness, bend

strength, and a low coefficient of thermal expansion, providing good resistance to thermal shock. The cost of these tools is high.

5_8.4.7 Cubic Boron Nitride (CBN) Tools

Cubic boron nitride (CBN) is the next hardest material to diamond. It has many similar, but not identical properties and is harder than any metallic carbide. CBN can be used for cutting hardened steel at high speeds without rapid wear as encountered with diamonds. A thin coating of CBN or polycrystalline diamond is also popular on tools made of sintered tungsten carbide substrate with a cobalt binder. Introduced in 1973, these tools are made by placing small grain-size diamond or CBN on the carbide surface. They work best on non-ferrous alloys, fiberglass, silicon-aluminum alloys, graphite, and other highly abrasive materials.

5_8.4.8 Polycrystalline Diamond

The hardness of diamond is related to and is the result of its crystal structure. Diamond tools are the hardest known, but very expensive. They have a much lower wear rate, with longer life than carbides or oxides. Where there is a high-abrasion potential resulting from the hardness of the work surface, diamond will perform well. Diamond cutting tools are up to five times harder than cemented carbides, or alumina. Rates of abrasive wear can vary by a ratio of 1:80. The use of diamonds for drill bits is limited due to the inability to create sharp edges in the tool. Another drawback is that diamonds are easily chipped.

5_8.4.9 Other High-Technology Materials

Limited application, high-cost materials have been developed for special purposes. For example, tools made of columbium (niobium), known as UCON (trademark of Union Carbide) contain columbium, titanium, and tungsten, and are diffused with nitrogen at 3000°F. The material is extremely hard, yet ductile.

5_8.5 The Cutting of Metals

5_8.5.1 Introduction

There are three primary metal cutting operations: turning,

milling, and drilling.

Turning(118), with a lathe, uses a single-point tool to remove unwanted material during the process of revolution.

Milling(119) produces flat and curved surfaces, using multipoint cutting- tools. There are three basic milling machines: plane-milling machine, face-milling cutter, and an end-mill.

Drilling(120) produces either rough or precise holes in metal parts. It can also be a preliminary process to reaming, boring, or grinding.

5_8.5.2 Making Holes by Drilling

This section will summarize the theory of drilling holes in metal. Cutting soft non-metallic materials requires "fine" cutting edges, such as found in a knife. Generally, a wedge-shaped tool is forced symmetrically into the material to be cut and actually severs it. In contrast, the penetration of metal by drilling requires a tool with a cutting edge that will withstand the stresses encountered during the cutting process. Metals and alloys, except very low melting point materials, will be impervious to "fine" cutting edges.

A cutting tool, such as a drill, must take the form of a large angled wedge, which is forced asymmetrically into the work surface in order to remove a thin layer of metal from the thicker composite. This layer of material must be thin enough to enable the tool and surface to survive the stresses imposed, yet the cutting edge must have a sufficient clearance angle so that it will not make contact with the work surface. Thus, for example, a high-speed steel drill bit will have the following characteristics:

- **The point is in the center of the bit;**
- **The cutting edges are parallel to each other and of equal length;**
- **The point is at a 45° angle to the cutting edges;**
- **The heel is lower than the cutting edge on both sides.**

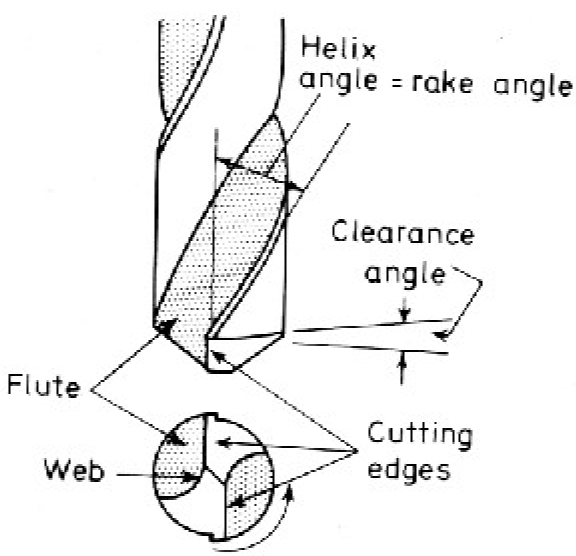
Generally, the included angle of the cutting edge varies between 55°-90°. This will allow for chip withdrawal through an angle of at least 60° as the removed layer moves across the rake face of

the tool. A great deal of energy is needed to deform the metal into chips and move them across the tool face. The chip or removed surface is a waste product and may seem to the reader to be insignificant to the drilling process. However, the transfer of energy required for the formation, movement, and removal of chips, and the problems associated with the rate of metal chip removal and commensurate tool performance, are of critical importance. **They are the essence of drilling theory and are given special consideration here.**

There are many different kinds of drills beside the common two-flute twist bit. These include flat drills, drills with one, three, or four flutes; and core, shell, and spade drills. The different materials used for making drill bits are described elsewhere in this chapter. Information about drilling barrier materials is also presented in **Chapter 35.**

5_8.5.2.1 How a Drill Cuts Metal

Our discussion will focus on the two-flute twist drill. It is probably the most common and is representative of the problems associated with most drilling operations. A twist-drill is a complex cutting tool, generally used in a drill press or drill rig. There are two cutting edges or **flutes**, which produce **chips**. Forming part of each flute is the **rake**; its orientation is controlled by the **helix angle** of the drill bit.



The product of drilling is a chip that slides up the flutes and is carried away from the center of the hole by the **web region** of

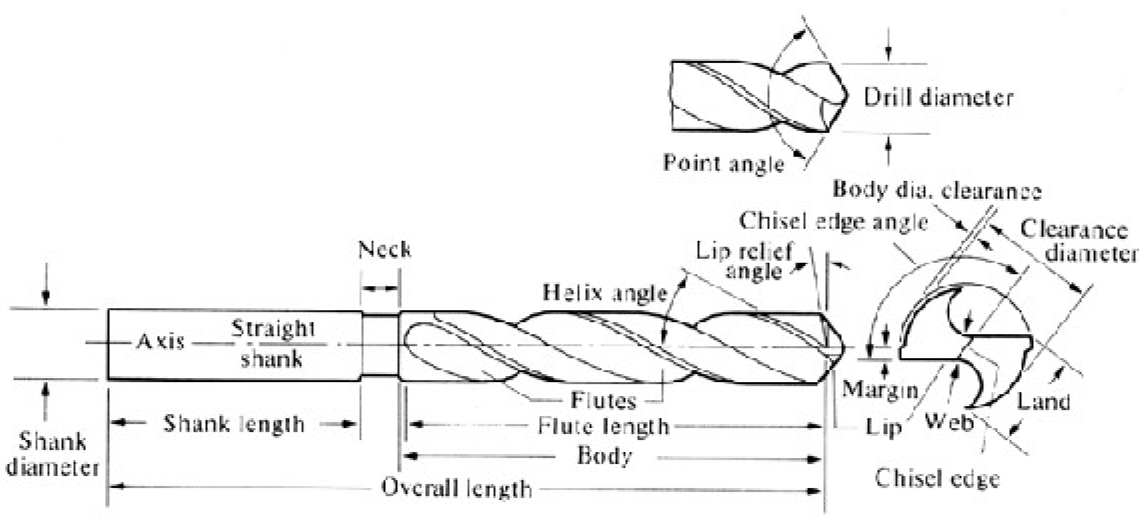
the bit. Each flute (cutting edge) has a variable **cutting angle**, **inclination angle**, and **clearance angle** along the cutting edge. There are actually four operations performed in the drilling cycle:

- **A small hole is created in the material being drilled by the rotating web;**
- **Chips are formed by rotating cutting edges or lips;**
- **Chips are carried from the hole by the helical flutes that are an integral part of the drill shaft and create a "screw conveyor";**
- **The drill is guided in the hole already produced by the margins.**

The two critical operating variables in any drilling operation are **speed** and **feed**.

5_8.5.2.2 Drill as a Complex Cutting Tool

The drill is said to be a complex cutting tool because there are a number of conflicting requirements in the geometrical design of its web, flutes, and helix. Each must be somewhat compromised to produce the required result.



To illustrate, a **small web** is needed to reduce the required thrust placed on the drill in order to pierce; yet, a **large web** is desirable for greater resistance to chipping and torsion rigidity. However, the same requirement for torsion rigidity has an impact upon flute design.

Large flutes provide a greater area for chip transport; they can also cause a loss of rigidity. Thus, another compromise must be reached. Finally, a **greater helix angle** will cause chips to be removed more quickly but will also reduce the strength of the cutting edges. The helix angle will vary with the radius to any particular point on the cutting edge.

5_8.5.2.3 Drill Performance and Design

Most critical to the cutting process is the design and computation of the **helix angle**, **point angles**, **web thickness**, **clearance angle**, and **drill diameter**. These criteria will determine drill performance. While the manufacturer will control the helix angle, the user can alter the other characteristics. The following can be said regarding the effect of altering drill design, with respect to web thickness, rake angle, point angle, helix angle, and other parameters.

5_8.5.2.3.1 Web Thickness

An **increase in the web thickness** will strengthen the cutting edge near the point, with a smaller increase in the rake angle. There is no significant effect on the periphery of the drill. Because structural failure at the drill point is common when drilling harder materials, greater web thickness is required.

5_8.5.2.3.2 Rake Angle

A rake angle increase will lower cutting and feed forces but will also reduce the strength of the tool edge. Negative rake angle tools provide the strongest cutting edge and thus are used for cutting harder grades of carbides and other tough metals.

5_8.5.2.3.3 Point Angle

Increase in the point angle will have a significant impact at the center of the drill and a corresponding increase in the rake angle. The effect is to offer better cutting at the point of the drill, but less support to the cutting edge. A small point angle can be used when cutting soft materials such as aluminum, because less cutting force is required. For drilling hard materials, a large point angle is desirable, because failures occur at the center of the bit.

5_8.5.2.3.4 Helix Angle

While changes in point angle and web thickness is largely irrelevant at the periphery of the drill, a change in the helix angle will have its greatest effect there. An increase in the helix angle will allow freer cutting but provide reduced support across the cutting edge, particularly at the areas away from the center of the drill.

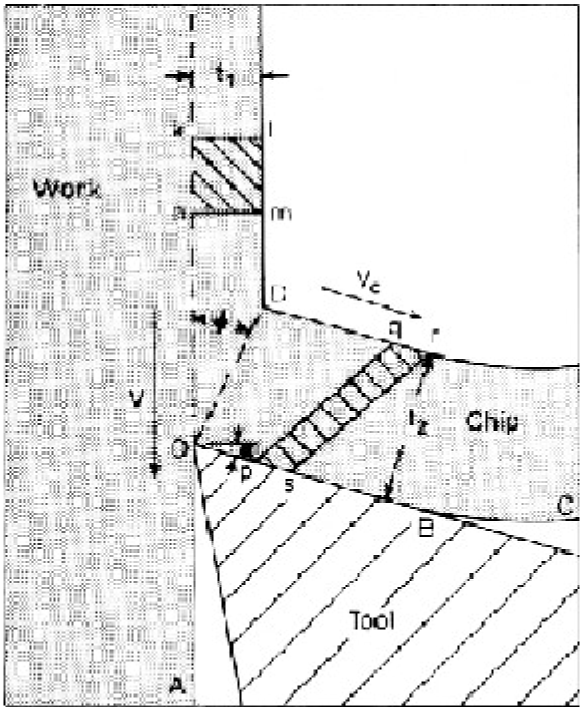
5_8.5.2.3.5 Overall Drill Design Parameters

Drill design will dictate a small helix angle, large point angle, and thick web for drilling strong materials such as high-temperature alloys and stainless steels. Generally, standard drill design will correspond to the following parameters: helix angle = 28°-32° (soft and hard metals); point angle = 100°-118° (soft metal); 135°-140° (hard metal); clearance angle = 8°-12° (soft metal); 5°-9° (hard metal). The chisel edge angle is an approximate measure of the clearance angle of the drill.

The web thickness, which is actually the metal that connects the flutes, represents a lessening of the diameter of the drill as the drill size increases. The design of the web is quite complicated. If a drill has a web thickness greater than actually needed, then the required thrust force will also be greater. If the feed rate is too high, a failure may occur through the web. Generally, a drill is slightly tapered toward the shank (.0005”-.001") to allow clearance of the drill body in the finished hole. Drill performance and long life also require that all of the cutting edges do equal work: both their length and height must be the same. If the lips are asymmetrical, inaccurate cutting and short life will occur.

5_8.5.3 Chips: The Product of Metal Cutting

Perhaps the most important aspect of metal cutting involves the formation and transport of chips. These are the waste product of the cutting process, are controlled by the cutting tool, and, together with their shape, size, and design, are generally the prime concern of tool designers and manufacturers.



Chips are formed by shearing at the point where the cutting portion of the tool meets the work material surface. Depending upon the work surface, chips tremendously vary in size, shape, and density. A great deal of energy is expended at the point of shearing and chip transport, and some materials will fracture under this stress.

Chips may be continuous or discontinuous, depending upon the structure and ductility of the work material. Generally, continuous chips are produced in softer metals. Chips may be studied by forensic technicians, for example, at a burgled safe in order to determine certain characteristics of the cutting-tool. The analysis of chips, including cross section, thickness, and formation, may yield information about grooves in the tool rake face and thus the design of the tool.

5_8.5.3.1 Contact Between Work Surface and Tool

The actual degree of contact between the cutting tool at the shearing plane will determine how a chip is formed and the stresses related thereto. In fact, the coefficient of friction between the cutting surface and the work surface is an important consideration in chip formation. In reality, work surfaces are

never entirely flat, and thus the surface of the cutting edge does not make complete contact with it. As noted by Trent, the contact area can be very small, in some cases as little as one percent of the apparent area of the sliding surfaces.

When materials of different strengths come into contact during the cutting process, the force that is required to move the cutting tool across the work surface equals the force required to shear the weaker of the two materials across the entire surface area.

The conditions that exist at the interface point between work surface and cutting tool are extremely significant. Research indicates that during the cutting process, the work surface and cutting surface become bonded to one another. The strength of this bond can differ or can change based upon factors including the tool and work material, cutting speed, and feed. In areas of bonded contact, the tool and work materials have effectively become one piece of metal. The point at which the work material and cutting material become interlocked is referred to as the **condition of seizure.**

5_8.5.3.2 Treatment of Work Surface

The treatment of the work surface will increase the force required to form a chip. Chip thickness will be inversely proportional to **shear angle.** Thus, where the shear plane angle is very slight, the shearing force can be up to five times greater, in comparison to where the angle is 45°. Shear plane angles will vary, from 5°-45°.

Many forces are encountered during the cutting process on the shear plane. The force required to form a chip depends upon the **shear yield strength** of the work material under cutting conditions. Shear yield strength of the work material will vary greatly. For example, the strength of nickel-chromium-vanadium steel is almost six times that of magnesium and almost twenty times that of lead.

In metals such as copper, aluminum, iron, and nickel, cutting forces are high, because the area of contact between the rake face and the material is high. Correspondingly, when the shear plane angle is small, thick strong chips are created at slow speed. This explains why pure metals are traditionally difficult to machine. High ductility results in high contact area.

Contact area will decrease with certain types of metals. When cutting magnesium, titanium, hardened steel and hard plate, chips will be much smaller and thinner. In fact, forces will decrease as the cutting speed is raised, because there is less contact area. Temperatures will also rise as the speed increases.

5_8.5.4 Tool Life and Failure

In the simplest of terms, the material it must pierce, its metal composition, and the skill of the operator will determine the life of a drill bit. Many complex factors affect drill failure. These include:

- **Changes in tool geometry caused by plastic deformation under compressive stress;**
- **Diffusion wear;**
- **Attrition wear;**
- **Abrasive wear;**
- **Fracture;**
- **Thermal fatigue;**
- **Wear under sliding conditions.**

Tool forces generally rise as wear increases on the tool. This is because the clearance angle is destroyed and the contact area is increased.

5_8.5.4.1 Changes in Tool Geometry: Wear and Deformation

In order for the tool to be effective and survive over extended use, the cutting edge must be accurately controlled and can be extremely critical in maintaining tool dimensions. Tool geometry is thus very important and must be maintained within a few tenths of millimeters to prevent burs, chips, and rounded edges. The action of cutting during drilling modifies the shape of the cutting edge, so that at some point the tool will cease to cut efficiently or effectively or will simply fail. Determining when a tool fails to perform satisfactorily may be evidenced by fumes, noise, vibrations, a change in tool shape, generation of chips, or other indicators.

Critical changes in tool geometry may be very small, with a microscope required to observe them. Such changes are referred to as wear and deformation. **Wear** generally means the removal of

small amounts of metal, such as found in abrasions. **Plastic deformation** involves conditions of seizure and geometry changes. **Deformation** is not considered as wear, because no material is actually removed form the tool surface. Generally, deformation occurs along the tool edge and is due to stresses and temperatures. It is rarely uniform in dimension. Deformation causes tool damage when working with harder materials and limits the ability of high-speed drills to penetrate hardened steel.

Tools may also be worn by metal and carbon atoms from the tool diffusing into and being carried away by the stream of chips flowing from the work surface. **Diffusion wear** occurs from 700°C-900°C and is accelerated by high temperatures and rapid flow rate. Tool surfaces may also fail due to **attrition** at relatively low cutting speeds and temperature. Large microscopic fragments may also be torn from the tool surface; in effect nibbled away. Attrition is in fact a slow form of wear.

Abrasive wear occurs because particles are present in the work surface that is harder than the martensite matrix of the tool. Wear will be greatest where sliding occurs, which is at the tool-work interface. In summary, drill bits can fail due to plastic shear at high temperatures, deformation under compressive stress, diffusion wear, attrition wear, abrasive wear, and sliding wear. The most common drill failures in small bits (<1/16”) are **breakage**; **wear** is the cause in large bits. Drills will generally break due to too great a thrust load, or torque.

5_8.5.4.2 Forces Encountered During Drilling

Major forces are encountered by the drill during the process of cutting. Drills with small rake angles experience increased stress on the contact area of the rake face. This force is compressive in nature and can be calculated by dividing the cutting force by the contact area. The compressive stress experienced by the tool correlates to the shear strength of the work material. Large contact areas will result in high forces.

The properly designed cutting tool will have a calculated distribution of compressive and shear strength. Unless properly engineered, tools will fracture or disintegrate in very short cutting time from stress and temperature. Up to ninety-nine percent of the force exerted during cutting is converted to heat in the chip, the tool, and the work material. Temperatures at the tool-work interface increase with cutting speed. This rise in temperature sets a practical limit to cutting speed for higher

melting- point metals and their alloys.

The point of highest temperature is at the **flow zone**, where the chip is seized to the rake face of the tool. Temperatures of 1000°C or higher can be encountered at this point. Solving the problems of increased temperatures during cutting has probably been the most critical design challenge over the past hundred years. It has spurred the development of new high-temperature materials.

5_8.5.4.3 Cutting Lubricants

Cutting lubricants may be very effective in preventing seizure at low speeds between tool and work surface and thus can greatly reduce forces inherent in the process. They reduce the seized contact area and, thus, the corresponding forces which act upon the cutting tool. Lubricants are not effective at higher cutting speeds.

5_9.0 Penetrating Hard Plate

This section provides information necessary to an understanding of the mechanics of drilling hard plate. Additional discussion is presented in **Chapter 35**, specifically from the perspective of the safe and vault technician.

5_9.1 Introduction

Drilling through mild steel and even tool steel is a great deal simpler than boring through hard plate due to the complex physics and metallurgy involved in the cutting, heating, and cooling processes. Even the observable physical results are quite different from drilling other steels: very few chips come out of the hole, and what is produced is extremely fine-grained. If more than 1” of hard plate is encountered, it may be considered as drillproof. Often, several layers of different alloys will be found with a combined thickness exceeding 1”. This combination can frustrate drilling and the effects of temperature from a torch.

There are three critical and equally important factors to consider when drilling hard plate: **speed**, **pressure**, and **stability**. Their proper combination will cause the metal to become hot enough to actually melt or anneal in order to allow the drill to remove material from the hole. It does not take

muscle to drill through barrier material; rather, it takes knowledge and skill.

5_9.2 Drill Bits for Penetrating Safes

Different types of bits are required for penetrating the various layers of metal within a safe. A thorough analysis of drills is presented in **Chapter 35**.

5_9.2.1 High-Speed Steel (HSS)

Mild steel is the first barrier layer on safe doors. Although this metal may be one-half to several inches thick, it is pierced using a high-speed steel bit with a positive rake flute. An HSS bit is also used to penetrate the last layer of steel to which the lock body is attached. These bits are run at high RPM and are designed to bore through relatively soft materials. They are not suitable for use with harder materials found in security barriers. High-speed steel bits are always positive rake and will generally have carbide tips. The flutes will slice away material at the work surface.

While soldered flutes are encountered in cheaper drills used for penetrating mild steel, they will not withstand the heat of drilling hard plate. Scratching the metal surface between the flutes and shank of the drill can easily make a determination that flutes are soldered or brazed. If gold in color, they are brazed; if silver, they are soldered. Once through the mild steel outer skin of the safe, a quite different type of bit is utilized, designed for high temperature and the stresses encountered when drilling hard plate.

5_9.2.2 Drills for Hard Plate

Drills for hard plate were first introduced at the end of the nineteenth century. They have always been designed to work when red-hot, often using carbide chips and cobalt for the drill point. Generally, these drills have a negative rake to avoid damage to the cutting edge. Regardless of the tip design, the drill must be harder than the material to be penetrated. In the alternative, the surface and structure of the hard plate must be altered.

Bits used for drilling barrier materials are specially made to allow for unknown and uncontrollable variances in the following parameters encountered during penetration:

- **Temperature;**
- **Required rotation speeds;**
- **Drill pressure;**
- **Stresses and shocks from the movement of bits;**
- **Changes in drilling angles;**
- **Density of the hard plate.**

The proper bit must be selected based upon the type of metal to be drilled. Depending upon the composition of the material, several bits may be required to drill through one hard plate, while the same job may be accomplished using only one bit on a different occasion.

The actual drilling process can be a great deal more complicated than encountered with mild steel. For example, **drilling and punching** may be required, rather than simply running the bit at high speeds with pressure applied. In hard plate, drills will stop penetrating as they become dull. Then it may be time to utilize a sharp punch in the partially drilled hole. Repeated blows to the punch are made in an attempt to fracture or dimple the material in order to give the flutes of the drill a place to bite. A sharpened piece of drill-rod, flame tempered until straw in color then immersed in oil, can be used for this purpose.

5_9.2.2.1 Chips

Very few chips are produced during the hard plate drilling process. Those that are ejected are extremely fine grained. Crime laboratory technicians should search very carefully for the metal powder produced by such drilling, and look for a match with clothing, hair, tools, skin, and any other materials with which a suspect may have come into contact.

5_9.3 Operating Conditions

Three essential actions must occur in the penetration of any metal when using a drill: **cutting by the flute edges**, **cutting action at the web**, and **extrusion by the web**. Each of these is in turn affected by **torque**, **thrust**, **feed**, and **drill diameter**.

5_9.3.1 Feed

Feed rate is dependent upon the size of the bit. Flutes can only transport a certain chip volume, which is closely related to the diameter of the drill. Thus, for standard drills, the formula **f=d/65** provides the standard, where **f** is the feed rate and **d** is the drill diameter. The result is expressed in terms of IPR. (inches-per- revolution). Recommended speeds for high-speed steel bits are increased by 50 percent from standard drill bits.

5_9.3.2 Speed and Feed

Drill speed and feed rate will vary, depending upon a number of factors. These include:

- **Chip volume;**
- **Material structure;**
- **Cutting fluid effectiveness;**
- **Depth of hole;**
- **Drill condition.**

Drilling speeds and pressure will change, depending upon the material. Slow speeds begin at about 500-2000 RPM, moderate speeds of about 1500 RPM, and high speeds greater than 5000 RPM. The pressure applied to the drill motor ultimately controls drill speeds. If high pressure is required, a **drill rig** is mandatory to provide stability of the bit.

5_9.3.3 Forces: Torque and Pressure

Drill forces determine how a hole is produced. Torque and thrust are dependent upon point angle, number of cutting edges, feed, drill sharpness, and cutting fluids. Drill speed, clearance, and small changes in flute shape will be of little importance. Application of incorrect pressure during drilling will result in broken bits, with the potential of sealing the hole. Bits generally fail when breaking-through the hard plate, so special care and expertise are required to gauge the progress and location of the drill within the material.

5_9.3.3.1 Pressure and Drilling Technique

There are two accepted techniques for penetrating tempered hard steel. The first involves running a drill at a slow speed with controlled pressure. The second requires high speed, between 4000-5000 RPM, coupled with high pressure.

Just how much pressure to apply during the drilling process is difficult to precisely state. Essentially, sufficient pressure is applied to begin cutting the outer surface of the hard plate. Listening to the drill motor offers an indication of progress. Obviously, the larger the drill, the more pressure that is required. Each material demands slightly different drilling technique. For example, when drilling aloxite (a soft aluminum-based material), low RPM and a great deal of pressure is required. If a diamond tip drill is used, low RPM with light pressure is employed.

It must always be remembered that making a hole through hard plate can be dangerous. A great deal of pressure must be applied during the drilling process. If a drill fails, pieces can fly outward, causing injury. In addition, if a drill rig breaks loose, the operator is at risk. If an amateur attempts to drill a safe without the proper tools or knowledge, he may be injured in the process. Evidence technicians should be vigilant for such signs.

5_9.3.4 Temperature

The creation of high temperatures during the drilling process is critical, especially with tungsten carbide tips. Annealing of the metal occurs around the hole and makes the steel softer and thus easier to cut. High-speed drilling requires heat; the process is called red-point drilling. The drill tip actually becomes cherry red in color and will work best in that condition. Once drilling begins, it cannot be stopped without the danger of heat-treating or work-hardening the metal, with the consequence of making subsequent penetration more difficult.

5_9.4 Drill Rigs

Hard plate cannot effectively be pierced with a handheld drill motor. Rather, drill rigs that attach to the front of the safe are required. Such apparatus allow constant pressure to be applied at a uniform angle. See the discussion in **Chapter 35.** There are three basic types of rigs: the **lever**, the **pressure bar**, and the **magnetic drill**. Each is designed to allow the controlled application of pressure in order to maximize drill motor control.

5_10.0 An Alternative Method of Cutting: The Thermic Lance

5_10.1 Introduction

Another form of cutting tool is available for the non-precise penetration of any metal. Information is provided about the thermic lance in this section and in **Chapter 35**. The burning bar or thermic lance presented a new and dangerous challenge to safe makers. Although these devices became popular in the 1960s, they were present in the U.S. in the 1930s, and the basic principle was known since the 1880s in England and Europe. The lance relies upon the principle that a metal, brought to a burn in an environment of pure oxygen under pressure, will generate a tremendously high temperature. As the material melts, the metal itself acts as a flux to speed up the intensity of the reaction and subsequent burning of the target metal.

The lance will virtually melt any material, including iron, steel, concrete, and granite. The high temperatures generated by these devices will destroy the molecular structure of any metal, including high-density barrier hard plate. The development of the thermic lance, as described in the Brower patent (**4182947(121)**, **4069407(122)**), provides a superior means of cutting metal and other materials. The system allows for a lightweight, readily adjustable, easy-to-handle tool. An arc can be developed in any non-explosive atmosphere, including water.

5_10.2 Development of the Lance

Developed for use in the shipyards and initially described as a burning bar, exothermic lance, or mini-lance, the first device was about ten feet long. It was actually a pipe filled with steel wool, aluminum, and magnesium wire or rods that were connected to a source of oxygen. An oxyacetylene torch was used for ignition. The original devices were large, awkward, and too dangerous to be considered as a reliable tool. Locksmiths began using the lance after the Second World War.

Today, the lance is handheld, compact, relatively safe, and can be transported in a briefcase. The active "pipe" is 18" long and ¼" in diameter. The lance operates on oxygen, and will cut through any barrier material in seconds. The early lances had three serious drawbacks:

- **Too dangerous to use because they were difficult to control;**

- **Destructive to anything lying near where they were operated;**
- **Could only be used outdoors due to the high temperatures, gasses, and smoke produced.**

Today, these arguments have been met and solved by technology and training. Safe technicians have come to realize that the lance, such as supplied by Broco, is a safe and effective tool. Proponents point out that a thermic lance may be the only method of entry into a particular safe. Further, a safe technician may use over one hundred dollars in drill bits to penetrate some doors, whereas the lance may do the same job in under a minute and costing only a few dollars.

5_10.3 Theory of the Thermic Lance

The active element of the lance is a consumable burning rod in the form of a hollow tube that forms the outer casing. Measuring approximately 18" to 36" in length, it is constructed of a relatively thin-walled, lightweight, electrically conductive steel. The tube is generally covered and protected with an insulating non-conducting material such as plastic, epoxy, vinyl, acrylic, or urethane. The purpose for the insulation is to prevent side arcing to the target material.

Within the burning hollow tube are many metallic rods or fibers. Some of these small-diameter rods will be made of steel or other ferrous materials, and some will be made of non-ferrous metals or alloys. Typically, steel and aluminum wires are placed in clusters, in a ratio of from 3:1 to 10:1, although it appears that the optimum ratio is 7:1. Metals other than aluminum may be selected, including magnesium, titanium, or their alloys.

5_10.4 The Broco System

The **Broco system** consists of few components, all of which can be carried within a briefcase. A pistol grip holder that receives a rod through its center allows for the transmission of oxygen from a connected hose and the conduction of an electric current for ignition. The holder is connected to an oxygen source through a standard regulator. A 12-volt battery and a striking plate are also required. A current is passed through the holder and rod tip and is used to generate a spark at the distal end of the rod to initiate burning.

In operation, oxygen is fed through a valve in the holder to the tip of the rod. Although other gasses will work, oxygen is most popular. Oxygen flow is directly related to cutting action and is controlled by the operator through both the internal valve and regulator attached to the oxygen source.

5_10.4.1 The Function of Oxygen

Oxygen performs two primary functions. It provides an oxidizing envelope at the tip of the rod, which aids in the complete combustion of materials and blows away slag created during burning. In addition, the oxygen initiates and maintains a continuous thermic process at the tip of the rod. The oxygen elevates the temperature to the white heat range and thus provides a gaseous cone for the ionized arc to form.

Low current is required to start the burn. A power source is not needed once ignition occurs, although if the current is maintained, the burning rate occurs fifteen to twenty percent faster. The arc, in conjunction with the oxygen, ignites the rod and creates a gaseous cone instantly. The melting of the binary metallic system of rods creates a eutectic.

Oxygen passing into this melt causes an exchange and reformation of Al_2O_3Fe- in the correct ratio. Continuous burning will occur so long as the oxygen flow is present. In actual operation, the end of the burning rod is moved to the target area, and melting, burning, or cutting begins. The rod is consumed at the point of burn to create a lava-like melt and subsequent flow of molten material.

Five cubic feet of oxygen is typically required to burn an 18" x 3/8" rod. The pressure is varied based upon the target material; the rate of oxygen flow is in part dependent upon whether the material is to be pierced, cut, or gouged. Typically, a forty-five second burn can be achieved using an 18" rod. Generally, 1” of rod will cut 1” of steel.

5_10.4.2 The Physics and Chemistry of Burning with a Lance

Burning in any form occurs when focused energy, in the form of heat, contacts a solid surface. The lance allows a concentration of energy in a small region of material at extremely high temperatures. This reaction produces such high temperatures that they cannot be removed at a fast enough rate through the ordinary

processes of heat transfer, such as conduction, convection, and radiation. This will result in the creation of a highly excited region, generally referred to as a **dense superheated plasmic cone**. The thermic lance creates a thermitic reaction cone at the point of burn.

Chemically, the classic thermitic reaction consists of eight moles of aluminum plus three moles of magnetic iron oxide. The reaction when completed produces four moles of aluminum oxide and nine moles of molten iron, as shown in the formula $8Al+3Fe3O_4$ --> $4Al_2O_3$ + 9Fe. The rod, when ignited using the aforementioned mixture, creates an enormous quantity of heat, approximately 758,000 calories per gram molecular weight. The target material is essentially vaporized, because the heat thus generated cannot be dissipated in any other manner.

5_10.4.3 Advantages Over Oxyacetylene

The system has many advantages over oxyacetylene. Most importantly, the thermic lance will cut virtually any material. A fine, precision cut is not possible but rather an irregular one is produced with localized high temperatures. The lance offers almost twice the temperature generation of oxyacetylene. No fumes, smoke, or poisonous gas is produced, unless the material being cut has been specially developed to emit such special gasses.

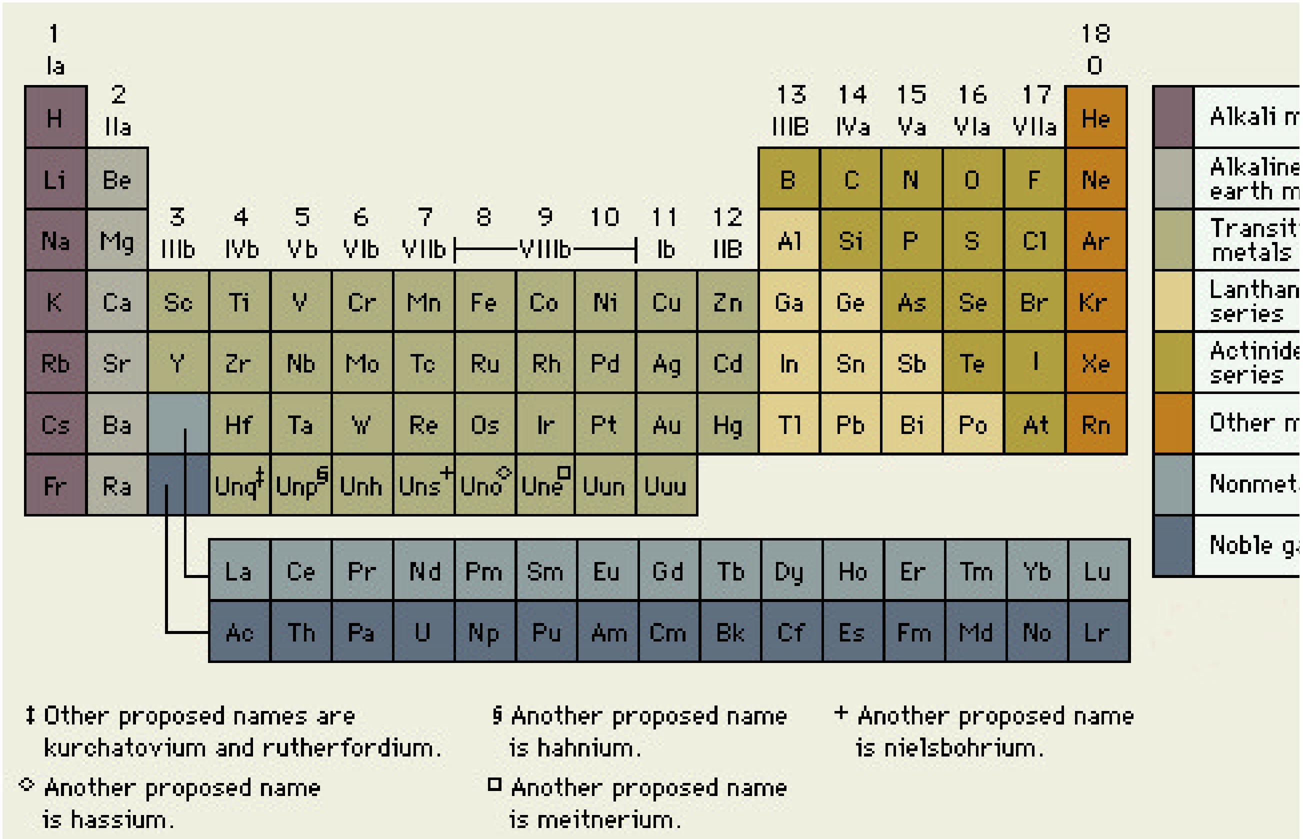


Figure LSS+501, Periodic table, courtesy Microsoft Encarta, 1998.

For complete data on any particular element, see **webelements.com.**

PART B: Systems

Key and Keying Systems

Chapters in Part B present detailed information regarding keys, and keying systems. The materials focus on issues specifically relating to standards, production, generation, and copying of keys, as well as the unique characteristics of keys for each primary type of lock. Specialized keying systems and high-security keys are presented in the next six chapters. The following topics are covered in detail elsewhere in this text:

- **How keys work in locks (Chapters 13-14-15-16)**
- **Producing keys for different kinds of locks (Chapters 13-14-15-16)**
- **Criminal investigations and evidence derived from**

keys (Chapters 24-25-26-27)
- **Decoding and producing keys from locks (Chapter 31)**
- **Evidentiary analyses of keys (Chapters 24-25-26-27)**
- **Impressioning locks to produce keys (Chapter 30)**
- **Investigation checklist regarding keys and crimes (Chapters 24-25-26-27)**
- **Non-metal, alternative forms of keys (Chapters 5)**
- **Picking with rocker and special keys (Chapters 29)**
- **Surreptitious entry utilizing keys (Chapters 24-25-26-27)**

For the criminal investigator or crime scene technician, important evidence about an offense may be revealed from keys left at the scene, found on suspects, or used in the commission of the crime. A locksmith may also be asked to testify as to his findings or conclusions when called to the scene of a burglary to open, repair, or replace broken locks or safes. It is thus equally important that the locksmith and investigator be attentive to detail, making detailed notes as to observations.

A great deal of information can be **derived from keys.** For example, the manufacturer, type of mechanism, and its possible physical location may be determined. Whether it is likely that the key fits a public locker, safe-deposit box, residence, hotel room, post office box, vending machine, or other area may in some cases also be learned.

Motor vehicles can, in some instances, be traced and identified by their keys, either through the number stamped on the key, by decoding, or by actually fitting it to a specific lock. Even the make and model of a vehicle can be ascertained in certain cases. For example, the General Motors VATS anti-theft system was initially utilized on the Corvette and Cadillac. Vats keys are easy to identify and decode.

Master keys are often stamped with "Master," "M," "GM," or some other similar designation and often can be identified from the pattern of depths. Post office keys can be readily identified, and their mere possession may lead to other fruitful areas of inquiry. In certain cases, a question should arise as to why a certain person, suspect or victim has a particular type of key in his or her possession. A juvenile, for example, may be found with several tubular keys, primarily used for vending machines and alarm locks.

Unauthorized keys may have been obtained from such areas as schools, hospitals, dormitories, and other large complexes. Possession may be linked to recent or continuing losses, the compromise of information, shrinkage of inventories, and so on. Again, their possession should be carefully questioned. A detailed investigative checklist is presented in Chapters 24-27, providing a comprehensive analysis for the investigation of crimes involving the possible use or compromise of keys.

CHAPTER SIX: KEYS

The Development of Keys

Master Exhibit Summary

6_1.0 History of Keys

This chapter shall begin with a simple, yet fundamental question: What is a key? The answer is equally simple: any object or device that allows the mechanism of a lock to be actuated to the locked or unlocked position. Keys have taken many forms throughout the past four thousand years, from Chinese finger rings, to early pin tumbler wooden keys, to modern metal keys incorporating sophisticated integrated circuits. They all,

however, perform essentially the same function: to open locks. Keys have come to symbolize responsibility and authority; most inhabitants of civilized societies carry them.

Although the ancient Greeks contributed to lock development, the Egyptians are credited with conceiving the first significant locking principle. It will be recalled from **Chapter 1** that the Greeks developed a form of key to move a crossbar mounted across the inside surface of a door. It replaced earlier, intricate rope locks. This "key" was extremely primitive and consisted of a large semi-circular blade measuring more than one foot in length. It had a long handle, often inlaid with semiprecious metals, and was tapered to a blunt point. The size of a farmer's sickle, the hook-shaped key was inserted through the hole in the door.

The Egyptian mechanism, in use some four thousand years ago, appears to be the first true mechanical locking device as we understand the concept today. This lock was made entirely of wood and the bolt was hollowed out to allow insertion of a key. There were metal pins on the end of the key that would mate with and raise wooden tumblers within the lock. When the tumblers were raised to clear and slide the bolt, the lock could be opened. Although this object, which resembled a toothbrush was the first real key, it had little similarity with anything we know today. Keys for the Egyptian locks were large, cumbersome, and heavy, mirroring the design of those first devices.

The Romans merged Greek and Egyptian designs producing door locks that used small keys. Although the Romans utilized the pin tumbler principle, they are credited with the introduction of wards. Until the use of metals during the Roman period, keys were only made of hardwood and measured up to three feet in length. They generally offered little resistance to duplication.

Roman artisans were already used to working with metals and began producing keys and locks in iron and bronze. These craftsmen recognized that the smaller the keyhole, the less likelihood that the lock could be picked. As the warded lock developed, the shape and design of the keys became extremely complex and intricate, with many angles, often creating a maze-like pattern. Even with the small, complex key designs, blacksmiths realized that only a few different "tryout keys" were required to open all of the warded locks.

Although warded keys became works of art, the problem of skeleton keys remained. This shortcoming would not be solved until the

introduction of the lever lock during the Renaissance, when keys began to resemble those in use today. During the nineteenth century, the lever became the most popular locking mechanism in England and the continent. These required small keys and offered a high degree of security. While the lever lock is still extremely popular in Europe, the pin tumbler became the lock of choice in the United States in the latter part of the same century and continues so to this day.

6_2.0 Terminology and Basic Definitions

The following terminology and definitions are common to all forms of locks and keys. Definitions relating to specific types of locks will be found in subsequent chapters.

Back Cut Key: A key having one or more angles cut so as to cause the tumblers to seat in the valley or root and prevent removal of the key from the lock. Too steep an angle will cause back cutting. Generally, a combined angle of 90°-120° is required to prevent back cutting.

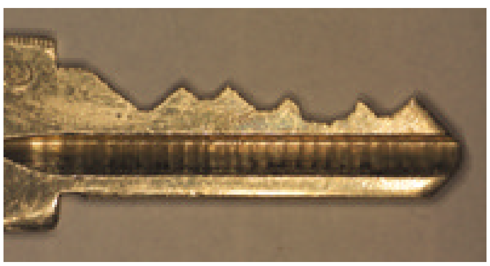
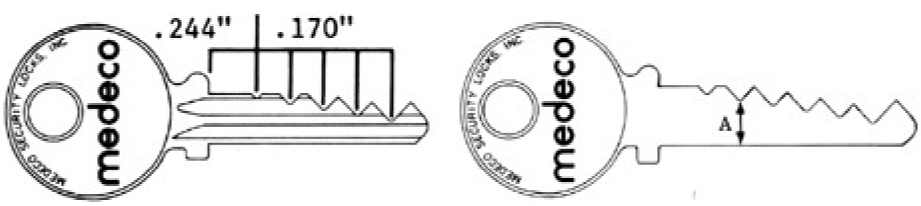
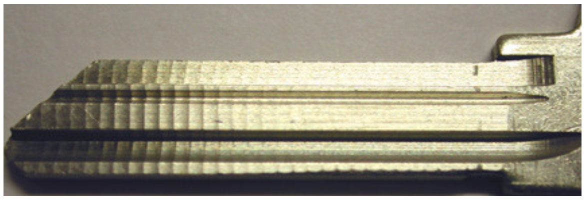


Figure LSS+601, a back cut key. Note the angle of cut of the fourth tumbler position from the shoulder

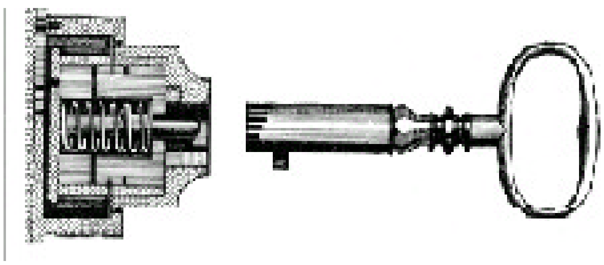
Bitting or Bit: That part of the key that enters the lock and meets the wards, levers, discs, or tumblers.



Blank Key: A key corresponding to the correct keyway that may be cut to any pattern of depths.

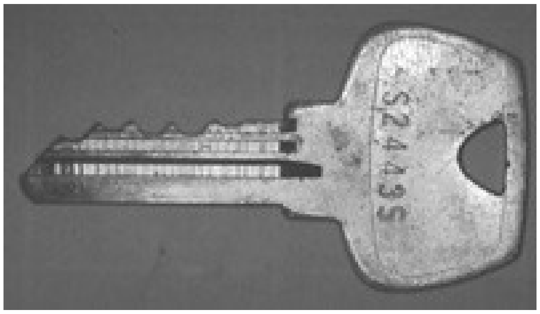


Bramah Key: This term refers to a tubular key design, introduced and patented in England during the latter part of the eighteenth century. The Bramah lock remained incapable of picking for almost fifty years until 1851. The unique design of the key that fit the Bramah lock in some respects resembled the modern axial pin tumbler key that was introduced by Chicago Lock and other American companies.



Change or Guest Key: The change or guest key refers to one that is coded to open only one lock, in contrast to a master key, which is coded to open a number of locks within a locking system. It provides the lowest individual level of keying. The term "change key" is also used in conjunction with "combination locks." See **Chapter 34**.

Codes of Keys: All manufacturers of locks will define precise measurements for each different depth and spacing assignment for each kind of lock and keyway they produce. The unique combination of depths for each individual lock will thus have a code number that will correspond to the exact design of the key. Keys may then be produced solely from these codes. The photograph shows a factory original Sargent code cut key. The code, 24435 is read from shoulder to tip, and directly correlates to the key cuts.



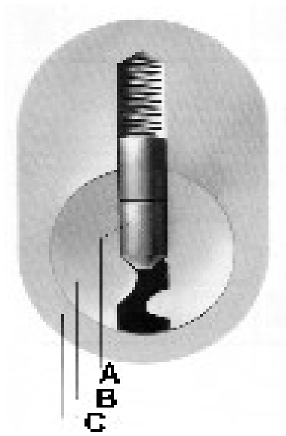
Corrugated Keys: These keys have longitudinal grooves running the length of the bitting surface. They are used for warded padlocks and certain specialized wafer locks, such as produced by Schlage and Winfield.

Cylinder Key: This term generally refers to a key for a pin tumbler, mortise cylinder lock.

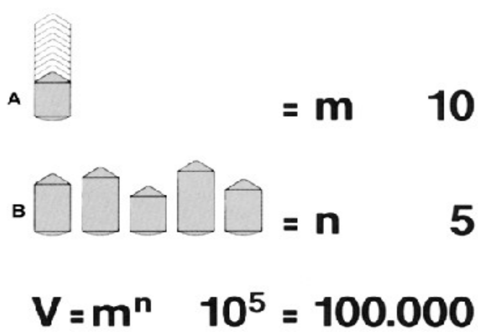
Depth Gauge: A depth gauge is a device that allows the decoding of the various depth cuts of a key. A key micrometer or specially designed gauge may be utilized for these measurements. HPC manufactures both instruments. The HKD-75 will decode all popular blanks. A key is inserted and read by a **floating stylus**, which is linked to a **pointer** that moves across the correct datacard.

Depth Keys: A depth key provides precise bitting information for a particular keyway and series of lock. Keys can be decoded and replicated using depth keys, for they will provide exact depth and spacing data.

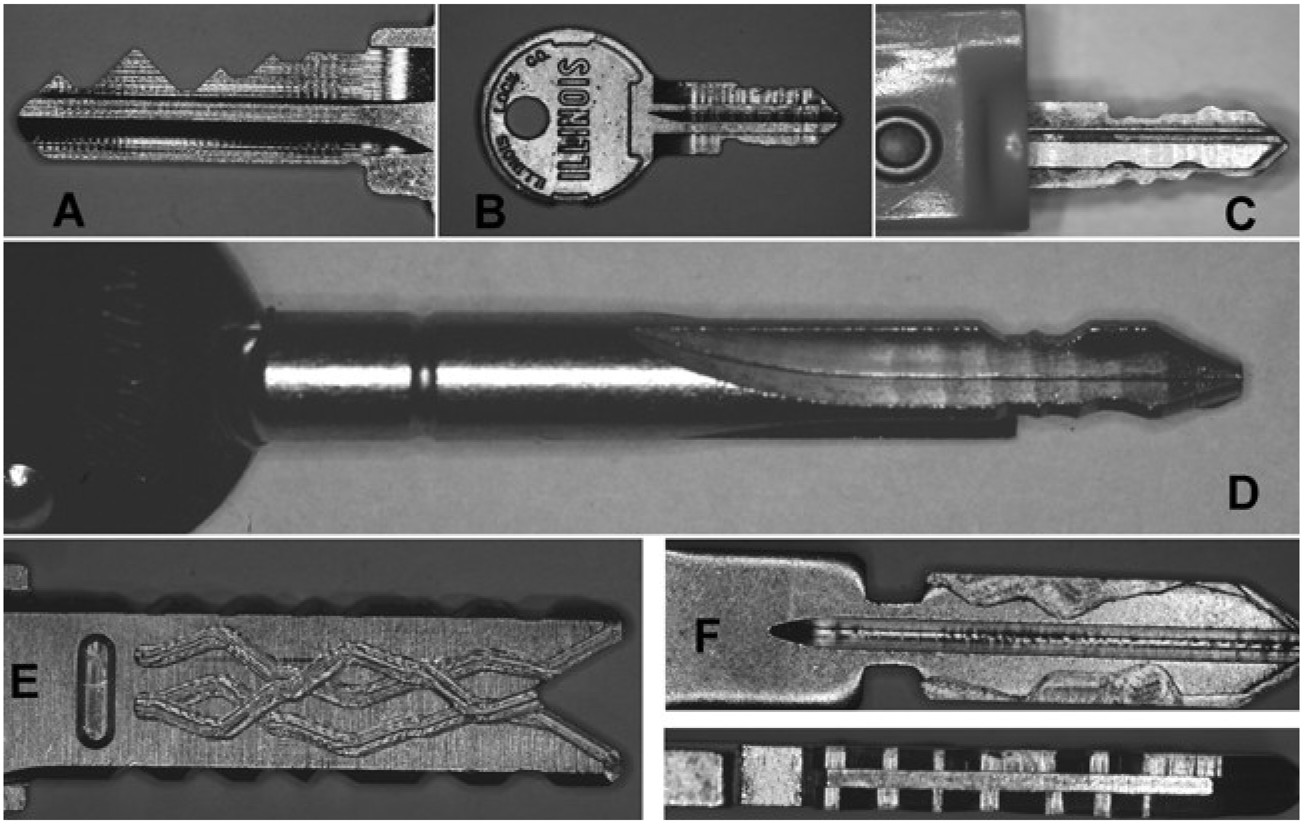
Detainers: The term will be utilized throughout this text when referring to pin tumblers, discs, wafers, levers, wards, or other components which inhibit movement of the plug, cam, or other moveable locking device within the locking mechanism. It may be recalled that the term "detainer" was originally used in **Chapter One** in describing the development of locking principles. All modern mechanisms operate on the theory of two or more detainers that must be raised to a precise point (shear line) in order to allow the lock to open. In the photograph, the pin tumblers represented by "A" are split, comprising an upper pin (driver) and lower pin. This illustrates the double detainer theory of locking; the pins must be raised to the proper height so that the split is positioned precisely at shear line. If the pins are above or below this division, the plug is blocked from rotation and the lock cannot open.



Differs and Differing: The English term "differing" refers to the number of different possible realistic or effective combinations and numbers of change keys which are possible for a given lock. Differs are calculated by taking into account the number of wards, levers, pins, or discs, as well as the design of the keyway and tolerances of the locking components. In the illustration, "A" signifies the number of depths available for each tumbler, and "B" equals the number of individual pins.



Double-Bitted Key: A key that is cut on two sides or surfaces. They are most often found in wafer locks.



Flat Key: A key made from sheet metal, produced without grooves, generally used in warded or lever locks.



Key: A device or object which is inserted into a particular lock or group of locks, causing the internal mechanism to align in a predetermined order, to allow actuation of a locking or unlocking mechanism.

Key Changes: See Key Differs. The term describes the number of effective changes possible for a particular lock.

Key Control: Manufacturer key control describes the keys that can or will work in one lock or a group of locks. It encompasses (1) the number of differs or change keys effectively available, (2)

the maximum possible number of changes, mathematically, (3) keying alike all locks, and (4) master keying or complex keying locks. Security key control relates to policies and procedures designed to inventory and restrict keys and access to locks by unauthorized persons.

Key Cuts: Any cuts made on the bitting of the key.

Sidewinder or Laser Key: A form of key having depth cuts on three or four surfaces. Mercedes (right photograph), Volvo (left photograph), and BMW automobile locks utilize these keys. The term "laser key" came into use because locksmiths believed that the bitting design was produced by a laser cutting system.



Figure LSS+602 lasertrack keys utilized in Volvo (left) and Mercedes (right). Wafer sliders move along the contour of the surface.

Single-Bitted Key: A single-bitted key has cuts on one side or surface. Most keys are single of this design.

Skeleton Keys: Skeleton keys are used to open warded locks. They can be identified by the removal of a large portion of the bitting. In effect, the keys are made to bypass all of the fixed wards.

Steeple: This describes the convergence of the peaks of the angled cuts between valleys of the bitting. Generally, the steeple at the tip of the V cut is pointed. In the photograph, the bitting is shown, with indicators above each steeple.

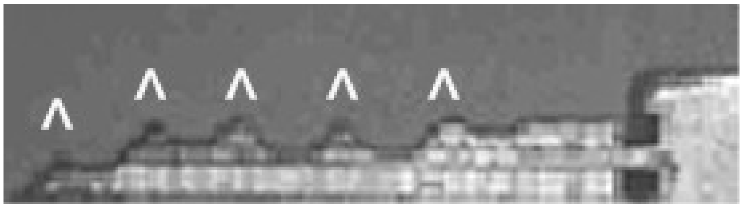
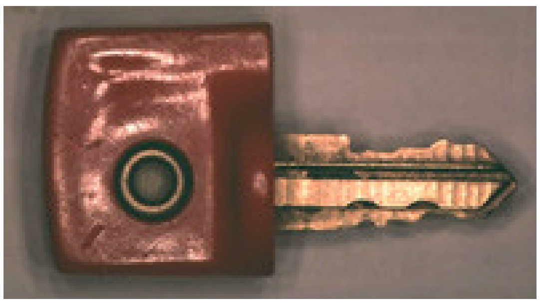


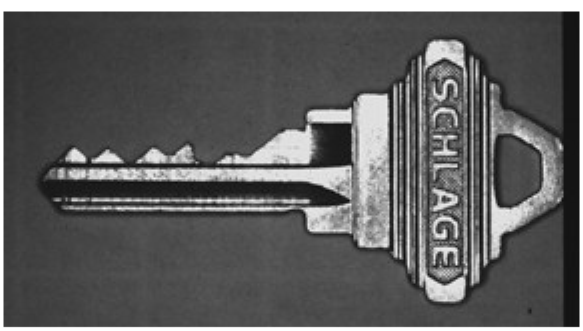
Figure LSS+603, bitting of key showing steeples.

Triple-Bitted Key: A conventional key that is cut on three sides or surfaces.



Tryout Keys: Multiple sets of keys have been designed with special depth and spacing patterns. When manipulated correctly within a lock, they may align the tumblers to shear line and simulate the correct bitting. Based upon tolerances, just a few tryout keys can open many locks.

Valley of Root of Key: The portion of the bitting which forms the bottom of each cut is referred to as the valley or root.



6_3.0 Basic Classification of Keys

6_3.1 Introduction

Although no worldwide standard system has been established, keys

can in fact be identified as belonging to certain primary groups based upon recognized parameters. A basic classification of keys is thus possible based upon: materials, mechanism or function, bitting, and keyway. A fifth parameter, size, may also be utilized, although the size of a key will not in and of itself provide absolute information as to what type of mechanism the key operates.

6_3.2 Materials

Six basic materials are utilized in the production of keys, primarily dependent upon the type of lock, manufacturing process, cost, and function. Keys are generally made in brass, steel, iron, nickel silver, aluminum or aluminum alloy, and zamak. Plastic and other polymers are also being utilized to a limited extent. A more thorough discussion of material content is provided in **Chapter 5**.

6_3.3 Bitting

Above the keyway, or as an integrated part of it, is that section of the key that encounters and acts upon the detainers in the lock. A properly designed key will allow enough bitting surface to provide for a sufficient number of different tumbler depths. This will allow for many differs. The bitting of a key refers to cuts, depressions, holes, indentations, build-up, or removal of material, affecting one or more surfaces of the key, to mate with discs, tumblers, pins, wafers, levers, wards, or other detaining devices. Keys may have bitting on one, two, three, or four sides or surfaces as shown.

6_3.3.1 Surface Cuts and Active Components

Many keys will have bitting on more than one surface, but not all surfaces are actually active. Thus, for many automotive and dimple locks, while the key is cut on two sides, there is only one actual set of tumblers within the lock. This design will allow the key to be inserted into the lock with either vertical orientation for the convenience of the user. Keys for many dimple locks will be cut on four or six surfaces, but the lock will only have two or three actual sets of tumblers for the same reason.

6_3.4 Keyways

Keys may be classified by the keyways they fit. Keyways may range from flat (no wards) to extremely complex. Major key catalogs, produced by Silca, Ilco, and other manufacturers always include keyway profiles for every blank. There are a number of design parameters involving keyways that are detailed below.

6_3.4.1 Mechanisms or Function

Keys are classified based upon the type of lock they are designed for or their function, in the case of specialty keys. Within this sub-grouping are the following categories:

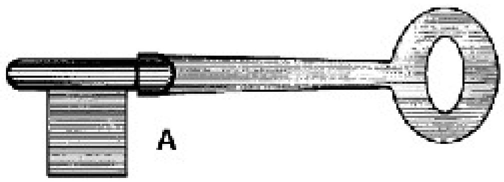
6_3.4.1.1 Axial (tubular)

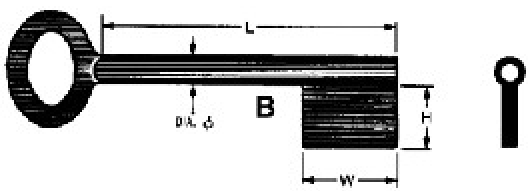


Tubular keys are primarily used in cam locks for vending applications. They were made popular by **Chicago Lock Company** and their Ace design.

6_3.4.1.2 Bit and Barrel Keys

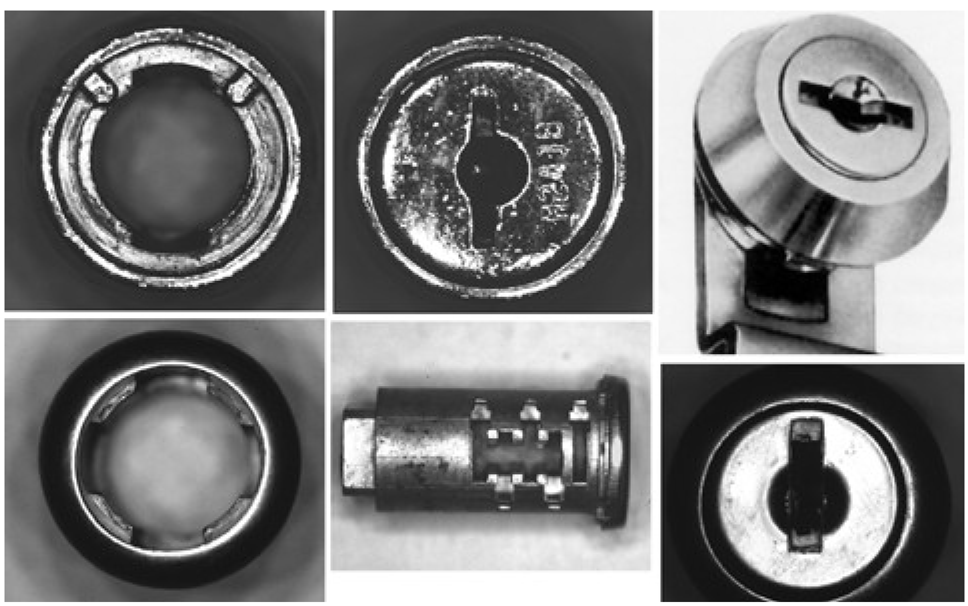
These keys are used with warded locks. They are essentially identical, except that a barrel key will have a hollow shank, and often do not have shoulders.





6_3.4.1.3 Cam Lock

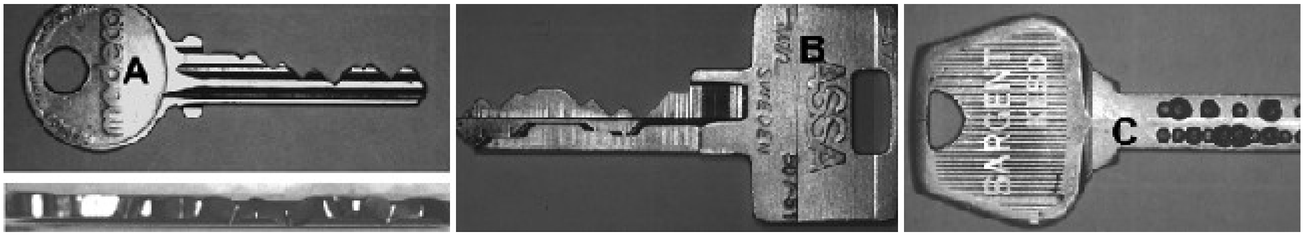
Cam locks are used in a variety of applications, primarily in vending, utility, control, and furniture. Wafer and tubular cam locks are the most popular configurations.



6_3.4.1.4 Cylinder, Special, and High-Security

This category encompasses pin tumbler locks, modifications in pin tumbler design such as sidebar and high-security cylinders, like ASSA, Medeco, Ikon, Sargent Keso, and DOM, and other unique keys. Included within this category will be sidebar rotating tumbler (Medeco), dual-sidebar (Schlage Primus, ASSA, Ikon), and dimple

keys (Mul-T-Lock, Sargent Keso, KABA, and DOM).



6_3.4.1.5 Flat Steel Keys

Flat steel keys are utilized in many applications, including safe-deposit, warded padlock, luggage, electric control, lighting control, cash box, and other low-security, low-cost applications.

6_3.4.1.6 Safe-Deposit

Safe-deposit lever locks use flat steel keys. They are generally made of brass, nickel silver, or zamak.

6_3.4.1.7 Specialty

Within this grouping can be found certain high-security designs, especially European, as well as stamped keys for locks offering little to no security. Keys may be grouped in this category as well as cylinder, special, and high-security.

6_3.4.1.8 Vehicle

There are many different kinds of locks utilized in motor vehicles throughout the world. The original Briggs and Stratton sidebar design is perhaps the most popular. It was introduced in the United States in 1935 and is still used today. All General Motors products that utilize this sidebar design have a key that resembles a wafer lock. There are, however, many different kinds of keys for motor vehicles.

Within the past twenty years, many different locks have been introduced for cars to provide a greater measure of security against picking and decoding. Perhaps most popular is the sidewinder key, utilized in Mercedes, Volvo, Honda, Lexus, and BMW cars. This lock, until 1991, was thought to be virtually impervious to picking and **decoding**.

6_4.0 Key and Keyway Patterns

Along with the basic classification parameters defined above, there are a number of other considerations involved in the design of keys, keyways, and locks.

6_4.1 Physical Dimensions

Several factors contribute to the well-designed and practical key. Each can affect security and can be altered or controlled by the manufacturer, including:

- **Length;**
- **Width;**
- **Height;**
- **Thickness;**
- **Number and shape of grooves forming the keyway;**
- **Width and depth of the bitting;**
- **Production materials utilized;**
- **Keyway design;**
- **Detainer mechanism.**

6_4.2 Design Parameters and Rules

In order for keys to operate properly in any given lock, certain design rules must be observed. These rules will affect:

- **How many tumblers, wafers, discs, levers, wards, or other detainers are incorporated within the lock.**

The length of the key, from the shoulder to the tip, will determine the number of possible detainers that may be spaced evenly across the various surfaces of the key.

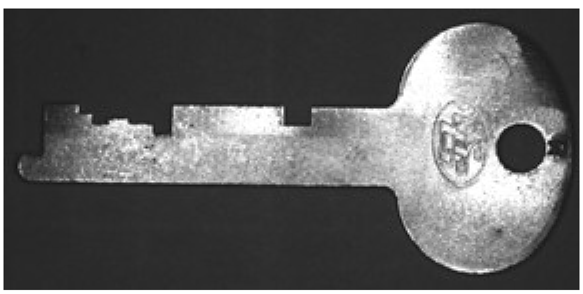
- **Where the detainers seat or are positioned on the bitting of the key. Depending upon the type of detaining mechanism, the cut key will appear differently with respect to spacing, depth of cuts, and the angles associated with each depth-cut.**

- **The number of available depths for the detainers. The number of different tumbler depths available in**

any lock is first a function of the dimensions of the active portion of the keyway, which allows differences in the bitting levels of the key. The actual number of depths will control how many different keys can be produced for a given keyway. This parameter is called differs.

- **Design of each depth-cut. The design of each individual depth-cut is controlled by three parameters: the angles on each side of the cut, the depth of the cut, and the width of the cut at the root. Standard terminology for these parameters has been developed within the industry.**

A V cut refers to the overall dimensions and design of each depth-cut. There is no standard actually established, although in practice, a 90°-120° composite cut angle for pin tumbler and wafer locks is established. This means that the composite angles of the V cut must be between 90°-120°. This will insure proper operation and prevent back cutting. The root or valley of the cut refers to the bottom of the cut where the tumbler, disc, wafer, or other detainer makes contact. The root may be a sharp V, a flat, or a radius.



6_4.3 Differs

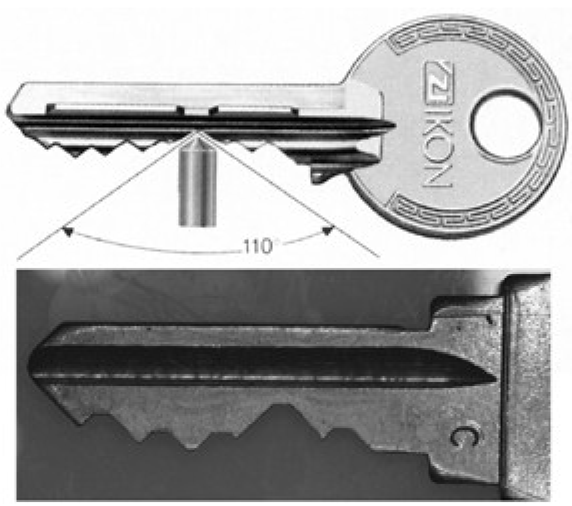
The number of **differs** is mathematically based although not absolute. Minute changes and tolerances are not relevant in determining the number of possible combinations; many factors are taken into account in determining the actual number of differs. Claims by manufacturers should be examined critically, especially with respect to a high number of possible combinations for a given lock.

Often, there are realistic mechanical restrictions as to how a key can actually be cut, which will in turn control the maximum

number of different keys that can be made to fit a given keyway and lock. The number of combinations may be increased by complex lock design, utilizing, for example, **magnetic** and mechanical locking action or standard pin tumblers combined with sidebar action. **Master keying** will reduce the number of possible combinations or differs in most locks, unless specially designed with **master rings**, sidebar action, or other schemes.

6_4.4 Keyway and Depth-Cut Design

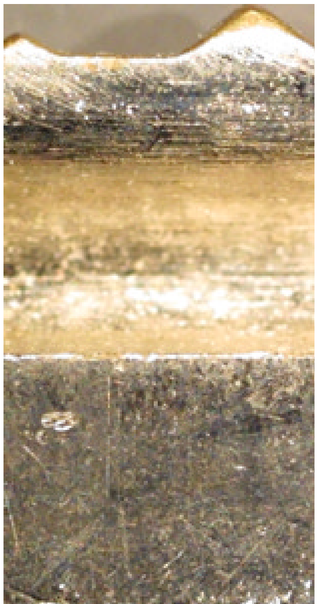
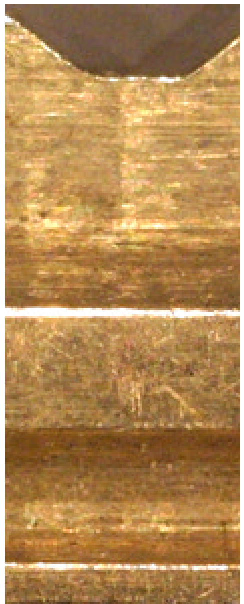
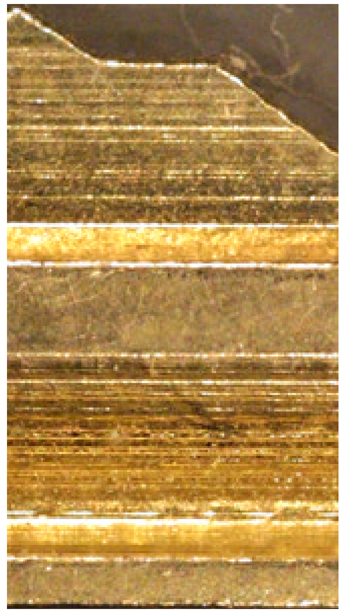
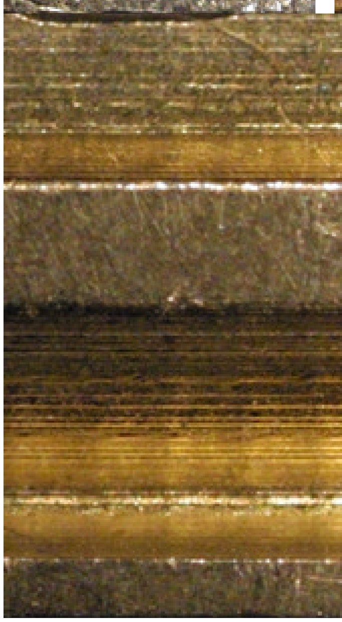
A keyway constitutes the opening into the lock through which the key enters. By varying the keyway, the manufacturer can control which blanks will operate the lock to the exclusion of all others. This illustration shows the interaction between the bitting angles for each cut, and the tumblers. The properly designed key must provide for each tumbler to properly seat at the root of each cut. The ramp angles that form each cut must allow for a smooth entry and exit of the key. Too sharp an angle will present an obstacle to the tumblers, or will prevent removal of the key.

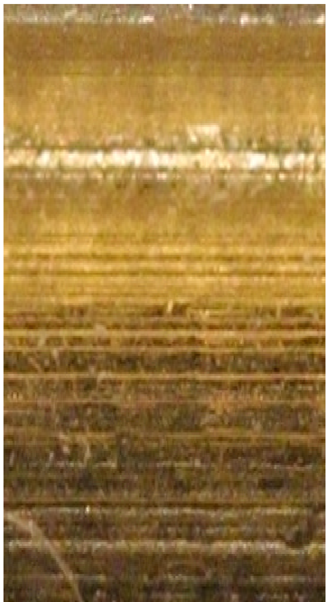


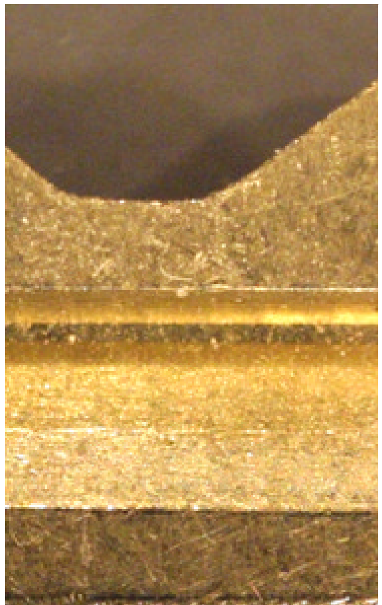
Keyways have many different patterns of wards, which are in fact projections from either side of the opening. Their purpose is to block entrance into the lock except by the key blank having the corresponding ward pattern. Thus, for every projection of a ward within the plug, there must be a corresponding depression or absence of material upon the key.

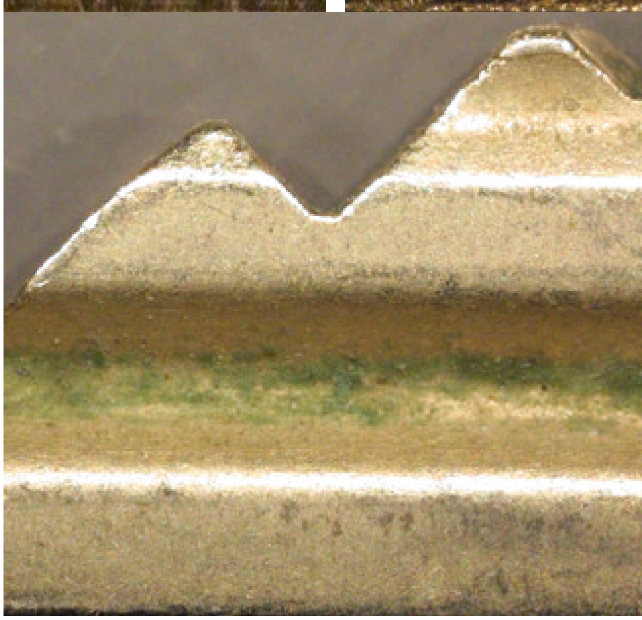
Wards may have many different shapes. Thus, they may be square, round, angled, flat, wedge-shaped, or other similar design.

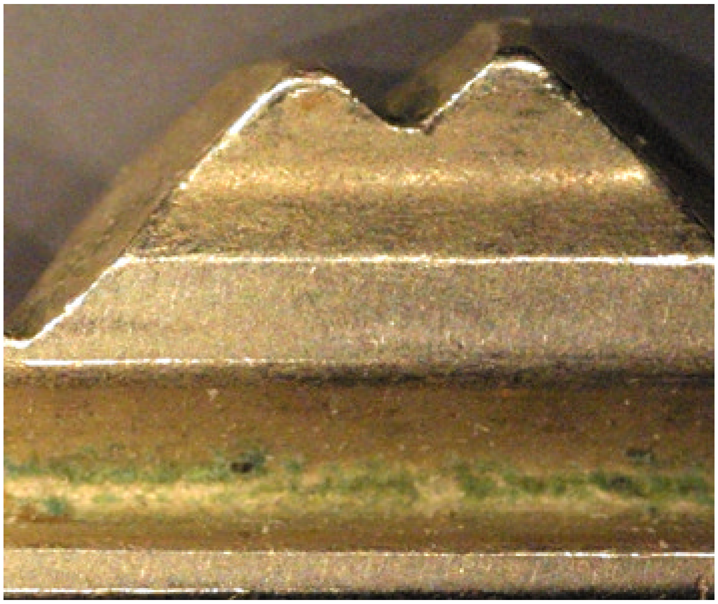
There are in fact five primary keyway design variations: left angle, right angle, square, V, and round. Varying angles are utilized in forming these shapes, and thus, an infinite number of groove patterns can be generated. In the photographs below, several different ward patterns are shown.

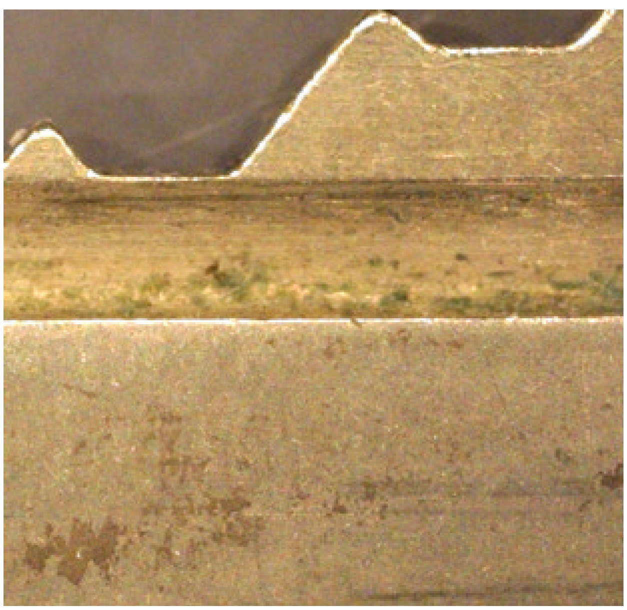






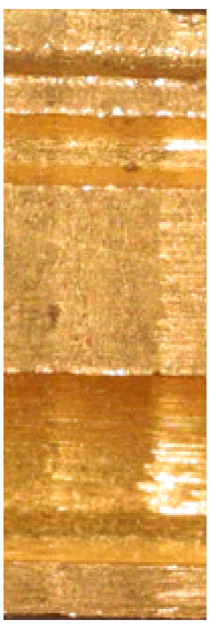


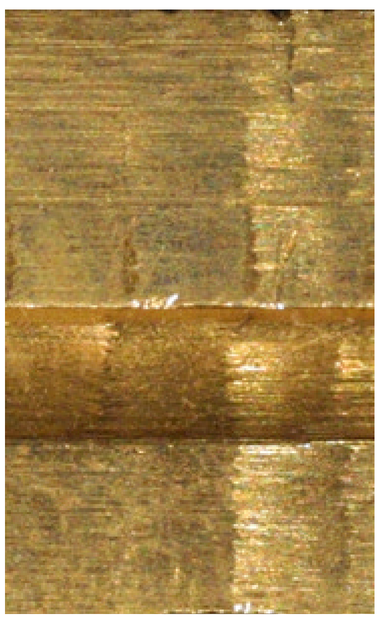


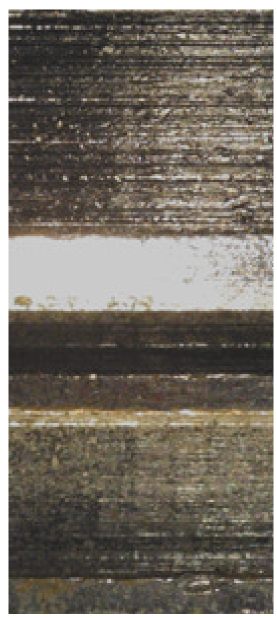












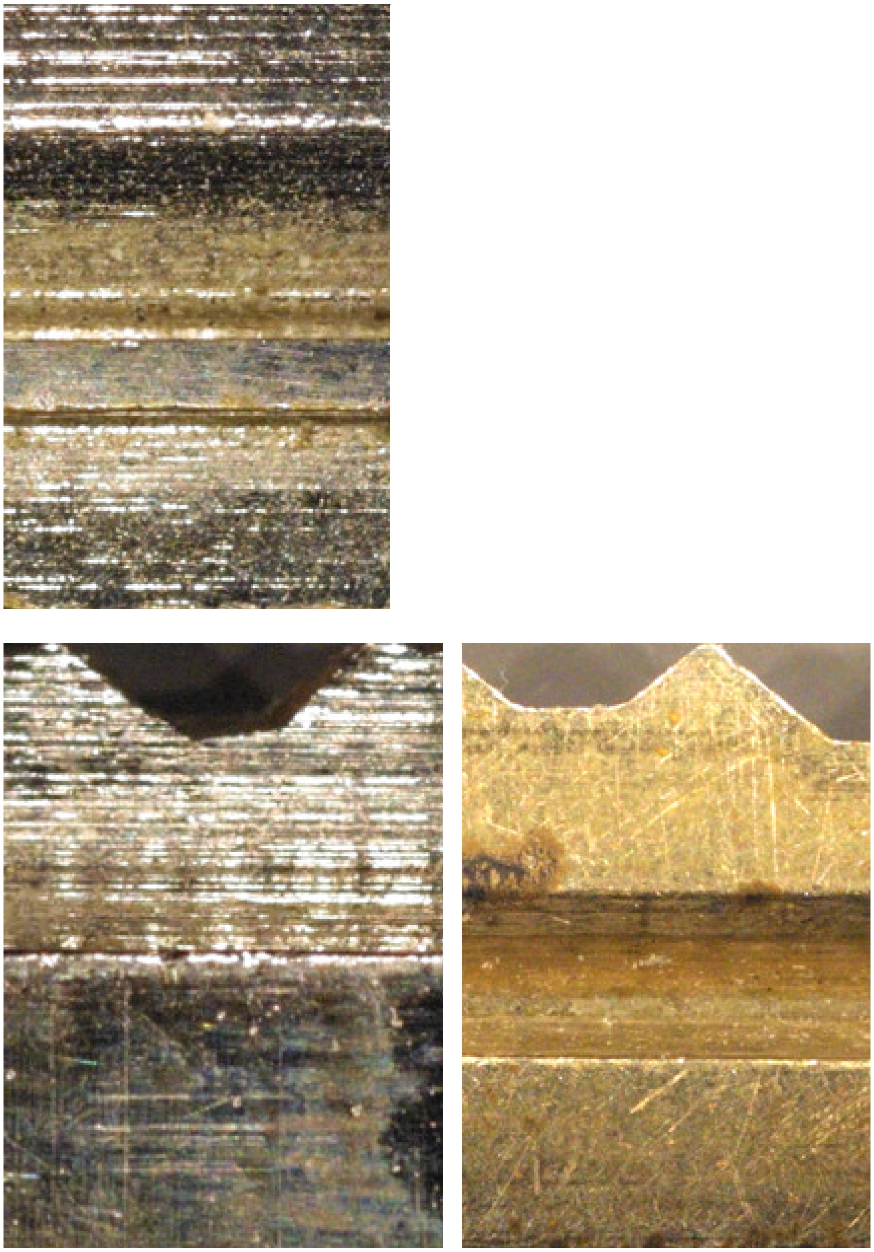


Figure LSS+604 Keyway ward sections take many shapes and forms.

When producing a new lock, the manufacturer will first determine the design of the keyway. Functionally, the keyway will reject all but the correct key from entering the plug. Different keyways provide the primary means to allow the production and use of billions of locks throughout the world. Without keyways, there would be no security against keys for one lock opening many others.

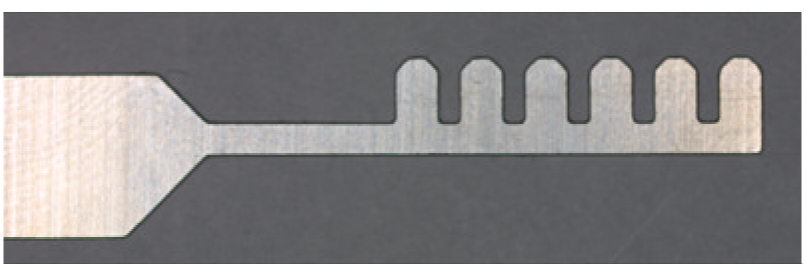
Each manufacturer will develop different keyways from that of its competitor. In this way, a manufacturer can be assured that a customer will purchase only his locks for a specific keying system. Otherwise, there would be no master keying options, because different blanks would be required for different locks within one system. Although many keyways may appear identical, there are always slight differences between vendors. Keyways form the basis of key control and are essential in complex master key systems.

6_4.4.1 Restricted Keyways

A manufacturer may also designate certain keyways as restricted. Generally, key blanks for restricted keyways may not be obtained by the public. They may be available only on a direct basis from the manufacturer or from licensed locksmiths. In certain cases, restricted keyways are designed for a specific customer and will not be used in locks that are sold to any other location. The post office and other government agencies have restricted keyways from Yale and other manufacturers, which will never be used by anyone else.

6_4.4.2 Anti-Picking Keyways

Paracentric keyways are designed to frustrate lock-picking, because they have wards that extend over the imaginary vertical centerline. The design of the keyway can prevent the pick from easily moving within the plug. Paracentric keyways will also prevent a picking technique called wedging, using a comb pick. There are some very complex paracentric keyways in high-security locks, which make picking almost impossible. One covert entry specialist utilizes a very fine saw to cut away difficult wards within the keyway, prior to picking. Although it may be effective, this procedure is not recommended.



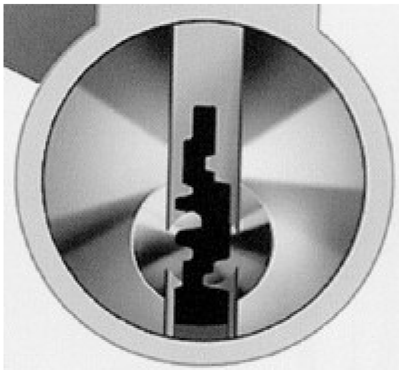


Figure LSS+605, a John Falle Comb pick. Paracentric keyway.

Figure LSS+606

Note how the wards cross the centerline to frustrate picking.

6_4.4.3 Keyways and Complex Keying Systems

Manufacturers will define a certain keyway group for large and complex master key systems. Thus, a keyway configuration may allow for a grand master keyway, with several sectional and individual keyways. In these types of systems, blanks for the higher keying level will always work in the sublevels. Thus, a grand master key will fit the keyway of every lock in the system. A **sectional** master will fit locks within that section but not other locks. Greater security is obtained in this type of a system.

6_4.4.3.1 Schlage Everest

The Schlage Everest cylinder employs a patented design that provides for an under hang in the keyway that interacts with a corresponding channel that runs the length of the key. As shown in the photograph, the raised portion near the tip of the key controls a spring biased check-pin in the plug. Unless the pin is raised by the channel, it will prevent rotation, even with the correct bitting values. The author does not consider this cylinder to be suitable for high security installations, but rather of another level of access control or equivalent form of restricted keyway. The locks are not difficult to pick with the correct tool, manufactured by Peterson. Although the key design is patented, it can be replicated to bypass the check-pin using the Easy entrie profile milling machine, or by simply producing a blank that bypasses the undercut portion of the keyway, in combination with the Peterson ET-1 tool, or even a spring steel

tyne. See the discussion relating to master key security in **chapter 31.** Picking technique using the Peterson tools are discussed in **chapter 29.**

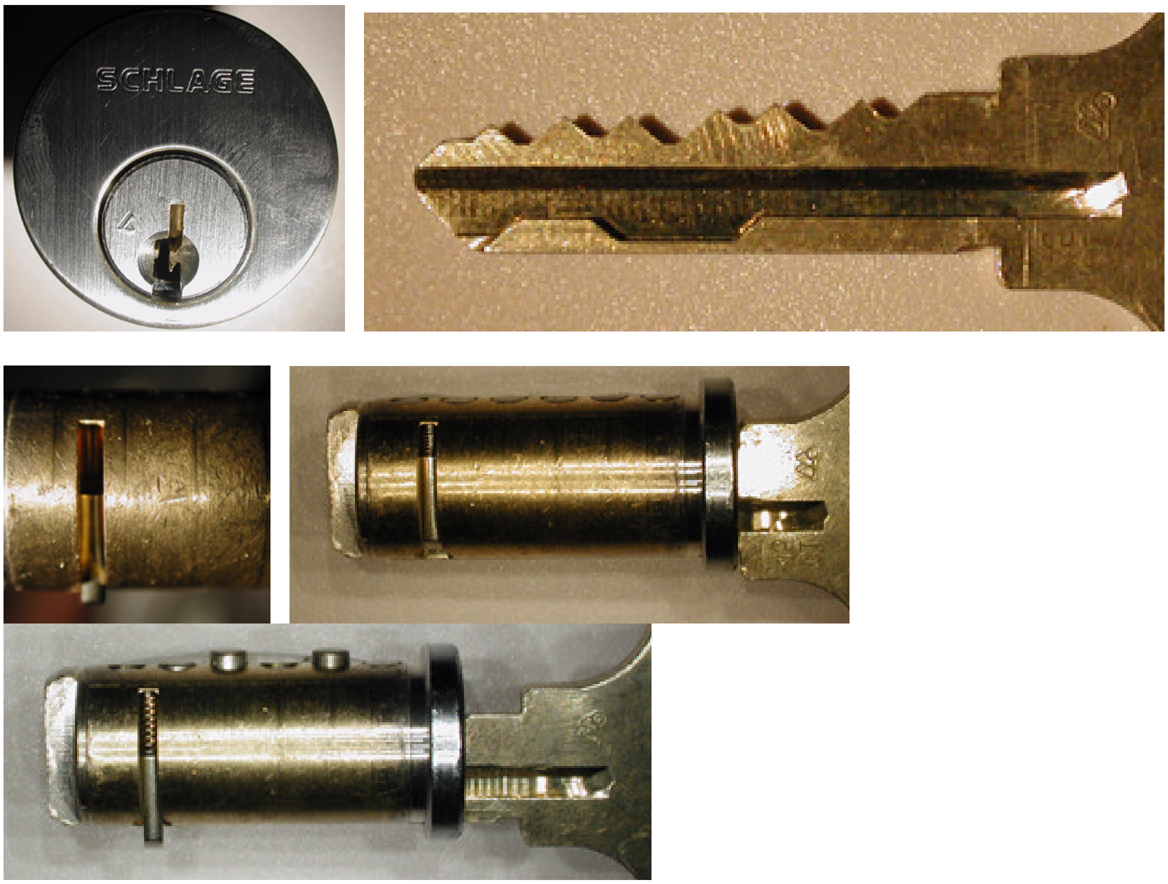


Figure LSS+610 Schlage Everest utilizes a unique keyway design that incorporates a check-pin that must be lifted by the corresponding channel on the side of the key. In the photograph of the plug and keyway, note the undercut on the right side of the keyway that prevents a key that does not have the corresponding channel. The check-pin is shown in a locked and unlocked state. Schlage supplies the blanks for this cylinder, and thus can control duplication of keys. It is a relatively simple matter to bypass this function.

6_4.5 Identification of Keys and Blanks

The procedure for the identification of a key will generally require:

- **Basic classification of the type of lock or general purpose of the key blank, from the shape, size,**

appearance, and metal;

- **Identification of the manufacturer from the keyhead shape, name, or identifying number or symbol;**
- **Identification of the specific keyway.**

To complete identification and matching with a known key blank sample, the length, width, thickness, and keyway should be compared on a side-by-side inspection. To compare keyways, examine the known and suspect key at the tips. A method for the computerized identification of keys was patented by Yanovsky in 2001 (**6175638(123)**). This shadow acquisition device allows the accurate analysis and storage of information regarding key blanks. A more complex and sophisticated system has been developed by Silca and is fully described in this text.



Figure LSS+607, examples of markings on a Sargent KESO key, and a Sargent LA sectional keyway series. Noted on the KESO there is an indirect code number and master key system number. On the Sargent LA keyway, the direct code 334874 appears. The key can be duplicated from this number.

The grooves of the suspect key must correspond perfectly with those of the known key. Be certain to physically compare all surfaces for a match. Some blanks are so similar that the shapes of the grooves on all sides must be carefully examined.

It may be important to learn what type of lock a specific cut key

will operate. The following indications may be helpful:

- **Length and height of the key;**
- **Number of tumbler cuts;**
- **Type of tumbler cuts (round, square);**
- **Shape of the cuts.**

Information can be derived from a key blank reference source, including:

- **The manufacturer;**
- **Code numbers;**
- **Coding system;**
- **Cross-references to the same blank produced by another vendor;**
- **Coding system used for a particular lock.**

A good key blank catalog, produced by ILCO or Silca, is a requirement for identification. These listings will contain 1:1 photographs of virtually every key blank and a keyway profile. The catalog will also contain cross-references to other vendors, allowing the identification of keys, regardless of the brand name that appears on the blank.







LSS+608, examples of blanks with distinctive markings to identify the manufacturer. Note the Ilco and Silca logos, and the identifying blank numbers. The Ilco blank identifies both the blank number (999) and the OEM (Yale) blank number Y1.

6_4.6 Identification of Keys and Manufacturer

Each lock manufacturer may offer hundreds of different key and keyway designs for their products. Multiplied by the thousands of lock vendors throughout the world, key blank identification can become difficult. Yet, there is no international standard for the design or classification of blanks. The identification of keys to a specific manufacturer, however, in most cases is not difficult.

There are a number of key blank manufacturers throughout the world whose business it is to produce blank keys, on an OEM basis, for many different lock makers. Perhaps the largest international supplier is Silca, located in northeastern Italy. This company produces more than 200,000,000 key blanks a year, for hundreds of different lock manufacturers. Silca has a state-of-the-art automated manufacturing facility that can generate a blank for any lock. Silca, as with all other suppliers, has a unique logo and key number that they stamp on each blank that they produce.

To identify a certain manufacturer from a key blank, we are concerned with several criteria. These include:

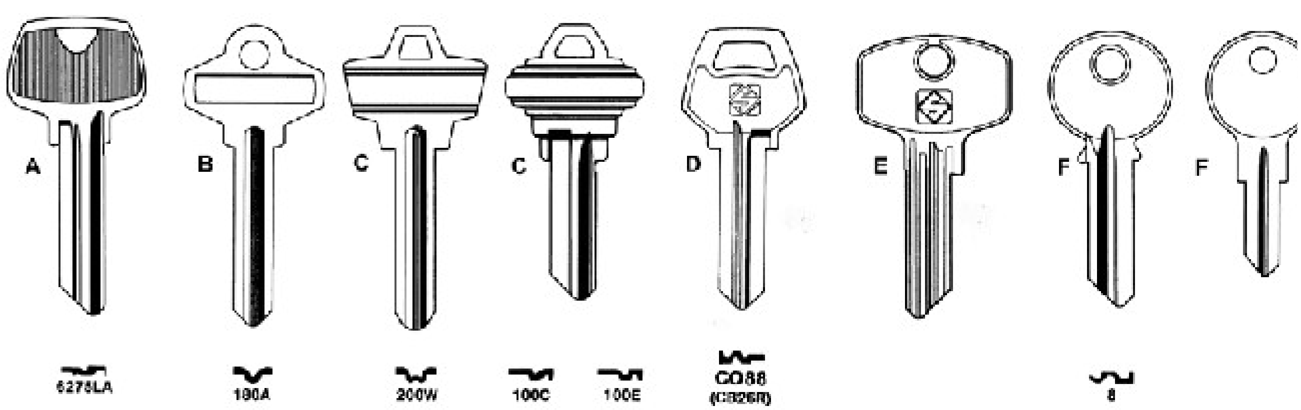
- **Name on the bow;**
- **Shape of the bow;**
- **Identifying numbers on the bow;**
- **Size of the key;**
- **Shape and design of the grooves that form**

the keyway;

The name inscribed on the bow may identify the manufacturer if the key is an original, supplied by the manufacturer of the lock, or by a company who produces original keys for the manufacturer under contract. However, just as often, the name on the key will be that of the company that produced the blank but not the lock. Thus, a blank with the name and logo of Silca would indicate that the key, not the lock, was manufactured by Silca. In this case, however, there would also be a number, which can then be correlated to the manufacturer.

6_4.6.2 Shape of the Bow

A primary method of identifying the lock manufacturer is the shape of the bow or keyhead. Essentially, every manufacturer has chosen and trademarked a unique shape for their keys. There are, however, neutral heads produced by a number of key makers. These generic shapes do not reveal anything about the manufacturer. A product number will identify the original lock vendor. There is an interesting **discussion** in Price's treatise found elsewhere in this Infobase, regarding the design of bows.



6_4.6.3 Identifying Numbers on the Bow

There may be as many as three different numbers on the face of a key and a name or logo. These numbers can identify the blank to the original manufacturer. They can also provide the code of the key, which will relate to the actual tumbler combination of the lock. Numbers may also indicate an office identifier or other internal designation.

6_4.6.4 Size of the Key

The size of the key may offer a clue as to what type of lock it fits. Thus, small keys for pin tumbler mechanisms, for example, may indicate that they fit a padlock or cam lock.

6_4.6.5 Keyway

The design of the keyway will often provide the best clue in identifying the lock manufacturer. All manufacturer catalogs will have pictures of both the keys and keyways. Once the search is narrowed as to one manufacturer, it is usually a simple matter to match the key to the proper keyway. Caution must be observed, however, for the keyways of many manufacturers are quite similar. In fact, often they are so close that the keys for one keyway may operate a slightly different design.

6_4.6.6 Production of Key Blanks

Several companies manufacture blank keys, including Independent, Curtis, National, and Silca. Although many lock manufacturers still produce their own original keys, there is a trend to contract with other vendors, such as Silca, to make their original keys. Many key blanks for different locks appear very similar and may be almost identical. Often, a blank for one keyway will operate in another. Thus, investigators should carefully examine suspect keys and consider the possibility that a blank has been selected that does not appear to be the correct one for a given lock. Blanks can also be milled in order to fit different keyways.

6_4.6.6.1 Milling or Alteration of Blanks

In large systems, restricted blanks often cannot be easily obtained by unauthorized individuals or criminals. In such instances, sectional keys that have been lost or stolen can be modified to fit other keyways. Simple milling of blanks to alter the longitudinal grooves can allow access to other keyways.

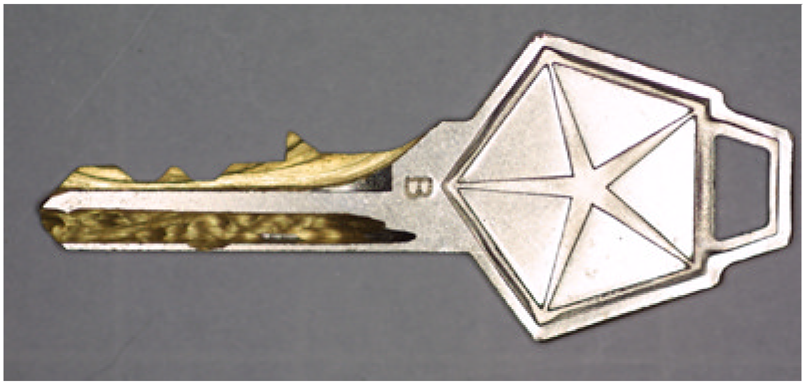


Figure LSS+609, a Chrysler automotive blank that has been milled to open computers in a major bank center.

CHAPTER SEVEN: BLANK KEYS

Processes and Materials for Producing Blank Keys

Master Exhibit Summary

7_1.0 Introduction

There are a number of different processes involved in the production of keys, depending upon the material, function, classification, cost, and tolerances required. This chapter will briefly outline the procedures required during the manufacturing process. For an excellent discussion of early key-making, the

reader is directed to **Chapter 20** in the Price text, contained within this Infobase.

Conversation with Chuck Murray, Kaba-Ilco, regarding keys and their production.

7_2.0 Materials for Key Blanks

Most keys are cut from dies, utilizing strips of brass, nickel silver, aluminum, or steel. In some cases, keys are hot or cold pressed or forged. This is usually the case for iron, soft steel, or zamak blanks. Most cylinder keys are made from brass or nickel silver, although nickel silver blanks are usually of superior quality and strength.

It is desirable to utilize dissimilar metals as between keys and locks, because similar metals wear more quickly when placed in contact with each other. Brass is a popular material for key production, because it is a self-lubricating metal, thus reducing wear.

7_2.1 Iron and Steel Keys

Iron or steel is preferred for the production of car keys, flat keys, and keys requiring extraordinary strength. Thus, Winfield Lock Company utilizes steel keys for their popular hotel room dual-keyway cylinder locks because of the high torque required to actuate the bolt. Brass or nickel silver would likely break in this application.

7_2.2 Brass Keys

Most OEM domestic cylinder keys are made of type #58 brass. Almost all blanks sold in hardware stores, gas stations, and places offering duplicating services are made of brass.

7_2.3 Nickel Silver Keys

Virtually every high-security cylinder and many OEM blanks are made of nickel silver due to their strength. They are superior to brass in this regard.

7_2.4 Aluminum or Avional Keys

Silca manufactures blanks in Avional, an aluminum alloy. These keys are lighter and stronger than brass and may be produced in many colors. Some manufacturers make keys in plain aluminum. They are not particularly popular with the consumer, however, because of the ease with which they break.

7_2.5 Zamak Keys

Keys are also produced in Zamak for poor-quality locks, such as used in mailboxes. Metal content for zamak is a mixture of zinc, copper, and aluminum.

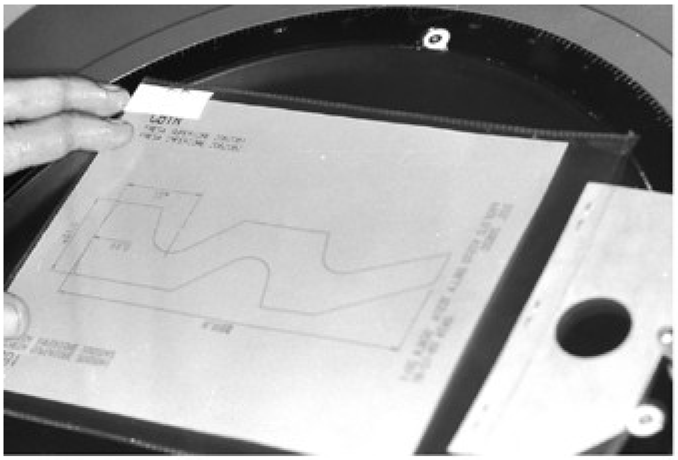
7_3.0 Manufacturing Techniques

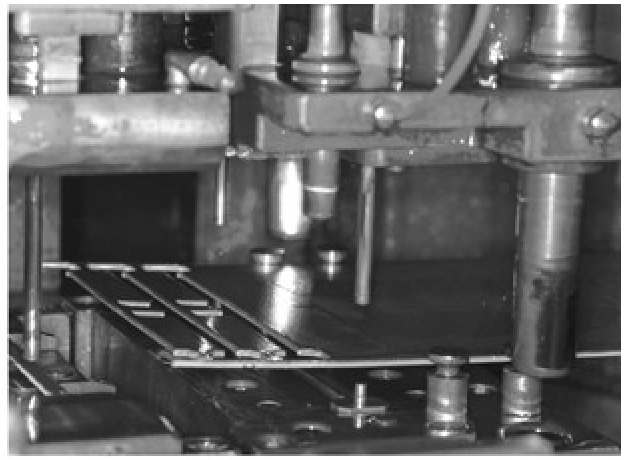
Silca is probably the largest and most sophisticated blank manufacturer in the world. Their production facility is among the most automated in the industry. Every phase, from design to final production, relies heavily upon computers. A blank for a pin tumbler cylinder is produced in the following manner at Silca. First, precise measurements are taken from sample blanks and keyways, obtained directly from the lock manufacturer. These measurements are plotted on a computer using special auto-cad programs that translate the dimensions to an exact facsimile of the keyway and, thus, the key. The required data and cutting instructions are then fed to computer-controlled milling machines for production of tool steel dies and coinage stamp dies. What previously required many weeks of work by highly skilled machinists now takes less than two days.

Once the dies are created, production materials are chosen. Then, long rolls or sheets of brass, nickel, aluminum, or steel are fed into a cutting die. This die will produce the required blank key shape, thickness, length, and keyhead design. This flat blank will then be fed into an automated milling machine, which will cut the required grooves on each surface, to form a keyway.

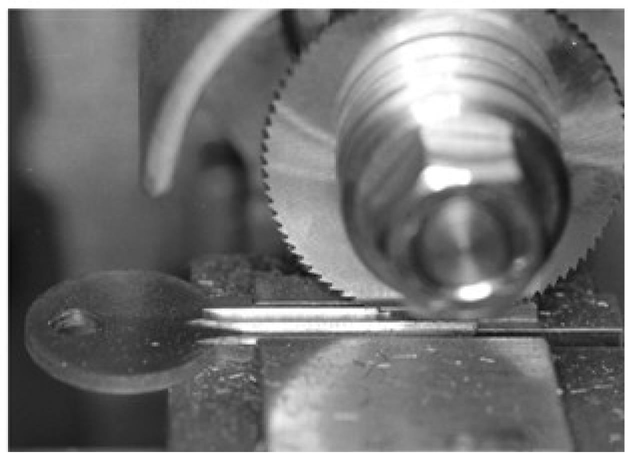
Once the keyway is milled into the blank, the key is "coined" with the proper logo, numbering, and any other required identifying information. The key may also be run through a plating process, to add strength and inhibit corrosion. In some cases, rubber or plastic covers may also be bonded to the head of the key. Other production processes for different kinds of keys may involve **pressing**, **stamping**, or **forging**. Pieces may also be

welded in place as in the case of certain warded or bit keys. An excellent description of early key and lock making and the different processes involved in forming of metals is provided by Hobbs in **Chapter 11** of his text.









7_4.0 Knockoff Keys

Many poor-quality blanks are being produced in the Orient and sold in the United States and other countries. In addition, counterfeit knockoff blanks are being sold as factory original. Thus, for example, just because the name Schlage appears on the face of the blank does not mean that the key was actually produced by Schlage. So also, original blanks are copied from those manufactured by Silca, Ilco, Curtis, and others.

Knockoff blanks can be identified by their poor quality in workmanship, tolerance and profile errors, higher lead content, and keyway misalignment problems. The thickness and composition

of metals used in such keys are often inferior to the factory original.

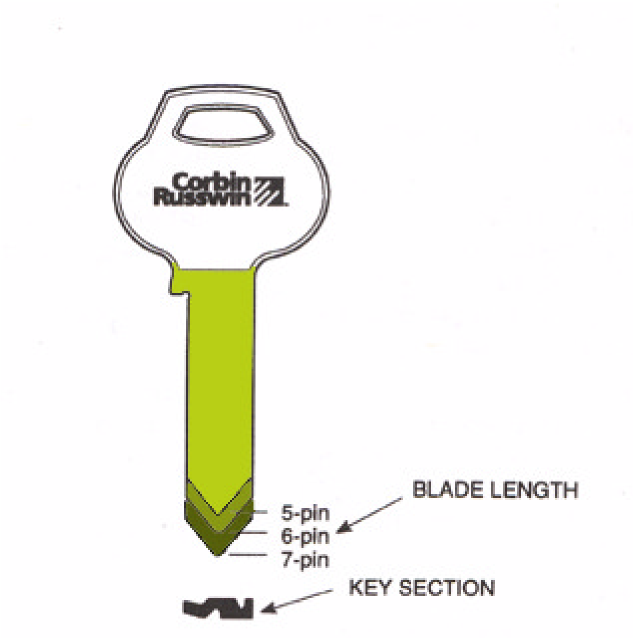


In addition, original logos are often copied imprecisely or are slightly changed to avoid copyright infringement. Many keyways are patented, and thus, the unauthorized production of blanks for certain locks, such as Medeco, violates both copyright and patent laws of the United States and other countries.

7_5.0 Design Considerations for Keys

With the exception of combination and electronic-based mechanisms, all locks require some form of key for their operation. The main function of the key is to transmit locking or unlocking motion to the bolt mechanism. In order to operate properly, the key must be designed to complement the inherent mechanics of the particular lock. That is, each different locking mechanism will dictate the design of the key, based upon the exact interaction between detainers and the bitting.

There are generally recognized design principles as well as a number of specific identifiable attributes of keys. These apply primarily to keys for wafer and pin tumbler locks. They insure proper mechanical operation and are detailed below. There are three primary components to any key:



Key section: The key section or keyway is a function of broaching. Different keyways are created for every cylinder by each individual manufacturer.

Blade length: The length of the blade must be correct for a five, six and seven pin lock.

Bow shape and marking: Each manufacturer defines the shape of bows for various products. Most key head designs are protected by copyright.

7_5.1 Smooth Edges

All edges on the bitting surfaces of a key as well as all grooves forming the keyway must be evenly contoured in order to make proper contact with tumblers and glide smoothly into the lock.

7_5.2 No Crooked Cuts

All depth cuts in the bitting surface should be oriented at a 90° angle to the root. Valleys should be symmetrical to each other in their positions, and each alternate valley slope or ramp should be parallel to valley slopes on each side.

7_5.3 Cuts not too Narrow or too Wide

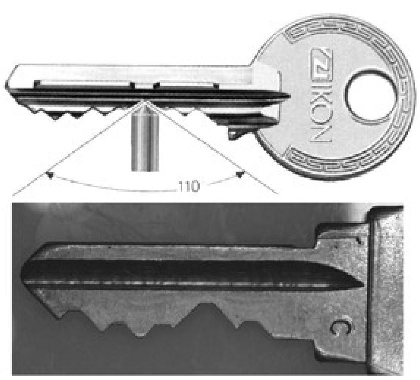
It is extremely important that each depth-cut be centered in the proper position with respect to all other depth cuts. Errors in spacing can result in faulty operation of the lock. If a cut is too narrow, tumblers will not seat at the root but rather on the ramps or valleys of the key. This will result in the tumbler not resting at the correct position with respect to shear line. If cuts are too wide, there will be interference with adjacent depth cuts, causing tumblers for those cuts to rest at the wrong position.

7_5.4 No Sharp Corners or Burrs

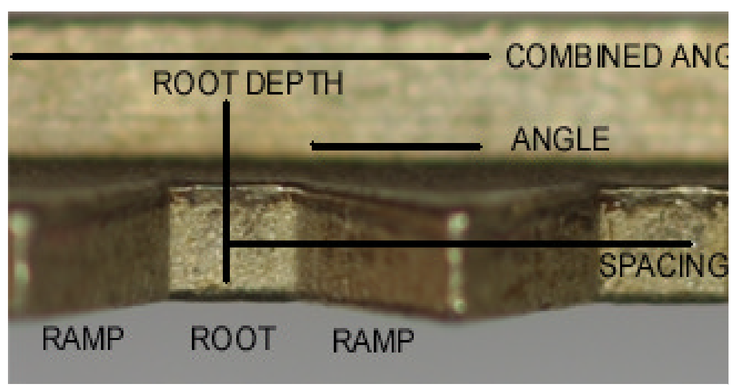
There can be no sharp corners or burrs on the surface of the key which will catch tumblers on insertion or removal. The convergence of ramp angles between cuts is called steeples. A symmetrical point will be formed, resembling an isosceles triangle having two equal sides and angles.

7_5.5 Proper Angles and Valleys or Flats

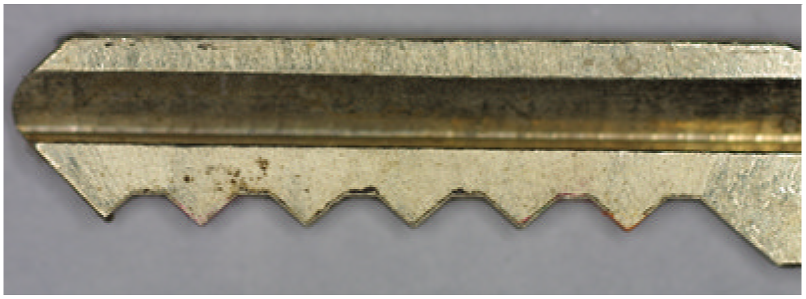
Proper cutting angles must be maintained for each depth-cut. Generally, 90°-120° total for both angles is considered acceptable. If the angle is improper, keys will not raise and lower tumblers smoothly and may cause the key to hang up in the lock. In the illustration **LSS+701a,** the Ikon key shows a combined angle of 110°.



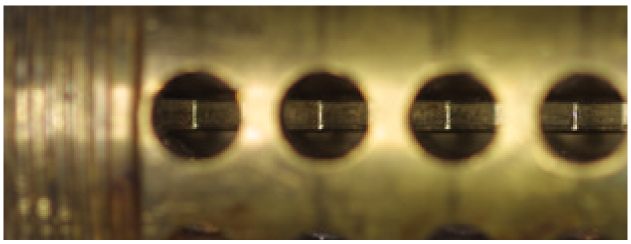
LSS+701a. Proper key design requires that ramps and root form a combined angle of 90°-110°, as shown in the Ikon and Schlage keys above.



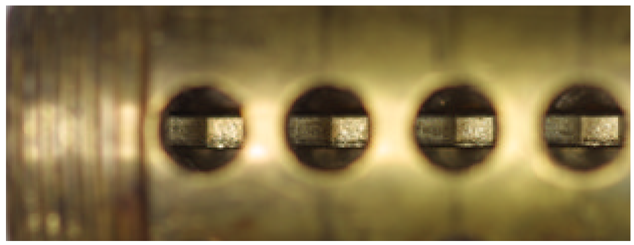
LSS+701b, This photograph shows the prope of a pin tumbler key. Note the symmetrica angles. Spacing is defined as center-to-c distance between cuts.



LSS+701c. This code-cut key shows the symmetry of each cut.



LSS+702a. A key must be properly positioned so that each cut is precisely centered under its corresponding tumbler. In this photograph, there is mis-alignment between chamber and the location of each depth cut.



LSS+702b. In this photograph, proper alignment between each cut and corresponding chamber is shown. Note that the root is positioned at the center of each chamber, thereby allowing the tumblers to seat properly in each root.

7_5.6 Bow

The part of the key that does not enter the lock but allows it to be held for operation by the user is the bow. Its design does not affect the operation of the key, but it should be configured so that it does not interfere with its use, either.



Figure LSS+703 Key bow.

7_5.7 Shoulder

The shoulder of the key must be designed so that it makes contact with the plug, so as to stop the key from forward movement at precisely the correct position. Care must be taken that spacing for the first cut is the proper distance from the shoulder.

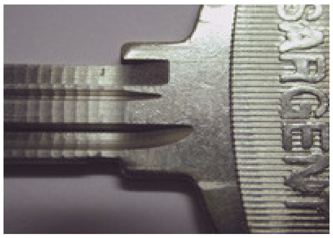


Figure LSS+704 Shoulder of key

7_5.8 Depth and Spacing

The distance between the center of one valley or V cut to the center of the next valley or V cut must be correct in order for all tumblers to set properly. A **micrometer**, such as manufactured by HPC can be used to measure precise distances between cuts, from the flat portion of one to another. The illustration shows a depth and spacing for a Yale pin tumbler lock. There are six spaces and nine depths.

DEPTHS					
0	.320	4	.244	8	.168
1	.301	5	.225	9	.149
2	.282	6	.206	0	
3	.263	7	.187		

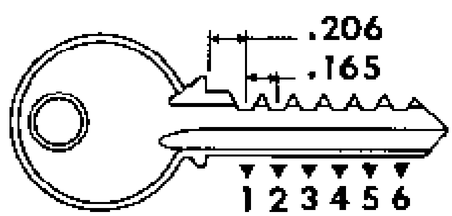


Figure LSS+705 Depth and Spacing diagram

It is interesting to note that a patent was granted to Simon in 1931 for a process of marking key blanks to readily display depth and spacing data on the surface of a key (**1795318(124)**).

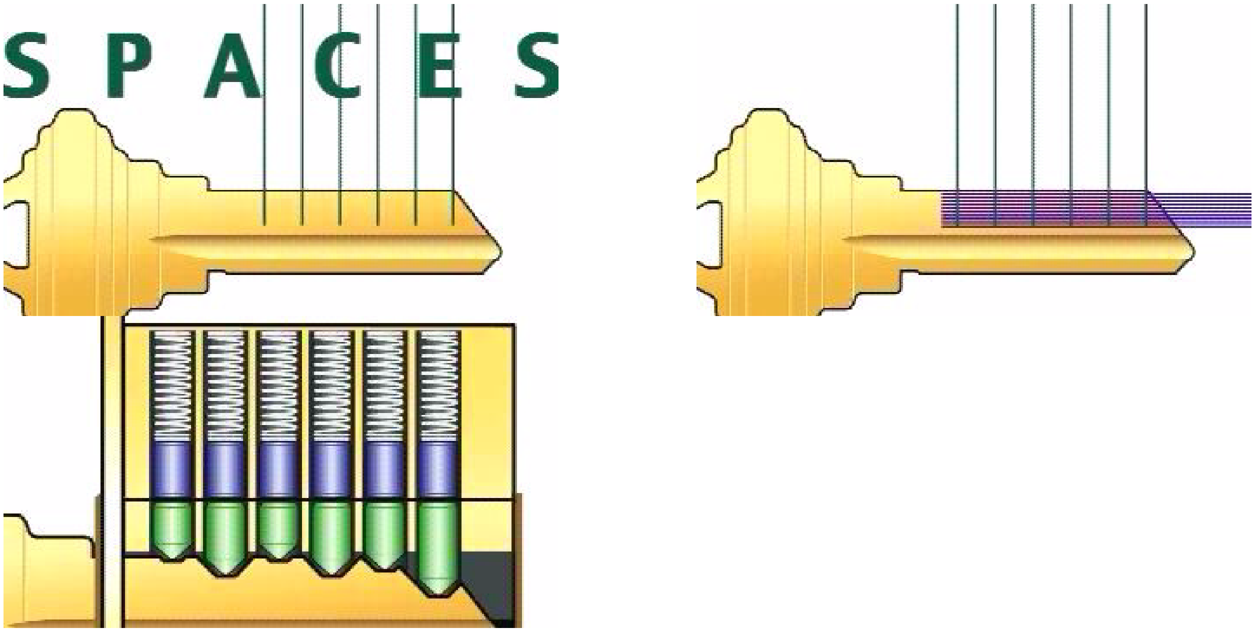
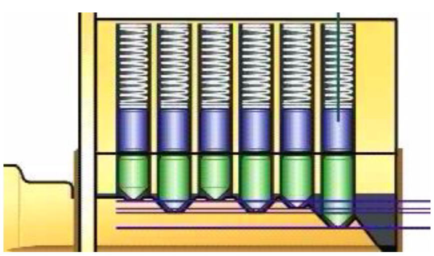
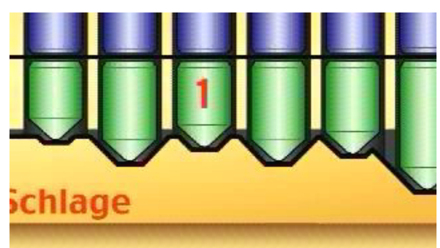


Figure LSS+706 A diagram showing the vertical (left) and horizontal (center) division of the bitting surface of the key, and how the tumblers interact with each position. The spacing between cuts precisely corresponds with the position of the chambers. Courtesy of HPC Interactive Learning Series.

7_5.8.1 Depth of Bitting

The depth of the bitting surface will determine the number of available differs. Keyway design and the structural integrity of the key will be factored into this parameter. Keys that provide for very deep cuts are subject to fracture resulting from the application of excessive torque by the user. In the above illustration, the Yale key has nine depths that range from 0.320-0.149 inches.





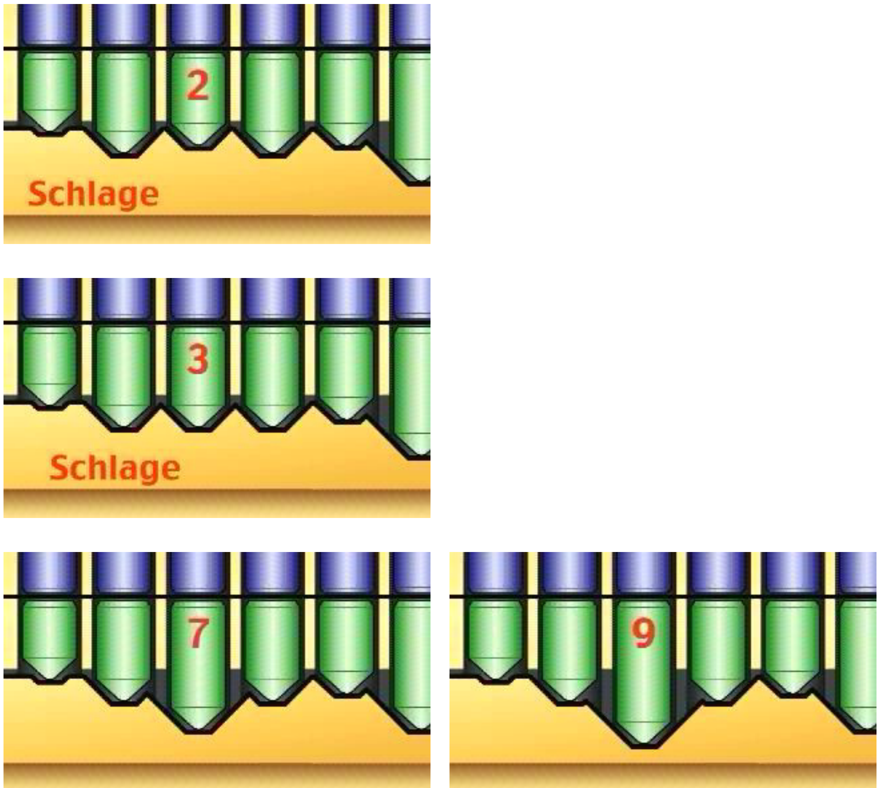


Figure LSS+707 These diagrams show an example of different pin lengths utilized by Schlage. There area total of nine depths available. The first photograph shows the relationship between each pin chamber and pin depths. Courtesy of HPC Interactive Learning Series.

7_5.8.2 Proper Depth Combination

The manufacturer must determine the maximum allowable difference between depth cuts adjacent to one another. Thus, a number 1 cut often may not be placed next to a number 9 or 0 cut because of the sharpness of the angles thus created. If the angle is too steep, the tumblers will not lift properly, and the key may be difficult or impossible to insert or remove. A key is “back cut” if the ramp angle is so steep as to prevent a tumbler from rising as it is withdrawn. In such a case, the tumbler is actually trapped within a valley, formed by acute angles.

CHAPTER EIGHT: CREATING KEYS

Methods of Producing Cut Keys

Master Exhibit Summary

Easy entrie

LSS201: Procedure for making keys with a clay mold. Courtesy of MSC.

LSS201: Making keys by silicone impression, Courtesy of MSC

LSS202: Kaba-Ilco Quattrocode key machine, Courtesy of Steve Fish.

LSS202: The Ultracode key machine, Courtesy of Steve Fish.

LSS202: The Kaba-Ilco Triax key machine, Courtesy of Steve Fish.

LSS202: Kaba-Ilco RW2 Transponder system, Courtesy of Steve Fish.

LSS203: HPC BlueSHARK third generation key cutting machine.

Keys can be copied through the use of clay molds. Courtesy of Hans Mejlshede.

Keys can be produced from codes, courtesy of Harry Sher.

LSS203: Easy entrie key machine demonstration

LSS204: Demonstration of the Keyway King, by Greg Brandt

LSS205: Gale Johnson on key codes

Easy entrie Operating Instructions

Easy entrie PC Software operating instructions

8_1.0 Introduction

Keys can be produced by hand or machine cutting. They can be duplicated or generated through casting, impressioning, and decoding techniques. A detailed discussion of these procedures and the required tools, including key machines, is presented in this chapter. Specific bitting combinations can be derived from another key by disassembling the lock or by code. See **Chapter 31** for a detailed discussion of decoding techniques and procedures.

8_2.0 Tools Required for Hand Cut Keys

In order to produce a hand cut key, certain tools, including files, decoders, measuring devices, and key machines, are recommended. These are summarized below.

8_2.1 Files and Miscellaneous Tools

The files listed below are suggested for use in cutting keys by hand. See **Chapter 4** for information regarding each type of file, and its proper use.

- **Warding files (for flat keys, warded and lever locks):**
- **4" warding file**
- **6" warding file**
- **Rat-tail file: 4" and 6"**
- **Triangle file**
- **Swiss file set**
- **Pippin Swiss pattern file**
- **Fine, slim taper file**
- **Clamp or vice to hold key**
- **Vice grips**

8_2.2 Decoding and Measuring Tools

Many decoders have been patented over the past one hundred years for measuring depth and spacing on keys. See an early mechanism invented by Phelps in 1902 (**709240(125)**).

The following instruments and tools are utilized for decoding source keys:

HPC SKM-2D Direct Reading Key Micrometer: This instrument is used in key duplicating and decoding for determining precise measurements of spacing and bitting.

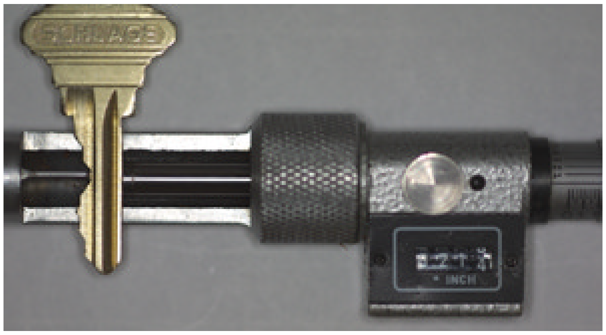


Figure LSS+801 The HPC key micrometer will directly read depths of bitting.

HPC GMTD-5 Decoder Gauge: This set of five gauges is utilized to decode General Motors sidebar locks. With pressure applied to the sidebar, the tumblers are raked to the aligned position. Then, each gauge is inserted into the lock so that the depth of the tumblers can be read.

HPC Key Decoder HKD-75: This is an extremely valuable instrument and should be a part of every tool kit. The handheld decoder allows the reading of virtually every wafer and pin tumbler key in the United States, simply by inserting the blank into the device and directly reading the depth of each bitting position. The unit is supplied with over 110 **reference code cards** for more than sixty locks, detailing blanks, depths, and spacing information. The data thus derived can be fed into the HPC 1200 and a key can be produced by code in seconds virtually anywhere.

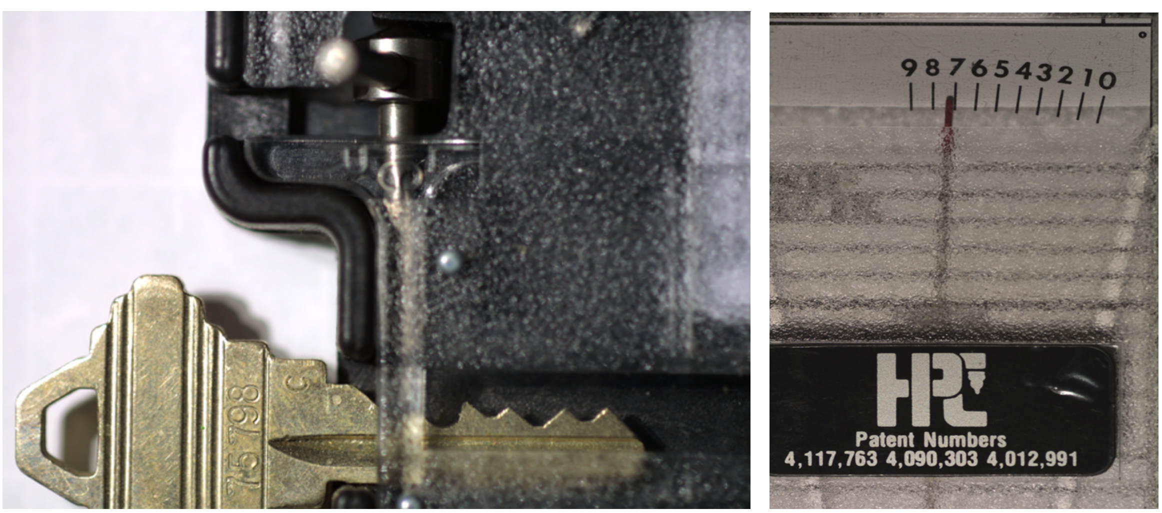


Figure LSS+802 HPC Key decoder. This tool will read all major key blanks and their bitting surface.

HPC Tubular Pin Tumbler Lock Depth Gauge: This tool is utilized in conjunction with tubular lock picks to "read" the position of the feeler pins within the pick after the lock has been opened. It will allow production of a tubular key by code.

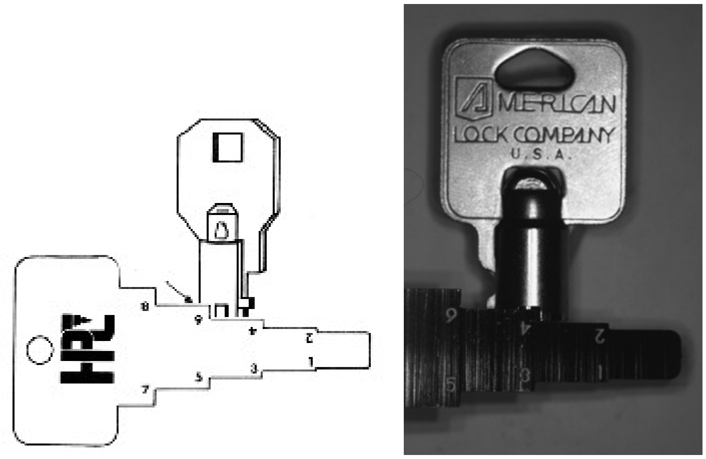


Figure LSS+803 An HPC axial decoding tool (and exploded view) for measuring the depth of each cut. This tool is also shown in Figure 31-7.

Many decoders have been developed specifically for automobile locks. See, for example, Leversee (**4638567(126)**) who invented a decoder for Mercedes-Benz locks in 1987.

8_3.1 Key Cutters

The original code-cutting key machine was developed in 1926 by the Independent Lock Company (ILCO). Today, many companies produce machines and cutters. They range in price from under two hundred dollars to over twenty thousand dollars depending upon complexity. The author utilizes cutting machines produced by the two leading manufacturers in the world: HPC and Silca. These companies offer a series of manual, electric, electronic, and laser-guided cutters that can duplicate or produce virtually any modern key. Each machine has its application; the serious locksmith or law enforcement agency may purchase more than one based upon specific needs.

8_3.1.1 Hand-Operated Key Cutters

There are a number of handheld key cutters that do not require electricity and which are extremely versatile for use in the field. The following three cutters are highly recommended:

- **HPC 1200PCH Manual Key Cutting Machine**
- **HPC TKM-90 Tubular Key Cutter**
- **A-1 Security Manufacturing Pack-A-Punch**





There are two versions of the HPC 1200: one unit is solely mechanical and the 1200CM is motor-driven. The 1200 will produce any wafer or pin tumbler key by code, using punch dies. The machine is extremely simple to use, compact, and can be taken anywhere. It is particularly suitable to field operations. The HPC TKM-90 (above left photograph) is a handheld cutter for tubular keys used in axial pin tumbler locks, such as the Chicago Ace. The A-1 Pack-A-Punch can be used to code-cut most automobile keys as well as Schlage, Best IC, and Kwikset. The punch features interchangeable cutting dies and code wheels. It is ideally suited for producing keys in covert operations and is described more fully in chapter 31, regarding the decoding of master key systems.



Figure LSS+821 The HPC 747XU tubular key duplicator will copy virtually any axial pin tumbler key. It can also be used to generate keys from an HPC tubular pick.

8_3.1.2 Motor-Driven and Computer-Controlled Key

Machines

All motor-driven and computer-controlled machines perform the job of cutting keys in similar fashion. The essential difference is logic, control, and the complexity of their databases. However, the job of actually cutting keys is relatively simple. The HPC 1200CM is the motor-driven version of the 1200PCH. The real distinction between this model and its predecessor is that it can cut Medeco keys and it requires less work to operate. The 1200CM has become one of the most popular key machines during the past ten years, although HPC has introduced the second generation "Blitz" version, and their new third generation machines.



Figure LSS+822 The HPC 1200 CM key duplicating machine (left) is one of the industry standard duplicators. The 1200CMB (center) is the second generation Blitz that provides enhanced options and allows cutting of a variety of high security keys. The HPC Premier Speedex 9160MC is a manual duplicating machine that will handle both large and small keys.



Figure LSS+825 The HPC 1200PCH mechanical punch cutter (left) can be utilized anywhere. The Drill Mill is an extremely clever key cutter that utilizes a drill motor for the driving force for the cutting wheel.

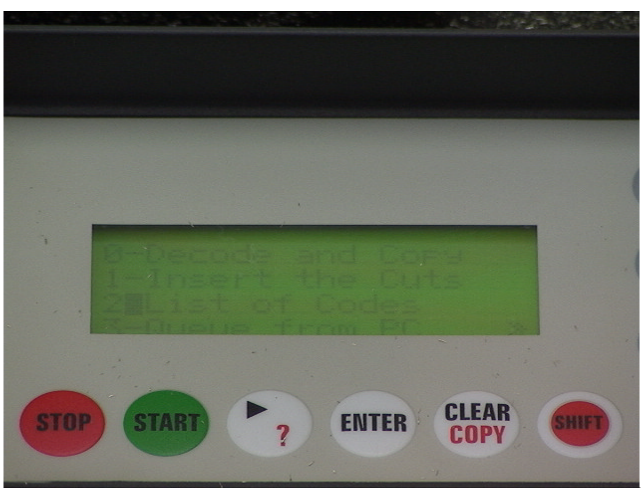
The HPC CodeMax and the BlueSHARK (described below) are the premier machines produced by HPC. The CodeMax is an extremely sophisticated, computer-controlled device, which is capable of cutting virtually any "standard" key by code. Data for hundreds of different blanks and codes are preprogrammed at the factory. The machine can also be set for custom configurations. The CodeMax is compact, easy to operate, and price-competitive. The BlueSHARK will replace the CodeMax, in terms of functionality and simplicity.



Figure LSS+826 The Codemax was one of the original HPC computerized code cutters.


Triax-e.code


Triax-e.code
STOP
START
ENTER
CLEAR
COPY


0-Decode and Copy
1-Insert the Cuts
2-List of Codes
3-Queue from PC
STOP
START
?
ENTER
CLEAR
COPY
SHIFT

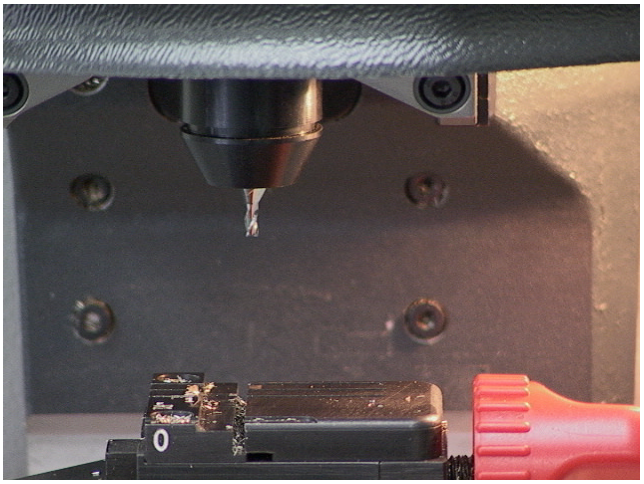


Figure LSS+827 The Kaba-Ilco Triax-e.code key machine.

LSS202: The Kaba-Ilco Triax key machine, Courtesy of Steve Fish.



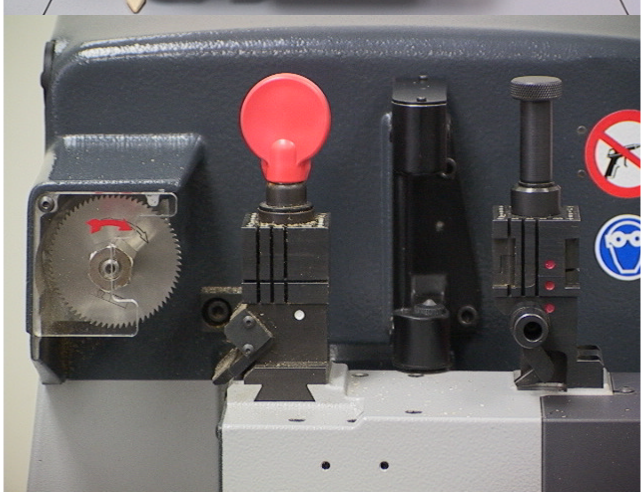
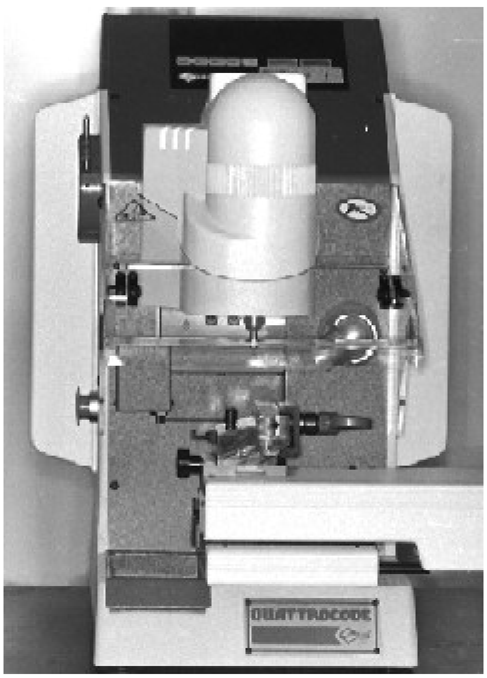
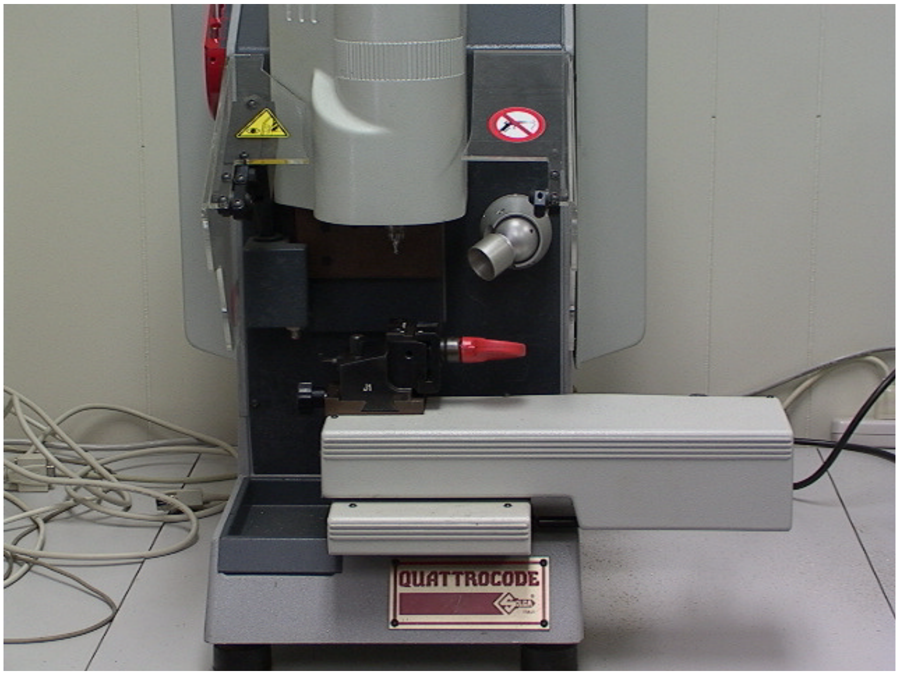


Figure LSS+828 The Ilco Ultracode computerized key machine.

LSS202: The Ultracode key machine, Courtesy of Steve Fish.

The Silca **Quattrocode** is probably the most sophisticated and expensive key machine in the world. This unit, controlled by a computer, can produce virtually any key from code. It has a number of attachments that allow even dimple keys to be cut with ease, and will read a key by laser and correct for errors in the source key being duplicated. Silca also produces a key machine that optically reads virtually any blank, and can reproduce ward milling as well as depth and spacing. This system is available only to law enforcement and certified locksmiths and is in limited production.





The Silca machine, with laser reading attachment, lends itself to the duplication of keys produced from wax, clay, or silicone molding techniques which are discussed below. The principal advantages to laser reading are accuracy and that the original will not be touched or distorted in the duplication process. Silca and HPC, as well as a number of other companies, maintain an extensive database and a complete set of code books for use with their machines.

LSS202: Kaba-Ilco Quattrocode key machine, Courtesy of Steve Fish.

8_3.1.2 HPC BlueSHARKtm

LSS203: HPC BlueSHARK third generation key cutting machine.

HPC has introduced its second generation computerized x-y axis key cutting machine, after several years of research and development, and intense focus groups with tradecraft. The acronym is coined from **S**tand alone **H**and-**A**ctivated **R**obotic **K**ey Machine, and reflects the integration of microprocessors, extensive depth and spacing databases for virtually all significant manufacturers (over 800), and the latest in key cutting and milling technology. The BlueSHARK is the logical progression that began with the 1200CM (Card-operated Code-machine). That product soon evolved into the 1200MAX

(CodeMax, the first computerized code machine), and now the BlueSHARK (which HPC calls the ultimate stand-alone computerized code machine). The 1200CM technology was used to create the 1200PCH (Punch Machine) and the later 1200CM was further developed into the 1200CMB (Blitz). The 1200MAX was further developed into the 1200MAXAA (CodeMax with auto angler).



Figure LSS+829 The HPC BlueSHARK third generation code cutting machine.

The latest entry into the extremely competitive global market demonstrates the sophistication of the locksmith profession, and the demands that modern key cutting machines must achieve. Locksmiths in the United States, as well as throughout the world must maintain significant code data in order to respond to their customers in an efficient and timely manner, in view of the proliferation of lock manufacturers. HPC and other vendors have recognized that key machines must evolve into cutting mills that are controlled by a computer, with comprehensive databases and sophisticated capabilities for a wide range of locks and locking systems. The problem to date has been the complexity of operation of some of these machines and their cost.

Although HPC, Silca (now Kaba-Ilco) and other manufacturers have responded with sophisticated machines, many are outside of the price range of the "traditional" locksmith. Other machines are complicated and require significant training. Both HPC and Kaba-Ilco have expended significant resources to develop

user-friendly computerized systems. This is especially important in the United States, where relatively few locksmiths have computers, or are computer-literate.

The introduction of the HPC system will likely drive other manufacturers to incorporate similar technology, in order to make key cutting virtually error-proof, with little required training for the end user. What HPC has done is to integrate data input and control functions through the use of a touch screen overlay on a liquid crystal display, with proven and rugged cutting technology. This means that the operator needs no computer knowledge or expertise, which translates into the elimination of costly learning curves for employees. From the viewpoint of the author, the system is both interactive and intuitive, and can be customized for each user. An employee can utilize the system almost instantly to produce accurate keys.

The mechanism provides an automated decode function to determine the code of a key, in order to allow for accurate generation to factory standards. This is similar to the system that is available in certain of the Silca machines, but utilizes a mechanical stylus to probe the contour of the key, rather than a laser.

The BlueSHARK system requires no adjustments, and is almost impervious to misalignment issues that are common to traditional cutters. However, the BlueSHARK will not cut certain kinds of keys such as dimple and lasertrack. Optional hardware will allow tubular and Tibbe keys to be produced. The HPC CodeSource database is included, thereby eliminating the requirement for a separate computer, or the purchase of additional software.

One of the interesting features of the cutting head and computerized key analysis is the ability to control the design of the bitting surface in order to assure smooth operation, minimal wear, and to prevent unintentional removal of the key while inserted into the lock. The system actually evaluates and generates new angles from cut root to cut root. Different patterns can be programmed, including standard cut, contour cut (removal of peaks), smooth cut with barb, angled cut, and radial flats.

The user can easily search for code data from any manufacturer within the database, and can download data from other HPC databases, including MasterKing and KeyTrail. Depth and spacing information is available by DSD number or manufacturer, and also

allows for modification on a temporary or permanent basis in increments of .001".

The system allows for future expansion in terms of data capture and system upgrade, and will surely find wide acceptance as did its earlier generations.

8_3.2 Cutting Techniques

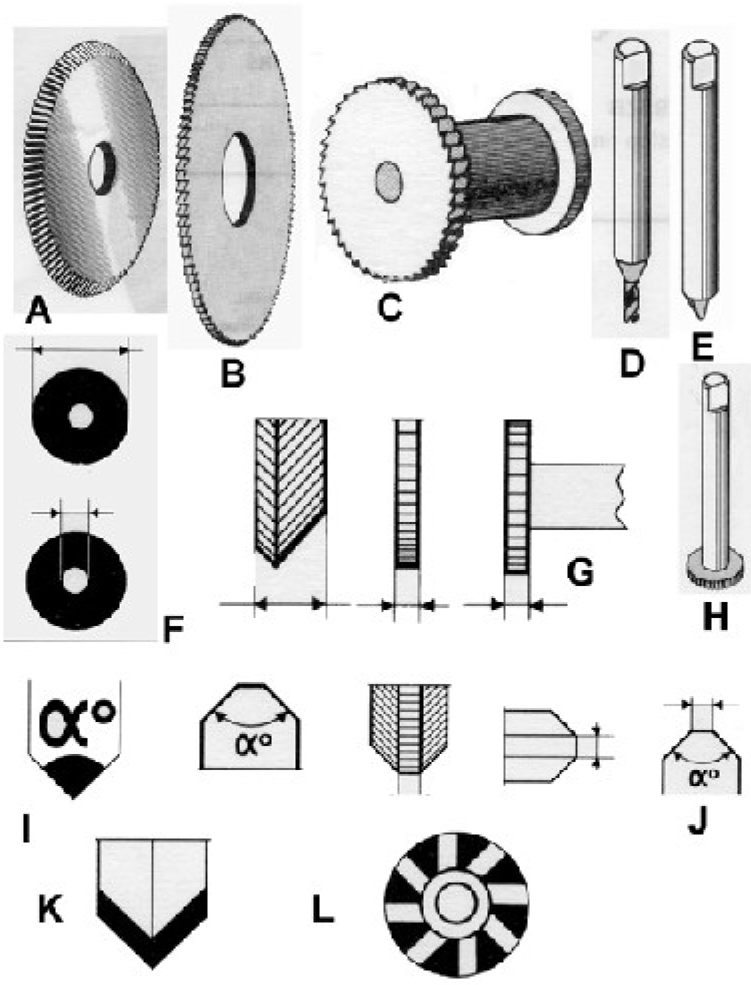
Key machines use cutting wheels with one or two angles. The inexpensive cutters, such as at the local hardware store, generally have cutting wheels that remove metal at a single angle, in a lateral direction, beginning at one end of the key. These machines usually have a motor driven cutting wheel that is mounted in a fixed position. The procedure requires that the tracing stylus be guided across the bitting surface of the source key, from the shoulder to the tip. This process may be automatic or manual, depending upon the sophistication of the machine.

The source and target keys are placed in separate vices, which are connected by a cross-arm. Both keys move in synchronization; one across the cutting wheel, and the other across the tracing mechanism. The source key is "traced" by impressing the bitting against a stylus, connected to the cross-arm. At the same time, the target blank is placed into contact with the cutting wheel. The target key is cut to the exact measurements of the source key, as the source key is "traced", from shoulder to tip.

In manually guided cutters, the operator determines the pressure applied to the source key by the tracing stylus and the speed of the cut. Errors can occur based upon a number of factors, including:

- **Pressure applied to tracing stylus;**
- **Angle of insertion of blank key and source key;**
- **Positions of the source and target key within vice;**
- **Misalignment between key vices;**
- **Poor quality blanks;**
- **Improper blank.**

In contrast, the more expensive commercial cutters and those used during the manufacturing process, generally employ a cutting wheel with two angles. They will generally cut the key straight into the valley or root, rather than from the side. In this way, correct angles are formed on both sides of the root.



8_3.2.1 Characteristics of Cut Keys

Keys cut by the more expensive and sophisticated commercial machines have recognizable characteristics that can often be identified by crime laboratory examination. Specifically, keys which are produced by code will have perfectly formed and equal angles on both sides of the root of each cut. If a high RPM cutter is utilized, the surface of the key will be smooth. Generally, commercial code-cutting machines will operate at about 2200 RPM. Less expensive key-duplicating machines will run at about 800 RPM and are primarily intended for making brass keys.

The more teeth in the cutting wheel, the smoother the cut. If one or more teeth are missing due to breakage, then the cut may not be even. The smoothness of the cut will also be affected by

the speed of travel of the key across the cutting wheel and the RPM of the motor. Misalignment or insertion angle differences between the source and target keys can also affect the appearance and accuracy of the duplicate key.

Commercial key machines will generally maintain tolerances of approximately .0075”-.003", with a variance of .02 mm per copy being acceptable. The tolerance in the production of blank keys is between .001”-.003". Both Silca and HPC can generally maintain acceptable tolerance for ten generations of keys. Thus, the tenth generation from the original key will still be within acceptable limits.

8_3.4 Key Profile Milling Machines

Specialized key cutting equipment is available that will mill and create a desired blank key. **Silca**, **Giuliani**, **DiMark International**, and **Easy entrie** produce or sell such equipment. The **Easy entrie(127)**, manufactured in Germany, is perhaps the most innovative, cost effective, and functional machine that is currently available. There are a number of other profile milling machines that can replicate blanks, but none appear as versatile and portable as the Easy entrie. The Easy entrie has found wide acceptance among locksmiths, crime labs, and special operations units because of its capability to replicate almost any conventional blank.

The ability to replicate almost any conventional blank allows great flexibility in an investigation or covert operation. In **chapter 31**, a detailed treatment of the tactical aspects of compromising master key systems is presented. The Easy entrie can be an integral part of such an operation because they offer the capability of replicating a cut key to produce as many blanks as are required.

8_3.4.1 Easy entrie Profile Milling Machine

The Easy entrie can produce blank keys for virtually all conventional pin tumbler locks and for many of the high security restricted keyways throughout the world. The machine is supplied in two configurations that allow for the production of blanks from a source key, or from a digital image of the keyway. A special software package is offered to government agencies that allows a computer to control the mill and to produce keys from a photograph or database. The hardware for both versions is

identical with respect to the measurement and milling processes. Only the interface and operating system will differ. The video will detail the use of the Easy entrie system.

LSS203: Easy entrie key machine demonstration

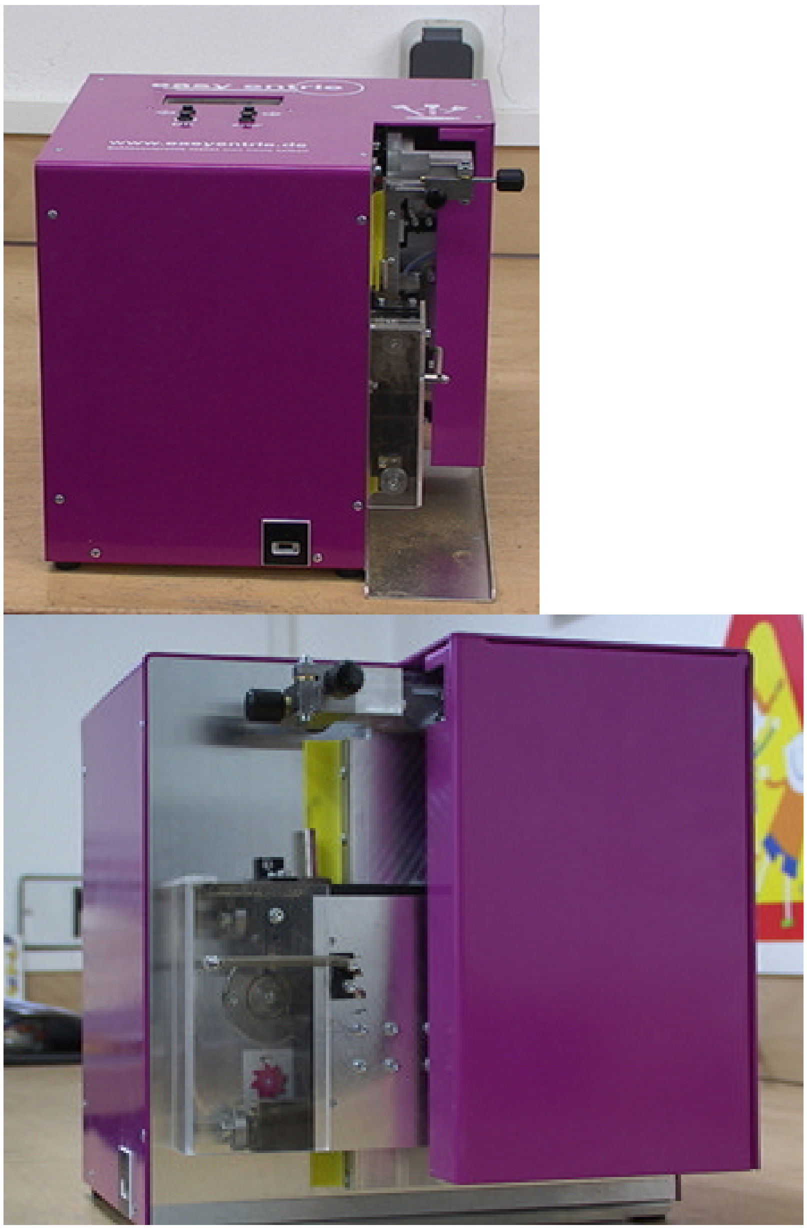


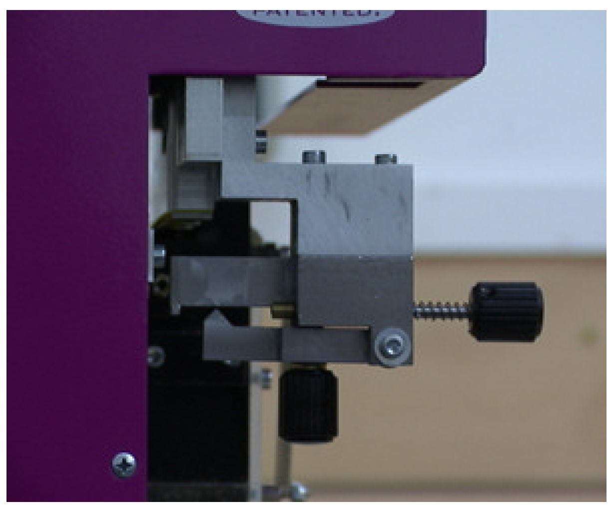
Figure LSS+830 Easy entrie profile milling machine

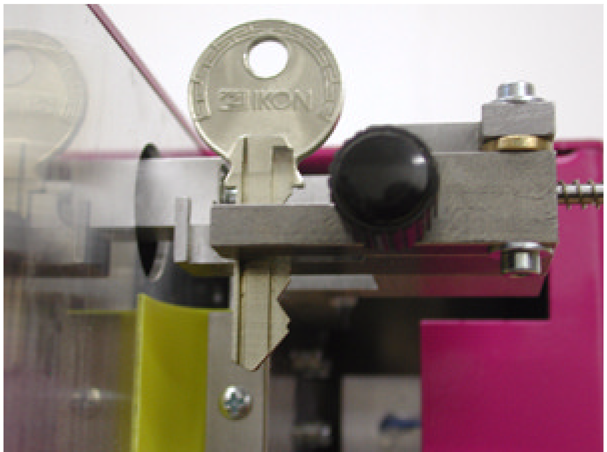
8_3.4.1.1 Overview of the Process

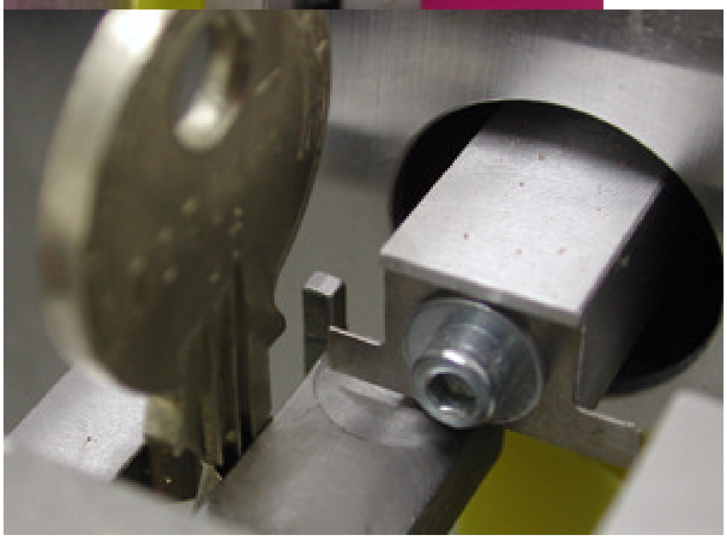
The Easy entrie milling machine is not a key duplicator, but rather a sophisticated system that allows the copying of either a bitted or blank key sample to produce a new blank key with a ward profile that will pass the keyway. The machine will also duplicate some high security blanks that may be unavailable through normal channels. This feature may prove especially useful to covert government operations. As shown in the accompanying video, a two-step process is required in order to generate a blank key.

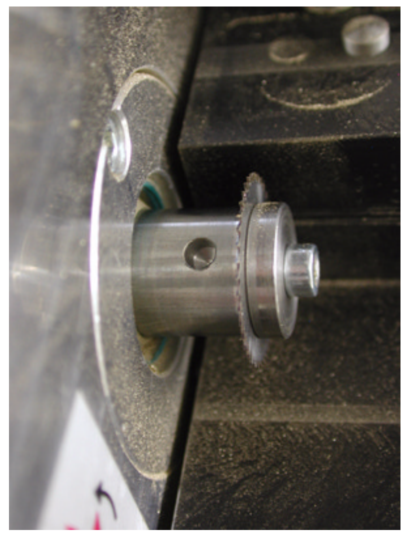
First, the sample key is measured with a mechanical probe. At the conclusion of the measurement process, the system specifies the correct blank that should be inserted for cutting. All supplied blanks from Easy entrie are the same length, but of different thickness. Each is identified with a unique blank number. The proper blank is selected and inserted. The computer-controlled mill then produces the profile. Once this process is completed, the blank is removed and the end is trimmed to the proper angles for insertion into the keyway. The bitting values are then duplicated on the blank key that has thus been produced using a regular key cutter. The cost to replicate a key blank on the Easy entrie is under two dollars, considering the cost of blanks and life of the cutting wheel (about fifty generations). The machine is portable and operates on 24 VDC.






IKON





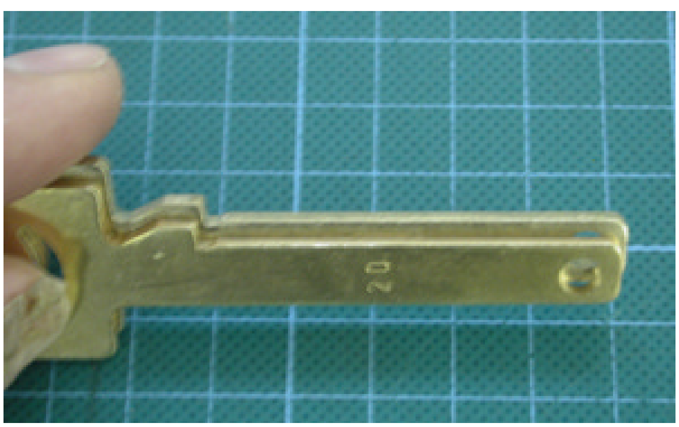




Figure LSS+831 The source key is measured mechanically with a thin probe. The correct Easy entrie blank key is then inserted into the cutting area and milled. There are at least five different blank thicknesses that are available.

As shown in the photographs above, the source key is inserted into a special holding vice that allows it to be read on both sides in one operation. At the conclusion of the measurement process, the on-board computer determines the correct blank and provides that information on a liquid crystal display. A detailed instruction manual is available as an Adobe PDF and is provided here.

8_3.4.1.2 Capabilities of the Easy entrie Milling Machine

The Easy entrie milling machine has a number of capabilities and limitations. These are summarized below.

- **The Easy entrie is not a key duplicating machine; it will not copy bittings or side millings;**
- **A blank can only be created from a source key, unless the enhanced software package has been obtained. Profiles can also be generated from data that has been previously stored within a database (if the machine is linked to a computer), or from a digital image;**
- **Measurements may be made from either the original key or from a copy that has been obtained through the use of a silicone impression and low temperature metal casting;**
- **Certain restricted or unavailable blanks can be replicated;**
- **A blank can be produced from a cut (bitted) key;**

- **All conventional blanks can be precisely replicated if they are less than 3 mm in thickness. In the future, a blank of up to 5 mm can be measured;**
- **Only the first 1/8" of the key will be sampled; the entire surface of the key is not measured. Any variances in the longitudinal surface of the key will not be replicated. NOTE: A sample key may be inserted at different positions for special applications. For example, a deep groove by the shoulder or other irregularities may prevent the source key from being inserted or read in the normal fashion. In such instance, the key can be seated as shown. Be sure that an area is selected that replicates the full bitting area of the blank. The index pin is equal to the sample are of the key. Also, be certain that there are no holes or irregularities in the sampled area;**
- **Side millings and unique bitting designs cannot be copied. Thus, Abloy, Assa, Schlage Primus, Medeco M3, Everest, lasertrack and other specialized blanks cannot be replicated. Note that in certain instances, blanks that are greater than 3 mm in thickness can be replicated by milling the sample area to less than 3 mm, as shown;**
- **Dimple keys cannot be replicated;**
- **Double and triple-bitted blanks cannot generally be produced;**
- **Extra thick blanks, such as Medeco M3 and Best, cannot be duplicated at this time;**
- **The replication of ward patterns is approximate and is calculated to pass through the keyway, but is not exact with respect to the source key. Precise angles are not reproduced;**
- **The duplication of sectional keyways may allow the reproduced blank to enter several different sectional families, based upon the measurement process of the Easy entrie;**
- **Blanks that are produced by the Easy entrie must be trimmed when cut in a key machine;**
- **All blanks that are produced by the Easy entrie must be cut on a standard key cutting machine;**
- **Certain profiles may require different holding techniques in order that the key be seated properly for measurement;**
- **Generally, only the front portch of the key can be sampled accurately. Unfortunately, different sections of the key may not seat properly in the holding vice;**
- **The Easy entrie can be used to measure a soft metal key that was produced by silicone impressioning;**
- **A blank key can be created from a sample that has bittings**

already present. Thus, a cut key can be utilized to generate a blank during the extrapolation of a top level master key, described in chapter 31;

- **The Easy entrie cannot mill portions of a key; it will reproduce the entire longitudinal surface based upon the sampled area of the source key;**
- **All standard lengths and thicknesses of blanks can be replicated. Non standard keys and profiles that are too thick cannot be copied;**
- **The normal Easy entrie machine will not store profiles for later reference without special software;**
- **Once a key is measured, it will allow any number of duplicates to be produced, but the parameters cannot be saved for later generation without special software;**
- **There is no method to modify the way in which the key is milled, unless the special software package is obtained. See the detailed description that follows;**
- **The length of the source key is not relevant; all blanks are supplied in standard dimensions;**
- **Keys with extra wide wards will not seat properly in the holding vice and cannot be accurately copied. Everest is an excellent example;**
- **An external power supply is required to convert mains power to 24 VDC. These are readily available;**
- **The Easy entrie may be operated in a mobile environment with an inverter that is capable of handling a 75 watt load;**
- **There is no bottom-stop or shoulder on the blanks that are supplied by Easy entrie. Thus, care must be exercised if a Pack-a-Punch or similar cutter is employed because there is no way to precisely index the blank;**
- **The design of the cutting mill only allows lateral cuts to be made across the entire surface of the key. No deviations with regard to depth or width can be produced for a specific area of the profile;**
- **An exact replica of the keyway profile is not possible, due to the design of the cutitng mill. The internal program analyzes the keyway and computes the required angles to pass the wards within the keyway; The standard configuration machine is not capable of storing a profile after the required number of blanks have been generated;**
- **Special software is required if the user requires the ability to build a database of profiles;**

- **Additional equipment that is required when using the Easy entrie includes a key cutting machine and a method to trim the end of the blank;**
- **Certain keys may be difficult to firmly lock into position for measurement, due to the design of the keyway.**

8_3.4.1.3 Legal Issues

There can be legal issues that may result from the use of the Easy entrie machine. Specifically, United States and foreign patent laws may protect certain blanks from being duplicated. Issues that may arise include infringement and contributory infringement of a patent. Such action may constitute a federal offense and could subject the offender to civil and criminal penalties. However, this machine does not precisely replicate the contours of a key because of the design of the cutting wheel and the computation of angles when it measures the ward pattern on the source key. If the primary purpose or use of the Easy entrie is to copy or replicate blanks that are protected by patent or to use the machine as a first step to duplicate such blanks, then you may be subjected to liability for doing so.

A number of interesting legal questions are raised with the capabilities of the Easy entrie. These include:

- **Can a specific keyway be protected, notwithstanding the Best v. Ilco decision;**
- **If a keyway is protected, must it be exactly duplicated in order to come within the protection of the patent;**
- **Can a key profile be copyrighted;**
- **Can patent protection be extended to encompass any device, including a replicated blank, that will operate the mechanism;**
- **If a copy of a patented key is made for a customer, does the customer actually own the key, or does he have a license to utilize it in a protected keyway;**
- **Would a simulation of a patented key that can enter a protected keyway be considered a substantial copy and could it come under the protection of the patent;**
- **Can the bitting patter be protected by copyright. If so, can the copying of such key constitute a copyright violation;**
- **Can the bitting values of a master key system be copyrighted;**
- **If the Easy entrie is utilized to replicate a portion of a**

patented key, and another machine such as the Keyway King is utilized to copy the side millings, can both of these machines be seized for infringement of a patent;

- **If the profile is replicated on an Easy entrie, but the blank so produced will not work in the lock without additional milling, can the operator of the Easy entrie be held liable.**

8_3.4.1.4 Producing Blanks From a Source Key

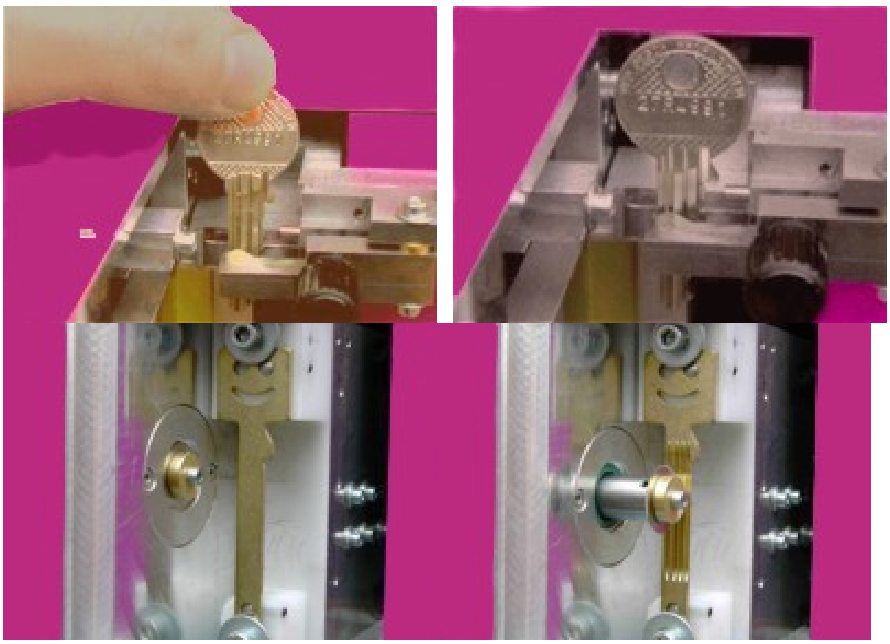


Figure LSS+832 Production of a blank key is straightforward and occurs in two stages. The source key is measured, then removed from the clamp. The correct Rholex is inserted into the milling head and is automatically cut on both surfaces. The finished product is then trimmed and inserted into a key cutting machine, or utilized for impressioning.

The Easy entrie profile milling machine consists of two primary components: measuring and milling. A measuring unit employs a thin shim to mechanically probe the countours of the source key in order to approximate its ward pattern. A milling unit cuts the computed profile into the "Rohlex" blank to fit into the keyway. The Easy entrie is constructed in an extremely compact case with a footprint of about one cubic foot (12" x 12"). Both the measuring and cutting system are self-calibrating. In addition, as the cutting mill loses material from wear, its ability to cut is computed as the profile is created to maintain proper tolerances.

A two-step process is required to replicate a key profile. After the machine is calibrated automatically upon power-up, the source key is inserted into the measuring unit. The system will then probe the key on both front and rear surfaces to measure the changes in the profile. The mechanical probe makes contact with the key and takes enough samples (fine or coarse mode) to insure adequate resolution to compute all required angles. The sample area is quite limited and consists of a very narrow vertical band just after the shoulder. Normal placement of the key assumes that there is a "front porch" that is devoid of bitting, and thus equal to a no-cut condition. The blank can be positioned and clamped at different vertical points if the sample area will not yield the full blade of the key.

Scanning of the source key is accomplished automatically. When completed, the operator is instructed to remove the key. The thickness of the blade is shown on the display, together with the required rholex that is needed for milling. The measurement is stored within short- term memory in order to allow for the generation of blank keys by the mill. The "Rholex" (special blank) of the correct thickness is locked into the mill. The three holes in the key are indexed to protruding pins that precisely link the blank to the cutting head.

The operator is prompted to begin the process. The measured profile will be cut into the Rohlex with a micro milling tool. Both sides of the Rohlex will be milled in sequence, during one operation, thus producing a high precision key blank that will fit its keyway.



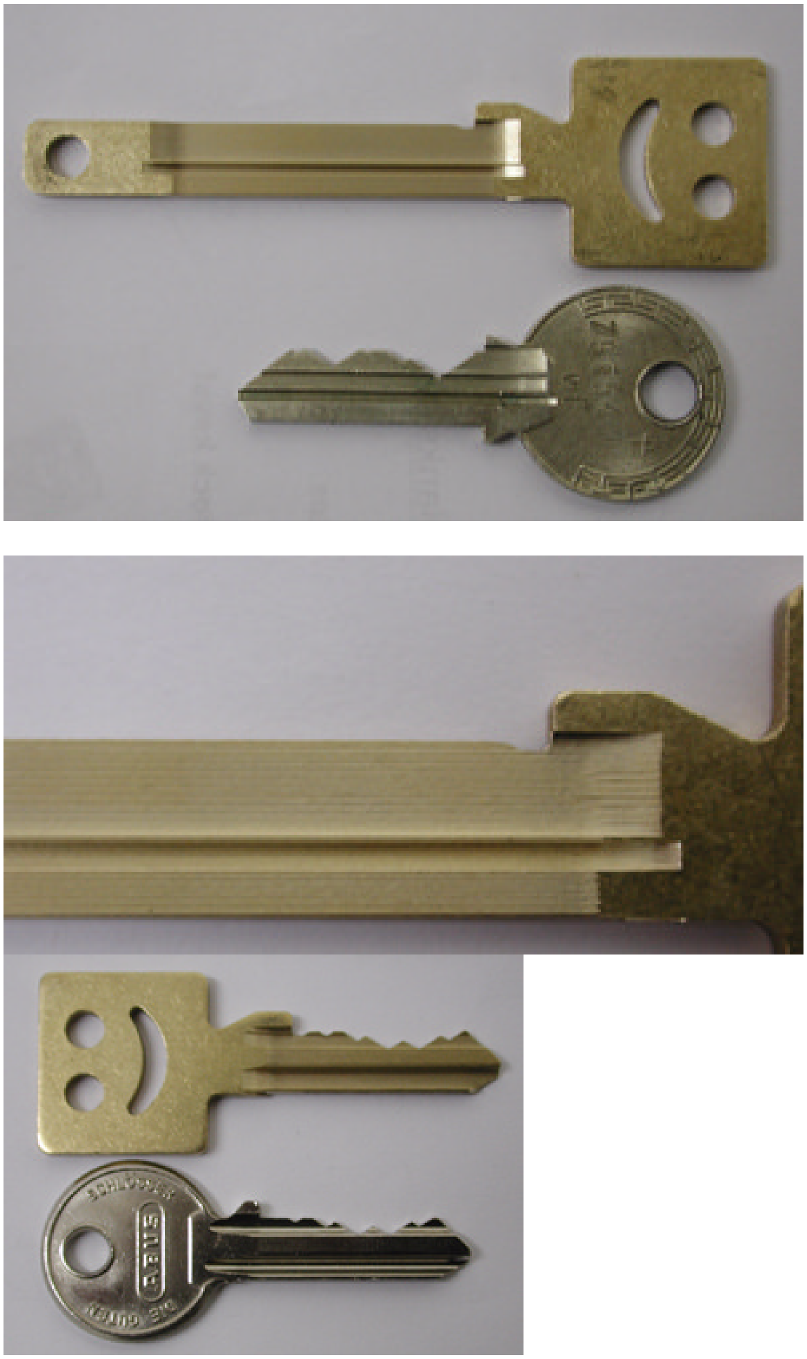


**Figure LSS+833 The milled blank is not an exact replica of the source key, but will
pass the wards within the keyway.**

The operation of the machine can be set for either coarse or fine resolution of the profile. Depending upon the exactness required, the machine will take fewer or a greater number of measurements

in order to analyze the keyway.

8_3.4.1.4.1 Detailed Operating Instructions and Cautions

Detailed operating instructions, as provided by the manufacturer and edited by the author have been included here in Adobe Acrobat format.

Easy entrie Operating Instructions

8_3.4.1.5 Producing Blank Keys from Digital Images

The Easy entrie is a necessity for special operations units that require the capability to produce a wide variety of blank keys for target locks in the field. Often, there is no advanced information that will identify the lock or the keyway profile that must be bypassed. The software has been developed to allow mapping of the keyway in order to guide the cutting wheel. Information regarding the profile can be generated from a photograph, an impression of the keyway, from measurements made from a source key by the normal process using the Easy entrie and stored within a database for later use, or by other means that would include the use of a fine wire pack to reconstruct the open spaces of the keyway to allow the production of its reverse image. This could then be photographed and input into the Easy entrie software. The Easy entrie PC software is available through **LSS+** so that the reader may utilize or evaluate it.

The Easy entrie software provides for certain enhanced capabilities that are not available with the standard machine configuration. These include:

- **One or more blanks can be produced from a photograph of the keyway;**
- **Blanks can be produced from information stored in a database or from a photograph directly, or after modification of the image;**
- **A source key can be measured and the information transferred to the database in the computer for storage and later generation;**
- **No information is required regarding the target lock in order**

to produce a profile that will pass the wards. Note: although the blank may enter the keyway, unless information is obtained regarding the mechanism, the produced blank may not be able to operate properly. This would be true, for example, in the case of the Schlage Everest and the Medeco M3;

- **The software will only allow conventional profiles to be replicated on two surfaces of the key;**
- **All of the restrictions regarding the measurement of a source key by the Easy entrie probe will apply to the use of a photograph. The digital mapping software replaces the measurement process but does not affect the operation of the milling hardware;**
- **The profile for the target lock can be modified prior to milling. A profile can be altered to:**
  - **fit a different section;**
  - **thin the blade to make impressioning easier;**
  - **longitudinal sections of the profile can be widened to allow more vertical movement to make impressioning marks more pronounced;**
- **The entire profile can be made thicker or thinner;**
- **Stored samples can be modified and saved for any number of configurations;**
- **Multiple copies of a key can be stored and generated;**
- **Profiles can be stored within a database for reference and can be e-mailed to other locations;**

There are certain software requirements and limitations. These include:

- **The Easy entrie PC software will only run on Windows operating systems;**
- **The Easy entrie PC software requires an RS232 serial connection on the computer. Most of the new notebook computers only provide a USB interface. In the event that the computer only has a USB connection, then a port adapter from serial to USB must be utilized;**

The software can be run without the Easy entrie machine connected to the computer. Thus, a remote facility can process the image and then transmit a profile back to the field for the production of the blank;

- **A security code is provided for each machine. It will not function for any other Easy entrie unit;**

8_3.4.1.5.1 Digital Imaging Requirements

A digital image must be provided that defines the outline of the keyway in sufficient detail to be mapped in the Easy entrie software. The author utilizes a Nikon Coolpix 990 camera, although many other models will suffice. Any camera with a macro capability is acceptable. The Nikon seems to out perform other models tested by the author and produces an extremely sharp macro image with excellent illumination characteristics. There is no special requirement as to resolution, and the pixel count of the camera is largely irrelevant. The diameter of the plug must be provided in order to reference its size for the software to properly compute its dimensions. The software can only process an image in jpeg format. The author utilizes Adobe Photoshop for image sizing and manipulation, but other image editing software will suffice.

There are certain guidelines for taking and editing images for the Easy entrie:

- **Shoot the photograph of the cylinder without the use of a flash, unless a ring strobe and macro lens is available;**
- **Be sure that the angle of the lens is perpendicular to the keyway to avoid distortion, parallax error and depth of field errors;**
- **Transfer the image to a program that allows editing, such as Adobe Photoshop, Photo-Paint, or Paint-Shop. A simple image editor is contained in all Windows programs. Go to ACCESSORIES + PAINT;**
- **Crop the photograph. Be certain that the outer diameter is visible, as shown in the photograph;**
- **Save the image as a Jpg file;**
- **The image can be saed into any subdirectory, although the default is "C:\Program Files\EasyEntriePc\ZylinderFotos" .**

8_3.4.1.5.2 Producing a Blank Key from a Digital Image: An Overview

The detailed instructions from Easy entrie have been included in this documentation, together with a video demonstration by the author. The software provides for the following capabilities:

- **Storage of data from source keys that have been measured by the Easy entrie in normal operation. This feature allows profile information to be retained for later generation;**
- **Manipulation of profiles to modify bullet patterns on the key or its thickness. This feature can allow the modification of a sectional profile, for example, in order that a different sectional family be accessed;**
- **Generation of a blank key from the original or modified photograph of the keyway;**

The following description provides an overview of the process.

The information for a previously measured key can be retrieved from the database and a blank can be generated, or a photograph of a keyway can be input into the system, calibrated, mapped, modified if necessary, and a key can be produced. The process is very simple and does not require any special expertise. Essentially, Easy entrie has provided for the storage of measurement data from a source key to allow for blanks to be generated as required. The software also provides a link between the mapped outline of an image and the cutting mill.

The system does not actually evaluate a photograph and determine its profile. Rather, it relies upon the operator to supply an accurate outline of the keyway. This is easily accomplished, using a cursor that is positioned to draw linear segments of the keyway, as shown. The drawing can be edited as required for a particular keyway. The finsihed map is stored within a database, and allows for the generation of blanks. The mapped image can also be modified as needed, and can be transmitted between computers for replication of blanks at remote locations. The data base file is contained in **C:\Program files|easyentriePC\profildaten\Profile.eep**. This file can be sent by email, if required.

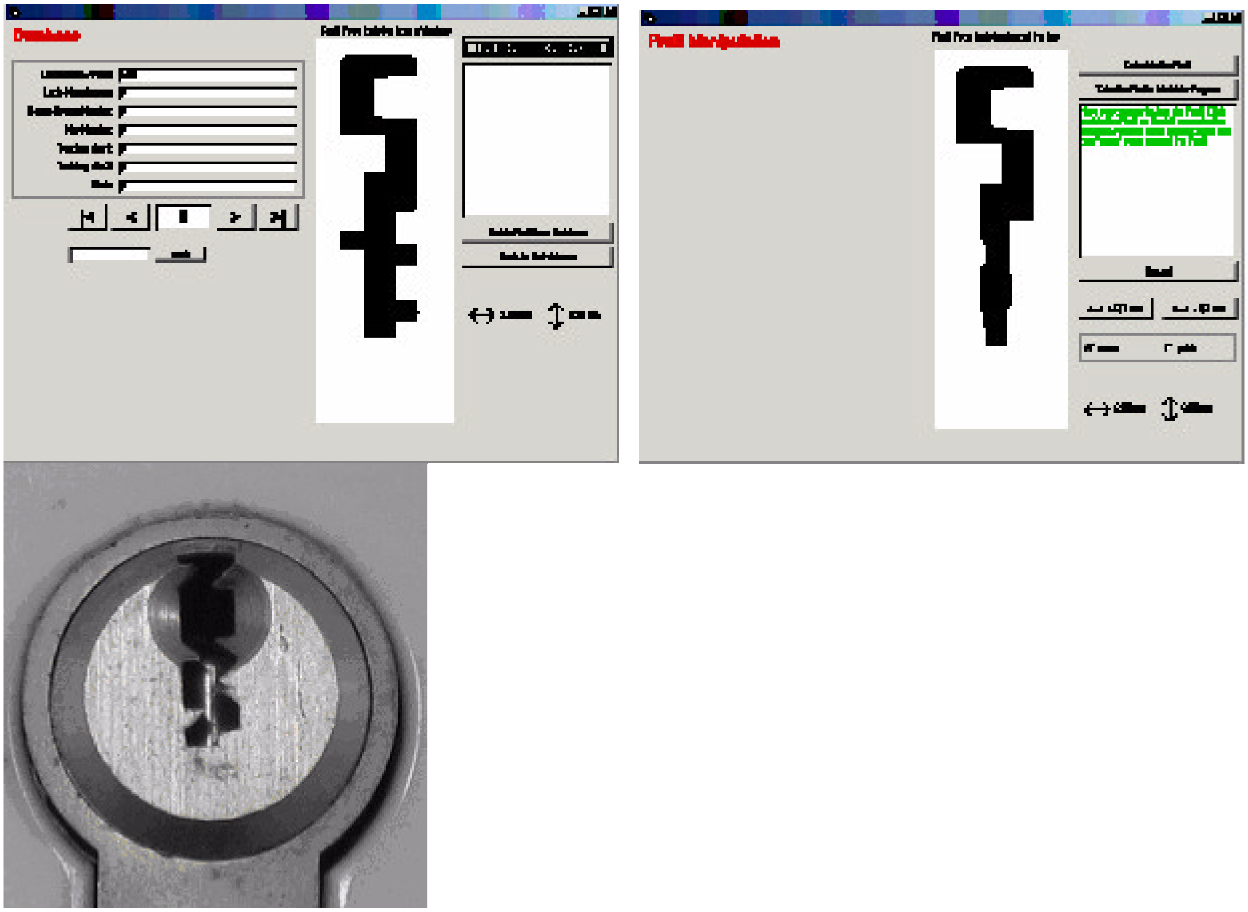
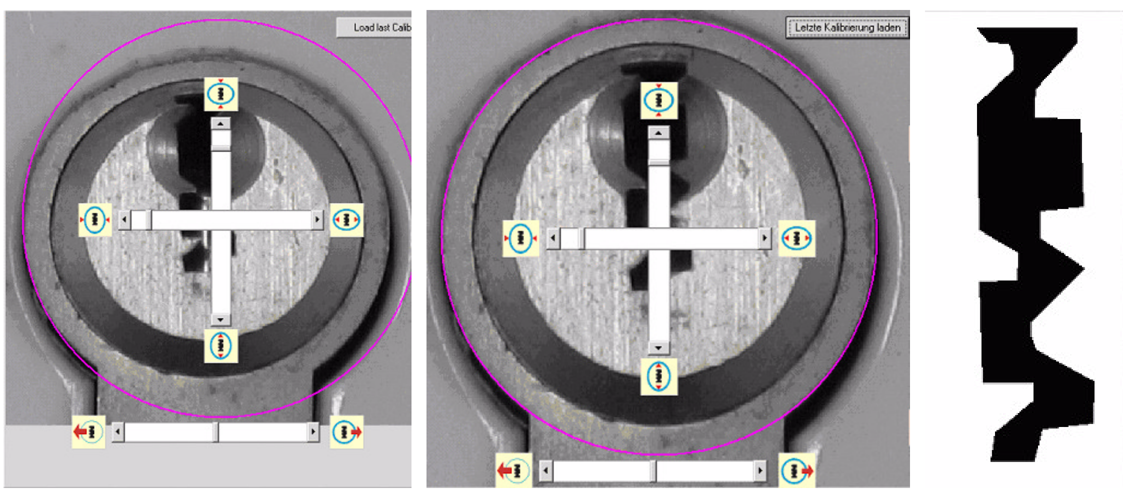


Figure LSS+834 A blank can be generated from stored information in a database, or produced from a photograph.
The software allows for retrieval of a profile and its modification.



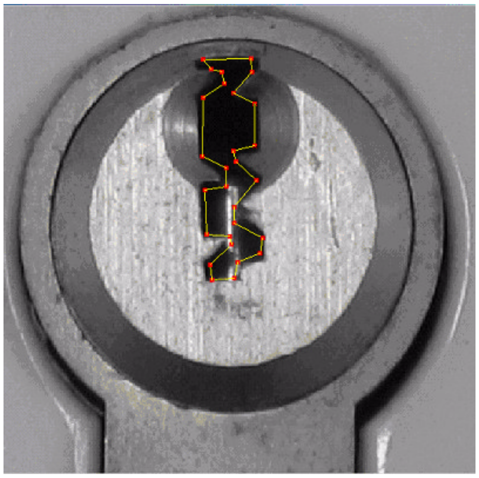


**Figure LSS+835 The edited image is centered within the circle (pink) which has been referenced
to the diameter of the plug in the target cylinder. The keyway is then mapped.**

8_3.4.1.5.3 Detailed Procedure to Generate a Profile

A precise replica of almost any conventional blank can be produced from a digital image. The Schlage Everest is a very difficult blank to reproduce, due to its patented undercut. It will be utilized here as an example of the capabilities of the Easy entrie. The reader is cautioned that replication of this blank may constitute patent infringement. The author does not recommend or encourage the practice except for government operations. Note that the image must be imported into the Easy entrie program as inverted, with the base of the keyway on top. This conforms to the European profile mounting configuration.

Easy entrie PC Software operating instructions

8_3.5 Keyway King Profile Milling Machine

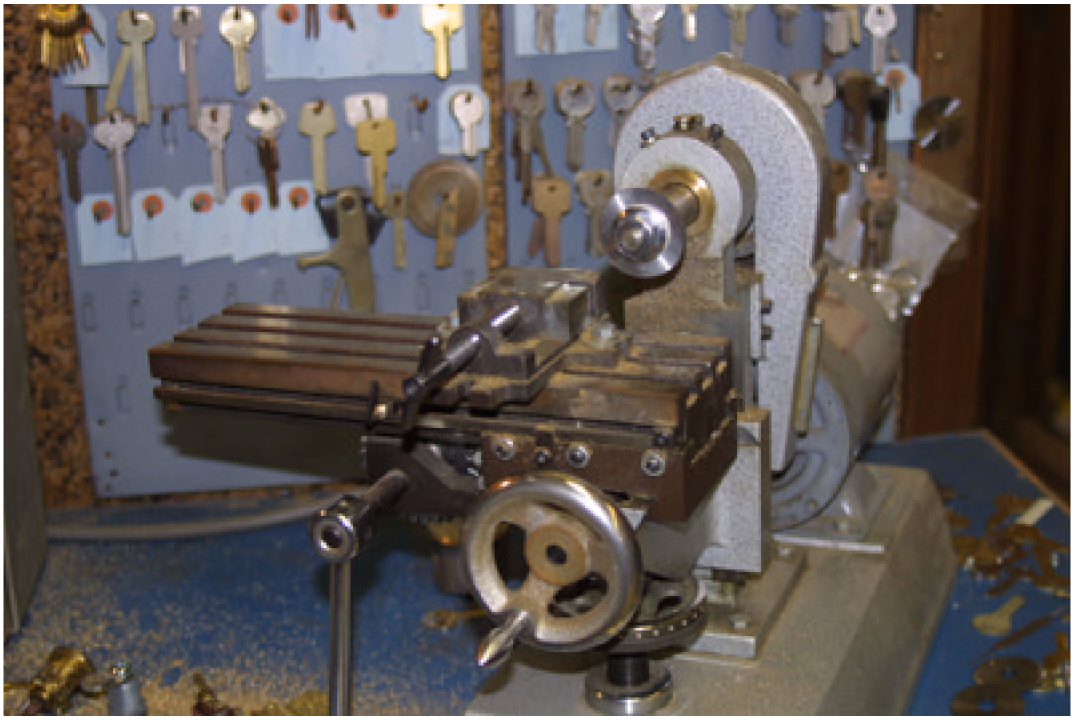


Figure LSS+836 The Keyway King is a milling machine that operates in three planes.

The Keyway King is a machine that allows milling to be accomplished on the X, Y, and Z axis. It is extremely useful for replicating restricted or unavailable blanks, and can be used to create millings on keys that are produced by the Easy entrie. The Keyway King is distributed by DiMark International in the United States. Its use requires a great deal more time, skill, and precision than does the Easy entrie, but it can produce complex key profiles by the use of different **cutting wheels**, shown below. A diagram, showing sixteen factory supplied cutting wheels, is shown in the link.

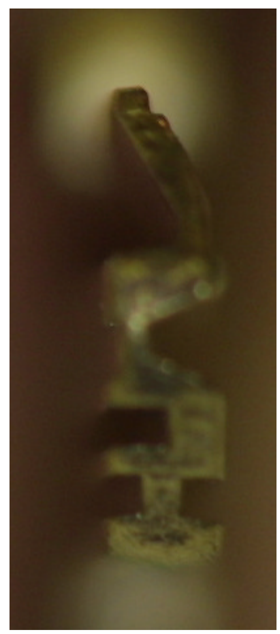


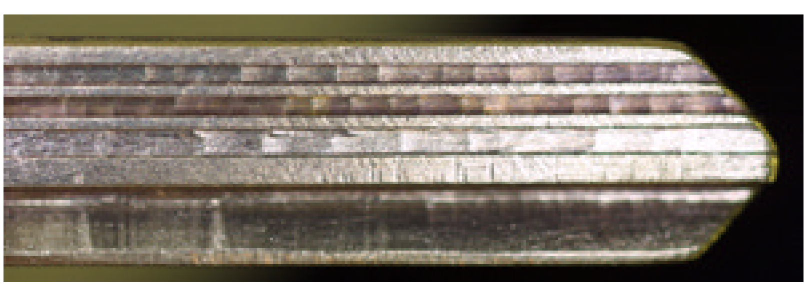
Figure LSS+837 Different cutting wheels are available for the Keyway King.

The process to produce a key is quite a bit more complicated than with the Easy entrie. It requires a visual analysis of a keyway. Lateral milling of a block of metal is accomplished to approximate the wards in the plug. It is a process of experimentation and attempting to closely match the millings with the bullets in the keyway. One feature of the Keyway King is the ability to produce several "blanks" with the same milling, as the key is "built." The vice allows rapid removal of a key and insertion of another. The photographs show two locks for which keys have been produced, at various stages in the milling process.


WINK
HAUS







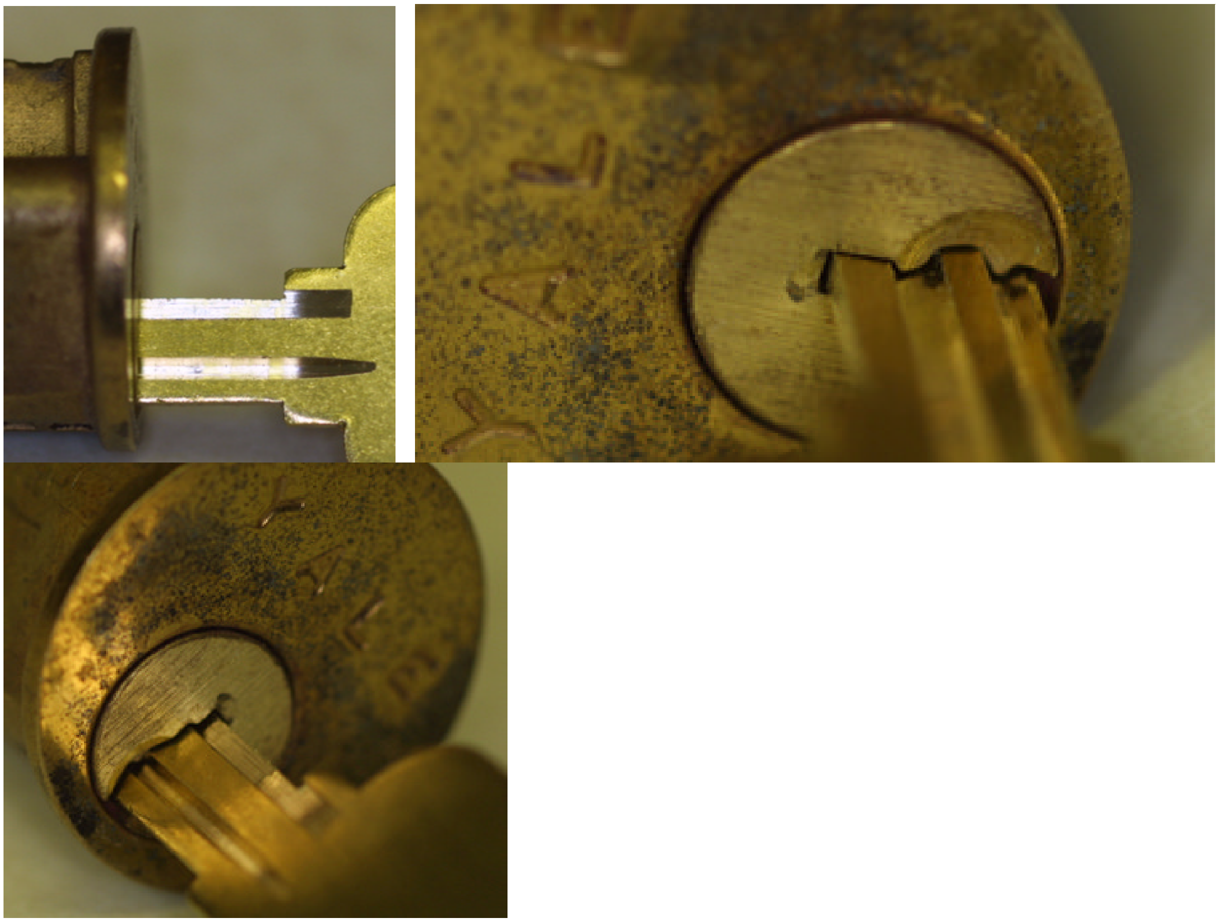


Figure LSS+838 Examples of two profiles that have been reproduced by the Keyway King milling machine.

LSS204: Demonstration of the Keyway King, by Greg Brandt

8_4.0 Key Coding

8_4.1 Introduction

All lever, wafer, disc, and pin tumbler keys are coded in some scheme by the lock manufacturer. Coding accomplishes several functions:

- **Facilitate and organize production;**
- **Properly meet customer needs;**

- **Provide complex master key systems;**
- **Inventory control;**
- **Security.**

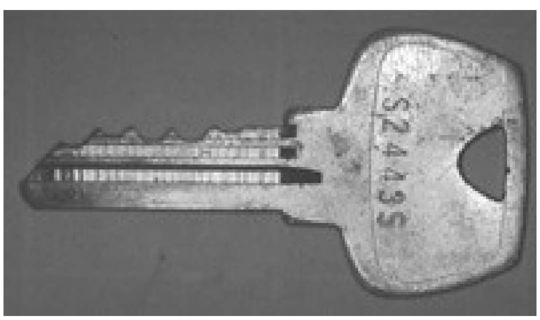
The establishment of a coding scheme relates to each specific lock and keyway in a product line. Each manufacturer has established standard lever, pin, or wafer lengths, as well as pin diameters for each chamber (in the case of pin tumbler locks). The spacing between detainers is also precisely defined.

8_4.2 Code Numbers on Keys

A manufacturer will generally stamp code numbers on hey heads that will either be **direct** or **indirect** reading. Many years ago, for example, General Motors stamped indirect codes on their keys. These four-digit numbers could be easily read by anyone handling the key, such as parking lot attendants. It was a simple matter to then have a duplicate key cut from this code.

A federal law was then enacted that required the code to be stamped on a knockout in order to stop the improper acquisition of codes and resulting automobile theft. The knockouts had to be removed before the keys could be carried on a ring. Some manufacturers will also stamp code numbers on the lock bodies. This practice is especially prevalent in automobile locks and padlocks.

In the photograph below, a **direct code** is stamped on the head of the key. With this number, a duplicate can be generated. Note the correlation between the depth of each cut and the corresponding digit. The code is read from the bow to the tip.



LSS+804 An example of a factory original key with a direct reading code.

8_4.3 Keys from Codes

Keys can be produced from codes, courtesy of Harry Sher.

LSS205: Gale Johnson on key codes

Once a coding scheme is established, both the manufacturer and locksmiths can produce keys by code for any given lock. Silca, HPC, and others have collected all of this coding information and established sophisticated and complete databases. This information allows keys to be generated on their machines as if factory originals. The HPC CodeMax and the SILCA QUATTROCODE has these databases built into the cutter, so all the user has to do is input the type of key and direct code. The machines will do a lookup retrieve all the needed spacing and depth information and generates a key.

All depth coding on keys produced by the manufacturer will initially be in direct readable form. Each different depth will have a number assigned to it that will correspond to the actual measured depth of the cut. For example, Schlage may establish for a specific keyway the following depth correlation for bottom and top tumblers:

DEPTH CODING OF KEYS		
TUMBLER	**BOTTOM**	**TOP**
0	165	
1	180	
2	195	30
3	210	45
4	225	60
5	240	75
6	255	90
7	270	105
8	285	120
9	300	135

If the bitting is measured from either the top or bottom of the key, depending upon manufacturer, each different depth will equal precisely the vertical distance assigned to a specific depth number. In this manner, keys may be manually decoded.

The factory either will utilize the actual depth numbers for coding keys or will correlate them to unrelated indirect codes. In the Schlage example, it will be noted that each depth has a difference of .150", and those depth cuts (2-9) allow for compensation in length of the top tumbler (called balancing). This is to permit both top and bottom pins to move vertically within each chamber.

8_4.4 Direct Coding

Direct coding means that the code will correspond exactly with the number of tumbler positions and their respective depths. A wafer lock, for example, may be coded by the manufacturer in the following way. The lock maker first decides there will be five different tumbler depths, each having an increment of 0.02”. Numbers are then assigned to each different depth level. A "1" cut would be 0.02” from the top of the key bitting area, a "2" cut would be 0.04”, and so on, to the number "5" cut, which would have a depth of 0.10”.

A code number will then be assigned for each key, which will in fact be the composite of all of the tumbler depths. With the direct code, it is possible to generate the key by use of the composite code number, using code machine or depth keys. Keys may also carry a code designation that is indirectly coded. This means that there is no easily recognizable relationship between the direct code number, to which the key was actually cut by the manufacturer, and the indirect code number that is assigned to the key. When indirect codes are encountered, the correct reference must be consulted to determine the actual direct code for cutting the key.

8_4.5 Depth Keys

Depth keys are available for every lock and can be used in two different ways for producing duplicates.

8_4.5.1 Depth and Spacing

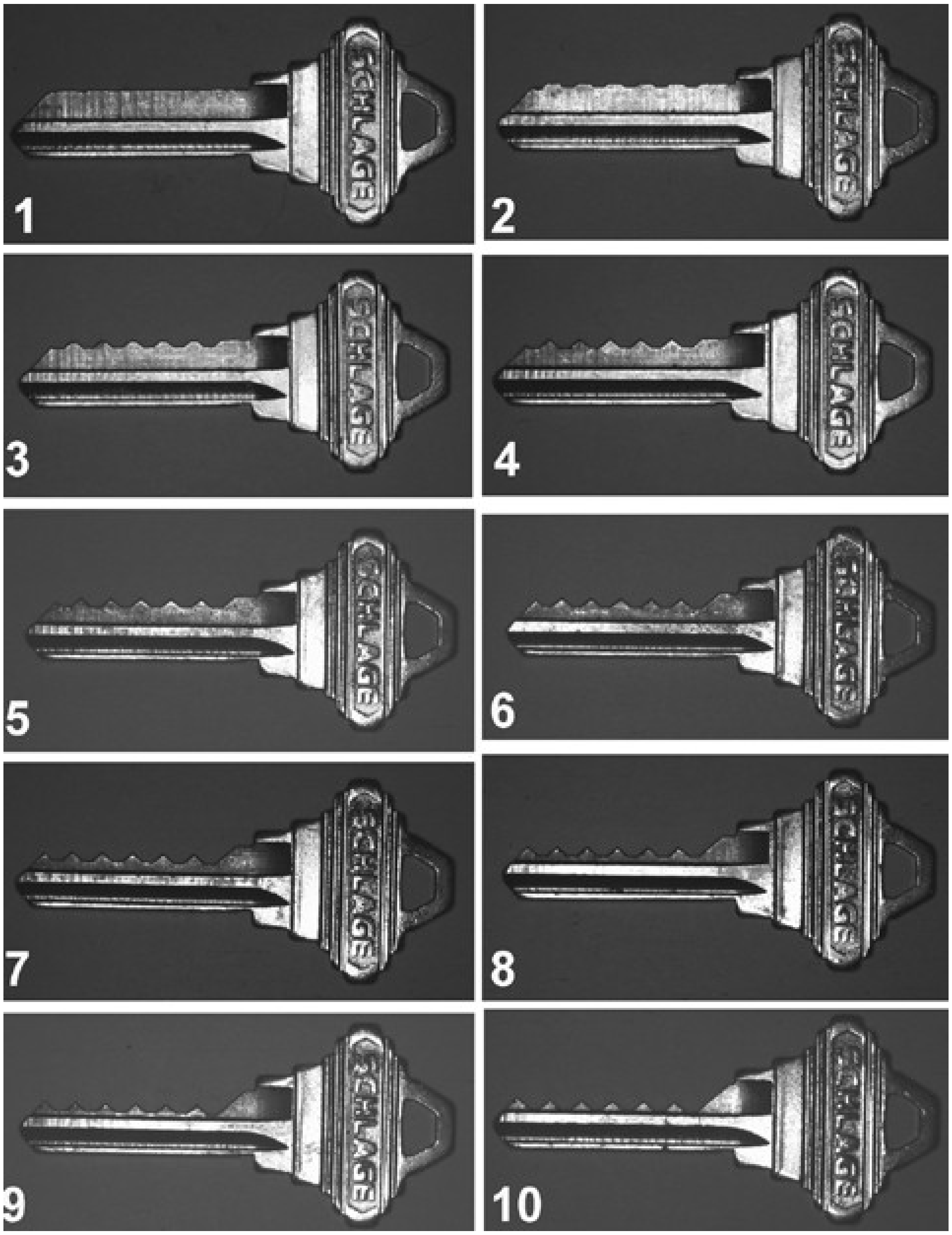
Source keys can be directly decoded, using a set of depth keys as a reference. This procedure requires that each tumbler position on the source key be compared with a set of depth keys having all depth and space variations for a particular lock. The keys are analyzed until the correct depth for each particular tumbler cut of the source key is determined. The resulting derived code can

be used to cut another key by hand or using a machine.

8_4.5.2 Depth Keys as a Reference

Duplicates can also be made by using depth keys, rather than code machines, as a primary reference. Depth keys are specially cut to provide a reference for each of the different tumbler depths and spacing. Thus, a set of keys for a Schlage lock having a total of eight possible depths and six tumbler positions, would be comprised of a set of eight keys. Each key would have six tumbler positions, all cut to one depth. Thus, the first key would be cut to a direct code of 111111; the second key, 222222, and so on.

To use depth keys, determine the direct code for the target key, then substitute the proper depth key for each tumbler position to be cut. If keys are to be made by hand, each position is filed until it corresponds to the proper depth as determined from the depth key.



8_4.5.2.1 Code-Cutting Machine

The information provided by depth keys is programmed into the code-cutting machine. Bitting material is then removed to the required depth for each tumbler position.

8_5.0 Producing Keys from Code

Information

8_5.1 Introduction

In order to cut a key for a specific lock, certain information must be obtained usually directly from the source key:

- **Manufacturer of the lock;**
- **Type of lock;**
- **Blank number or type;**
- **Number of cuts.**

There are, however, instances where the source key may not be available. The information can still be obtained through other means. Circumstances that may dictate obtaining information to allow the generation of a key from alternative sources might include:

- **Keys have been lost;**
- **Keys have been improperly obtained and copied utilizing various decoding techniques;**
- **Locks have been taken apart and decoded;**
- **Law enforcement or intelligence operations requiring repeated surreptitious entry.**

Keys can be made from a source key with a cutter, or information can be obtained from or about the key while in the possession of the holder. A key can then be generated later under more secure or controlled circumstances. Keys can also be produced as a result of information obtained from the lock.

8_5.2 Depth and Space Information

Ultimately, depth and spacing information is needed to make a key. This data, for any specific key and lock, is available from a variety of sources. Once that data has been obtained, it is a relatively simple matter to produce the key, either manually by hand cutting or through the use of mechanical, electric, or computer-controlled key cutters described above.

Methods of obtaining coding information are of primary interest to criminal investigators, crime lab, intelligence, and security personnel. The information can be utilized both for operational

use and as a starting point in analyzing burglaries or surreptitious entry, or the potential vulnerability of such attack by unauthorized individuals.

8_5.2.1 Sources and Methods for Obtaining Key Coding Information

Procedures relating to decoding keys will be detailed in this section, but related information regarding the use of keys as lock picks and other relevant topics regarding keys and surreptitious entry will be found in **Chapter 29.** All applicable techniques can be accomplished rapidly, quietly, and surreptitiously.

There are many sources and methods for obtaining depth and spacing information. These include:

- **Keys visually decoded, then reproduced;**
- **Keys measured utilizing a special micrometer, the measurements translated to depth codes, then cut by code-cutting machine;**
- **Code lists kept on premises by the maintenance department;**
- **Code lists maintained by the local locksmith;**
- **Code lists accompanying invoices from lock manufacturers;**
- **Codes obtained from the factory;**
- **Professional code books produced by HPC, Reed, Silca, and other manufacturers;**
- **Codes stamped on source keys or locks;**
- **Codes obtained from the manufacturer in response to an inquiry regarding a specific lock. In this instance, fraudulent information may be provided to the vendor in order to secure the needed data or to order duplicate keys;**
- **Information retained by a manufacturer or dealer.**

The author, for example, routinely obtains the codes for motor vehicles that are to be seized as the result of drug use or other criminal activity by their owner. The procedure is quite simple. First, the vehicle identification number (VIN) is obtained through a listing by license number or registered owner. Then, a motor vehicle title search is performed to provide the chain of

title and, ultimately, the car dealer who originally sold the automobile. The dealer is then contacted for code information. If the dealer does not maintain such data, then the automobile manufacturer database is queried for the numbers. Once the codes are thus obtained, it is a simple matter to cut a key.

8_5.2.1.1 Keys Duplicated from a Source Key

Depending upon whether restricted blanks are utilized and the level of restriction, all but high-security keys may generally be duplicated without difficulty at locksmiths, hardware stores, gas stations, and many other retail establishments. Direct duplication requires that the source key be available to take to a cutting machine to make at least one copy. If there is a machine on premises, then the task becomes easier. Source keys can be borrowed, removed temporarily without permission, or stolen.

8_5.2.1.2 Keys Ordered from Manufacturer by Unauthorized Person

Keys may be ordered from the original manufacturer or from a local locksmith by submitting false authorization forms or letters to obtain duplicates. The locksmith will generally produce keys by code without verifying the authority of the requesting individual. Likewise, a manufacturer will often supply keys based upon letterhead requests. In any investigation involving access by keys, especially where high-security locks are installed, one source of information would be the lock supplier or installer regarding recent orders for duplicates.

8_5.2.1.3 Keys made by Visually Decoding the Lock or by Using a Depth Gauge

Locks may be visually decoded by looking into the plug and examining the position of each tumbler or by a depth gauge. Visual decoding is generally employed with wafer locks. Unlike the practice of actually disassembling the lock to obtain the required depth and spacing information, this procedure only requires proficiency in viewing and judging the tumbler positions through the keyway. A thorough explanation of the procedure is provided in **Chapter 31.**

8_5.2.1.4 Code Numbers, Books, and Lists

There are many sources for key coding information provided directly by the manufacturer, or taken from new keys and locks by locksmiths and then transmitted to code list vendors for compilation and publication. A number of companies produce comprehensive lists of key and combination codes for the locksmithing industry, both in printed and computer form. **HPC**, Reed, **Silca**, and a number of other vendors sell code books that encompass U.S. and foreign locks.



Figure LSS+823 HPC makes their codes available on handheld, laptop, or desktop computers. Shown is the HP720 handheld. Hewlett Packard produces one of the most sophisticated devices for this purpose. The HP720 is a 206 MHz. processor and allows the storage of more than 1 Gigabyte of data on removable PCMCIA cards.

8_5.2.1.5 Keys Made by Visual Inspection of a Source Key

Keys can be visually decoded and later reproduced. With knowledge of depth and spacing parameters for any given lock, it is generally a simple matter to visually inspect a key and derive the direct code for each tumbler. Depth keys or a code machine is then utilized to cut the key. Visual decoding requires that the source key had been cut by code originally, so that the bitting depths are precise.

8_5.2.1.6 Keys Made by Precise Micrometer Measurement

A micrometer, such as the **HPC SKM-2D**, or the HPC **KM-60** may be utilized to precisely measure each depth and spacing position of a source key. A duplicate can then be directly generated from this information, or the data may be correlated to direct codes and input to a code-cutting machine.

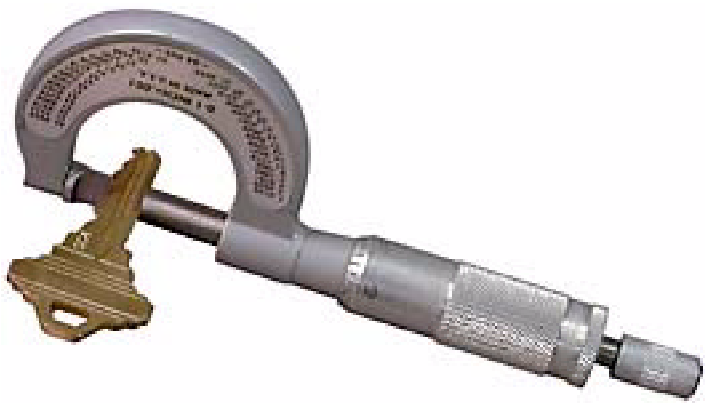
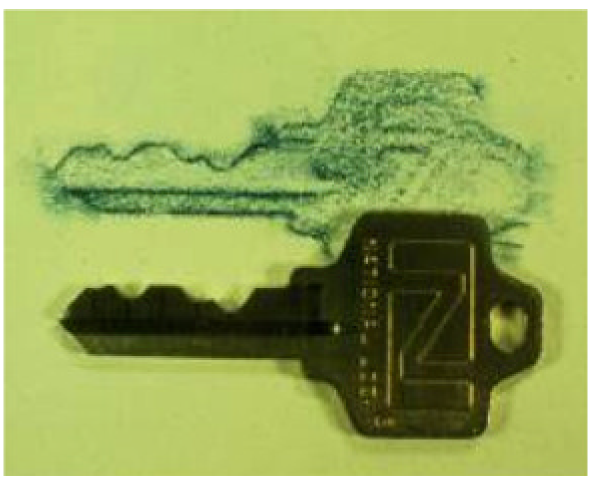
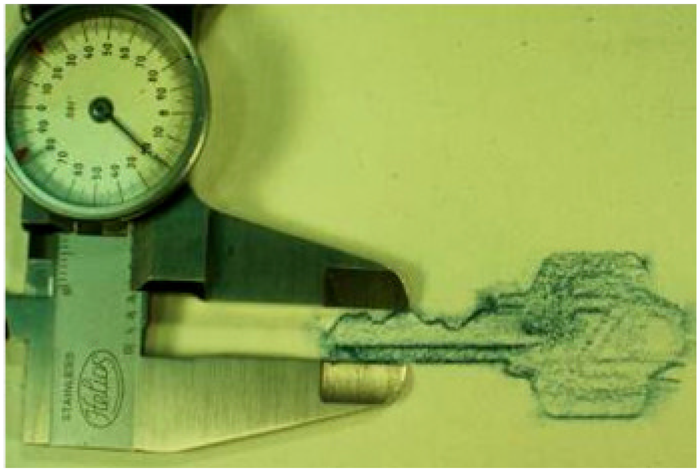


Figure LSS+824 The HPC KM-60 direct reading micrometer.

8_5.2.1.7 Keys Made by Photograph

Source keys can be photographed for an exact 1:1 reproduction. This will generally be accomplished using a macro lens and a finely graduated ruler placed alongside the source key for use as a reference. Likewise, keys may be traced, then measured or decoded. Keys may also be overlaid onto photographic paper and exposed for a precise outline, or placed in a 1:1 copy machine. In the photographs below, a key has been copied by the use of carbon paper, then decoded by measuring the 1:1 reproduction.





8_5.2.2 Keys that are Made by Taking Apart the Lock

Direct codes can be derived by disassembling the lock and examining each tumbler location. A correlation of each tumbler depth to a direct reading code is performed, then a key is cut to that code. The individual tumblers can be measured using a micrometer. Keys can also be made directly from the lock, once taken apart, by cutting the blank until all tumblers, wafers, discs, or levers are visually aligned at shear line.

8_5.2.2.1 Procedure to Produce the Key

A lock may be taken apart in order to produce a key directly from the tumblers. The procedure requires that each tumbler position first be marked on the surface of a blank key inserted into the plug. This will precisely indicate the correct spacing for each chamber. Cuts are then made into the bitting with the proper file for each tumbler. Material is removed until that tumbler is aligned exactly at shear line. Fitting keys to locks is more thoroughly explained later in this chapter.

A special note is required regarding the reproduction of keys for General Motors locks. When the glove compartment cylinder is taken apart in an effort to produce an ignition or door key, some experimentation is required. The glove box lock uses four wafer tumblers, in contrast to the six-wafer tumbler sidebar locks used everywhere else in the car. Thus, the last two tumblers must be determined by a progressive method until the correct combination is found. Since 1974, the ignition cylinder is keyed by itself. The door, trunk, and glove compartment locks are all keyed alike.

8_5.2.3 Keys Made by Impressioning a Lock

Keys can be generated by impressioning the lock. The procedure does not require disassembly and can often be accomplished quickly and without detection. Techniques for impressioning are covered in **Chapter 30**.

8_5.2.4 Keys Produced from Impression Material

Copies of keys can be made by the use of various impressioning materials, including Styrofoam, wax, clay, silicone rubber compounds, epoxy, and low-temperature ductile metals. The copying of keys by these materials should not be confused with the impressioning of locks that involve the production of a key from markings made by tumblers. Specific casting and impressioning techniques utilizing these materials are presented at the end of this chapter.

Impressioning can be accomplished quickly and in virtually any environment. The procedure will allow the copying of any key including restricted blanks. The resulting copy may be used to operate a lock directly, or a brass or nickel silver duplicate can be made. The Silca Quattrocode key machine will generate duplicate keys from impressioned keys using a laser scanner, thus insuring that no damage occurs to a "soft" duplicate.

8_5.2.5 Keys Made by Picking and then Decoding the Lock

Some locks may be picked to an unlocked position, then visually decoded for generating an original key. A borescope may also be used to look down the keyway of a picked plug to determine tumbler depths. In one investigation of surreptitious entry, the author was able to determine that a specific type of lock could be picked, then visually decoded. This would allow a thief to derive the master key combination from only one cylinder without the necessity of ever taking the lock apart.

8_5.2.5.1 Keys Made with a Pick/Decode Tool

Specialized pick tools will decode and display each tumbler using feelers as the tumbler is aligned and brought to shear line. Tubular lock picks in particular will usually allow the generation of a key.

8_5.2.6 Other Methods of Obtaining Code Data

Keys can be produced for warded and some lever locks by placing carbon or wax deposits on a blank key. It is then inserted to obtain markings of the tumblers. This technique is detailed in **Chapter 30.**

8_5.2.7 Keys Made by Feeling and Decoding the Tumbler Positions

In certain cases, keys can be generated through the use of special feeler picks or tools. These devices are inserted into a lock to feel the position, rotation, or depth of each tumbler. This technique has special application to Medeco sidebar and Abloy disc locks. It is discussed more fully in **Chapter 31.**

8_5.2.8 Keys Produced Using Foil Overlay for Dimple Locks

Certain dimple locks can be picked and impressioned utilizing aluminum or similar metal foil. Once the procedure is accomplished, the foil can be decoded and a key produced from the impressions left by the tumblers. The procedure for opening locks utilizing this technique is covered in detail in **Chapter 31.**

8_5.2.9 Master Key Generation

Master keys can be generated by a variety of methods, generally involving the taking apart of one or more locks. This process requires extreme caution and attention to detail during the disassembly procedure, because the orientation, sequence, and placement of each tumbler segment is critical. It is often necessary to take apart several locks to determine the correct master key code in a complex system. The principles of master key systems are detailed in **Chapter 11.** Once a cylinder is disassembled, one or more levels of master keying can be determined by an examination of the tumblers. In certain instances, however, it is not even necessary to open a lock in order to derive the code of the master key or change key. Cylinders may be shimmed and the splits of all pin stacks determined through the use of depth keys. Master key systems can be analyzed and the top level master key determined through a process described in chapter 31.

The author has conducted investigations in cases involving special types of cylinders where disassembly was not required to determine master key coding. In the case of certain magnetic based locking systems, the master key can be derived with little difficulty through the examination of several locks. The composite coding will provide the necessary information. In contrast, standard pin tumbler locks will not ordinarily yield master key coding data from an examination of individual change keys.

8_6.0 Making Copies of Source Keys by Impression

This section provides detailed information about how keys can be reproduced from molded impressions. **Chapter 30** explains the process of impressioning a lock to produce a key from **tumbler markings.** The two types of impressioning methods are quite different, yet they are employed to accomplish the same result: to produce a working key for a given lock.

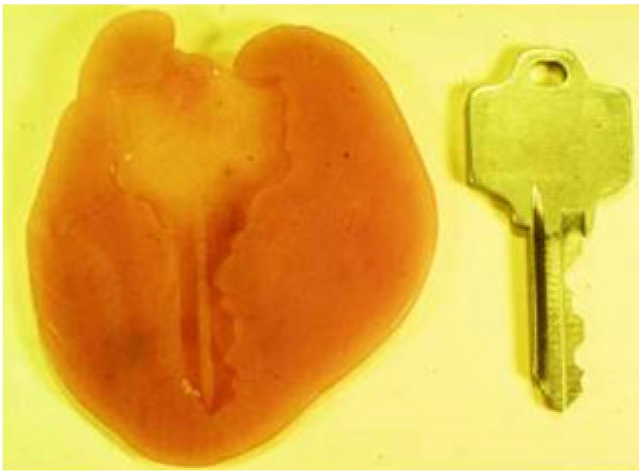
8_6.1 Introduction

Impressioning techniques were developed at least two hundred years ago by thieves for making secret copies of keys. The first documented major crimes occurred in Europe during the nineteenth century, using keys obtained by wax and clay copies. One of the most famous cases involved the theft, in the early 1800s, of a gold bullion shipment en route from England to France worth £12,000. The shipment was stolen in transit by the use of a key produced by impression to open a safe on a railroad car.

In a similar theft, a like amount was taken from the Bank of England, in a scheme that took months of careful planning to execute. In this case, a bank officer was befriended. After gaining his confidence, one of the perpetrators was able to obtain the bank and vault keys from the employee's jacket pocket for a few minutes. Copies were made and the bank was successfully burglarized.

There have been many instances of keys being copied through impressioning techniques. Today, these procedures can be of value in certain security and intelligence operations. Crime laboratory examiners also employ impressioning and casting

techniques for lifting tool marks, fingerprints, footprints, and other unique evidence. There are several methods of impressioning and casting keys, using materials such as wax, clay, silicone, epoxy, and low temperature metals. The photograph below shows a key that has been copied by making an impression in wax.



The requirement to impression keys generally occurs during intelligence and security operations and in certain evidence-gathering procedures by crime laboratories. Within the context of intelligence and security, the employment of impressioning techniques is dependent upon a number of factors that are outlined in **8_6.3** below.

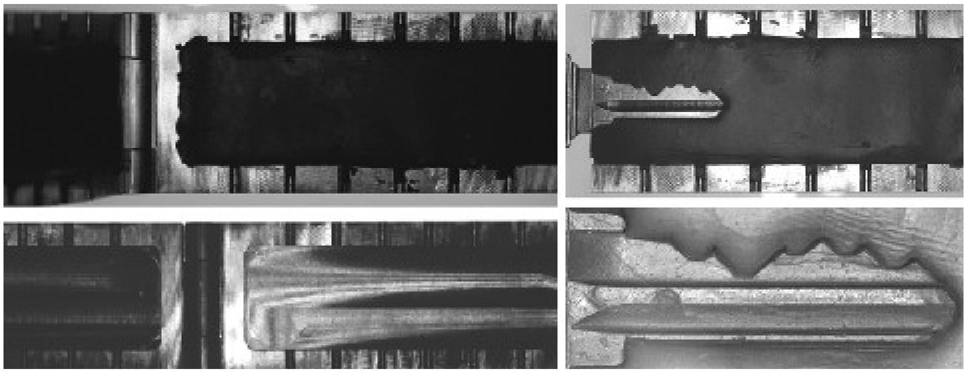
8_6.2 Overview of the Process

LSS201: Procedure for making keys with a clay mold. Courtesy of MSC.

The procedure for producing a copy of a source key occurs in two stages. Initially, an impression is created as an exact negative image or replica of the key. The precise outline is imprinted into a soft material that will retain the exact dimensions of the source key without distortion. This can be accomplished using silicone or clay. The material is formed within a mold, into which the source key is briefly impressed.

Next, a casting is made to create a positive image, or exact physical replica of the source key. A positive image is formed by pouring molten metal, epoxy, or silicone into the mold containing the impression of the source key. This positive can then be used to directly operate the lock. Otherwise, a copy will be made of the product of the casting in a hard metal such as brass or

nickel silver. See detailed explanation and photographs below.



8_6.2.1 Definitions

The following terms relating to casting and impressioning will be used in our discussion.

Casting is the process of creating a positive image or copy of the source key, through the infusion of material into a mold.

Impressioning refers to the procedure for obtaining and replicating the exact negative image of the source key.

Mold retains the impression of the source key as a negative image contained within wax, clay, or silicone.

Negative Image is the term that defines the original impression of the source key. The negative image is created when the source key is exposed, under pressure, to the impressioning material.

Positive Image is the term defining the product of the casting process after infusion or pouring of material into the mold. The positive image is the actual duplicate source key.

Setup Time refers to the time required for the impressioning or casting material to change from a liquid to a solid, permanent state.

Shrinkage defines the amount of contraction of the casting material that occurs as it changes from a liquid to a solid state. Typically, the shrinkage factor is relevant when low-temperature metals are poured into the mold. During cooling, the metal will slightly contract, causing a minute change in dimensions of the target key.

Source Key is the original key being copied.

Target Key is the key produced as a result of infusion of casting material into the mold. It is the positive image of the source key.

8_6.3 Preliminary Considerations for Impressioning

A number of factors will determine whether impressioning is an appropriate procedure. The following considerations are relevant:

- **Time to make the original impression;**
- **Time to keep the original key in order to verify a good impression has been secured;**
- **Design of the source key and its ability to be withdrawn from the mold without distortion or damage;**
- **Necessity of casting rather than utilizing other technique;**
- **Can the source key be duplicated in a cutter rather than cast;**
- **Location where the source key must be impressioned and where the duplicate key is to be made;**
- **Availability of casting materials.**

8_6.4 Difficulties with Impressioning Techniques

Three major difficulties can be encountered in impressioning or casting procedures.

- **Setup time can be critical in sensitive or urgent operations when using certain materials. Thus, if an operation does not allow much time for processing, then selection of the casting material is extremely important.**
- **Shrinkage after setup can cause tolerance errors in the target key that may result in malfunction. Poured molten metal has a tendency to shrink slightly. This will result in distorted dimensions of the target key.**
- **Soft metal targets may be damaged unless laser**

copied or decoded . If soft metal is poured into the mold to make the original cast, then a harder metal such as brass will be required to make a duplicate of the target key. Otherwise, the original duplicate may be distorted or damaged when inserted into a lock.

8_6.5 Materials Suitable for Casting and Impressioning

Many materials may be used for casting and impressioning.

8_6.5.1 Impressioning Materials

Recognized standard impressioning materials include clay, wax, and silicone. The author utilizes Fimo clay and Kerr Extrude silicone.

8_6.5.2 Casting Materials

Several materials are suitable for casting. These include silicone, Cerrobend or Cerrosafe (low temperature metals), epoxy, and wax. Each material requires a slightly different casting technique.

8_6.6 Impressioning

The initial operation to produce a duplicate source key requires that an impression be obtained. The following discussion relates to impressioning as the precursor to casting.

8_6.6.1 Implements for Impressioning with Clay

The following tools are necessary when using clay as an impressioning medium:

Mold: The impressioning compound is held by the mold. They generally take the form of clamshells or small square boxes, into which agents are poured or impressed. Molds can be made of many materials, but are generally constructed of aluminum, hardwood, plastic, clay, silicone, or layers of sheet aluminum. A mold should measure no less than 4" x 5" x 1" if using metal as a casting compound, and 3" x 1.25" x .25" when casting in clay, epoxy, or other material. Obviously, the exact measurements will

in part be controlled by the length, height, and thickness of the source key. In the case of silicone impressioning, the author uses a small shot glass to hold both the source key and silicone. When the mold is in the form of a box, seating pins are generally anchored on one side of the mold. When the two halves of the mold are pressed together, the pins provide for exact registration of the halves.

Clay: Modeling clay is generally utilized for impressioning. It should be warmed prior to use so that it is easy to manipulate, form, and cut.

Scraper: A scraper is required to trim excess clay from the edges of the mold.

Artist Brush: It is used for spreading talc over the mold.

Slicer: It is used to trim excess clay.

Mold Release: A lubricant is required to keep the impressioning compound from sticking to the source key. Talc, WD-40, silicon spray, Pam, or mold release is recommended.

8_7.0 Impressioning Procedure

Procedures for impressioning with clay and silicone are detailed below. Although the process is straightforward, there are a number of difficulties that can be encountered which can affect the accuracy and quality of the target key. These were summarized in **6.4** above.

8_7.1 Procedures for Impressioning Using Clay

Impressioning requires insertion of the source key into a mold containing clay, to create an exact impression of the bitting. A casting material in fluid form is then poured into the mold and allowed to harden until a firm, positive image is obtained. Materials that are required to properly complete the process include prepared mold halves, masking tape, and the source key.

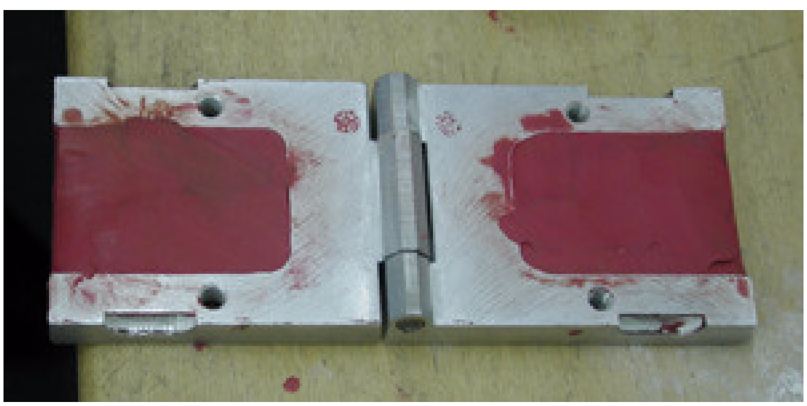
Keys can be copied through the use of clay molds. Courtesy of Hans Mejlshede.

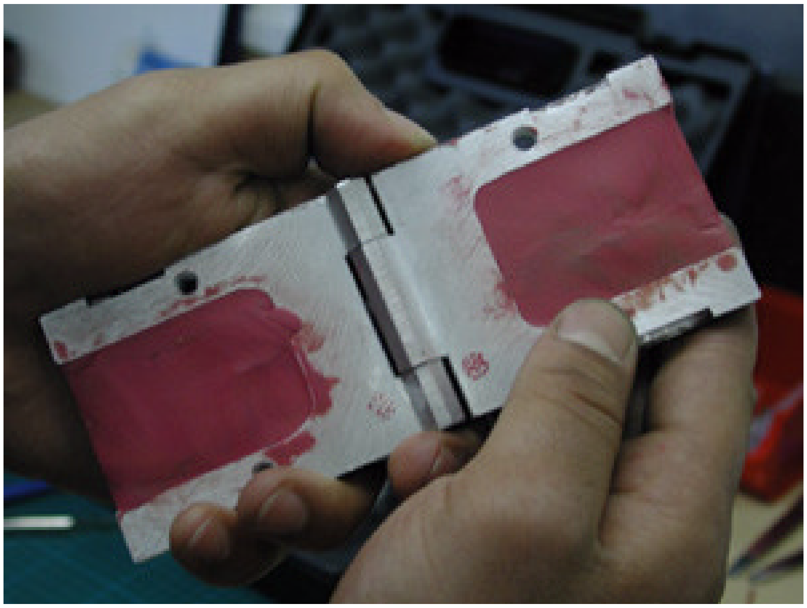
8_7.1.1 Detailed Procedure

Clay must be pressed into each half of the mold in separate actions and then worked so that it is evenly distributed. There should be no overlapping of clay between the halves, although the clay should initially protrude slightly above the mold. The material should be devoid of cracks to prevent chunking or flaking apart. If there are holes, gaps, or flakes in the surface, more material should be added to the open end of the mold and worked into the mass. Clay should not be added directly to the surface.

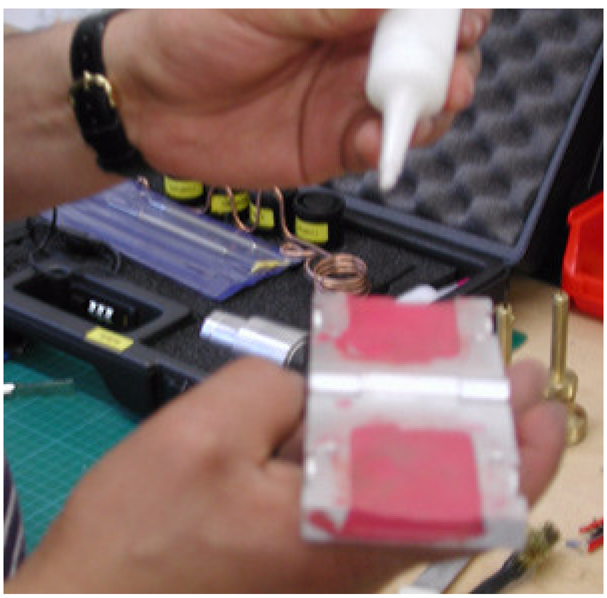
Once material is evenly impressed into each half of the mold, a cheese slicer should be used to trim the substance so that it is even with the top edge. Caution should be exercised not to cut any clay below the level of the mold. A scraper can be utilized to remove excess clay from the ends. A fine line should be run through the surface to allow air to escape, and to prevent air bubbles.

Both sides of the mold should then be dusted with talc using an art brush to prevent the clay from sticking to the source key. WD-40, silicon spray, or mold release is suitable for this purpose. Then, the mold is closed, making certain that there is no extra clay protruding on the surface. The mold should fit together tightly, with any excess clay being removed.



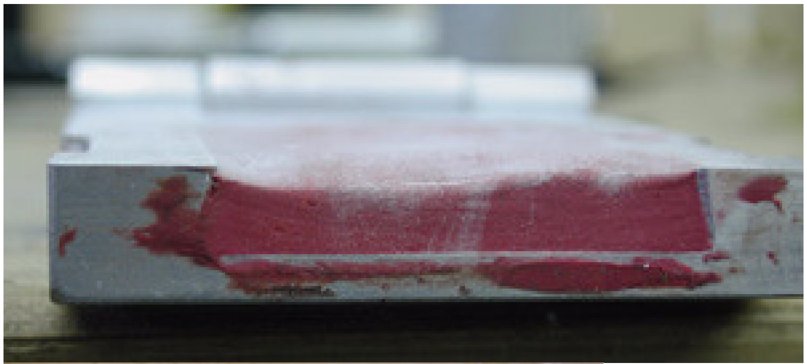


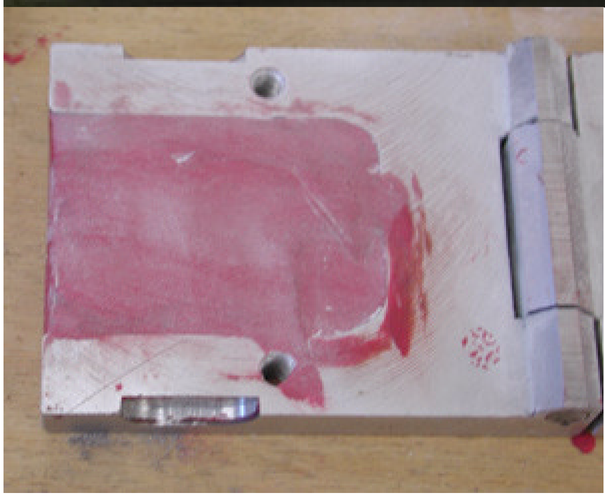
LSS+805 The aluminum mold is prepared by filling with clay, then smoothing the surface to insure uniformity in the impression.





LSS+806 Talc or other lubricant is applied to the clay to facilitate removal of the source key after an impression is taken.

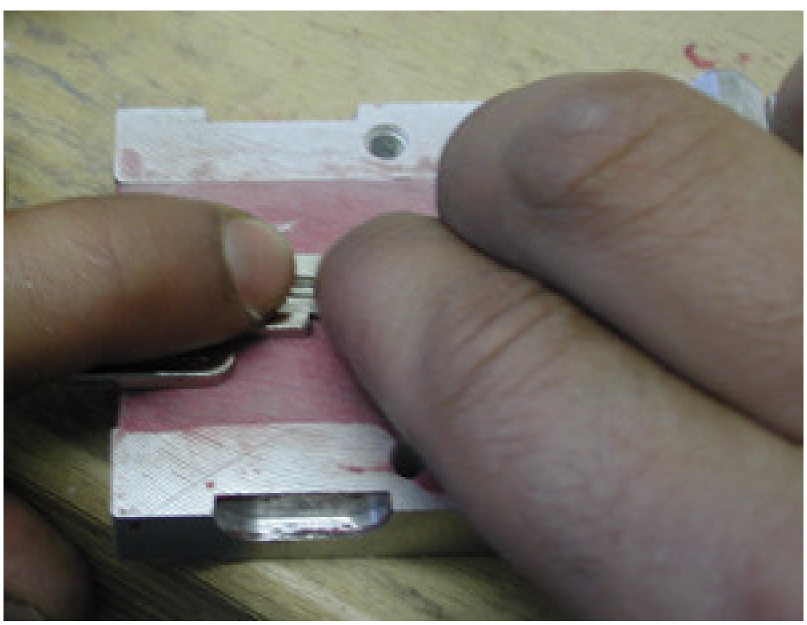




LSS+807 The excess clay is trimmed from the edge of the mold.



LSS+808 The source key is gently placed in position within the mold.





LSS+809 The source key is impressed into the clay to about half of its physical depth. This insures that both halves of the key will be equally impressed in the material.

8_7.1.2 Potential Problems During Impressioning

There are a number of potential problems inherent to impressioning in clay. The technician must understand and be able to correct deficiencies in the process to obtain the desired result in the subsequent casting. Simply, these problems relate to an uneven, skewed, or warped impression that will result in unusable negative images. Raised edges within the mold indicate a warping of the original impression, which may cause errors in the target key. This can result in an imprecise copy of the original. Tolerances between the source and target must be held to .002”. Any impressioning errors will likely cause the target key not to work. Warping problems and resulting distortions can be caused by a number of procedural errors. These include:

- **Excessive twisting of the key when removing it from the mold;**
- **Pushing or pulling the key while loosening it;**
- **Failure to lift straight up;**
- **Carelessness in removing the key from the mold;**
- **Creation of air bubbles.**

8_7.1.3 Making the Key Impression Using Clay

Although clay is an excellent impressioning medium, it must be prepa properly to prevent casting errors. The following protocol should be followed to produce an impression of the source key.

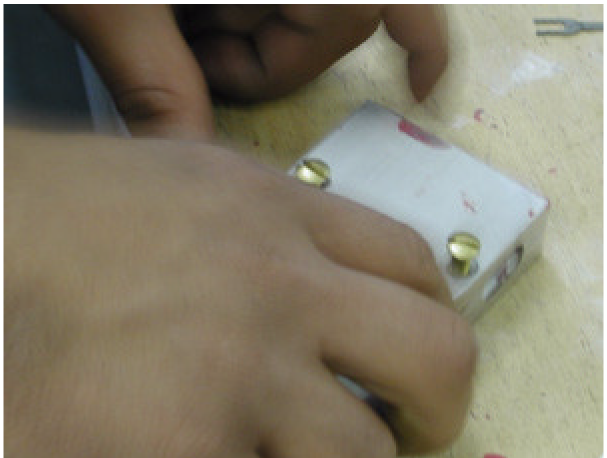
- **Press the key slightly into one side of mold, just**

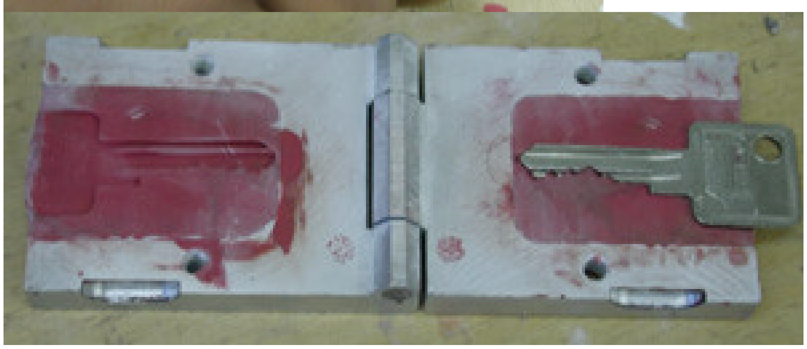
far enough to be held in position by the clay;

- **Allow half the bow of the key to rest in the clay. This is very important, because a handle is needed to remove the key from the clay once the impression is taken. In addition, keyhead identification data will be impressed into the clay;**
- **Place both halves of the mold together to form a tight fit, being certain that the halves align with the open end out. Be careful that the two halves are exactly parallel when pressing together, so that the resulting impression is not skewed;**
- **Hold the mold together for a few seconds to be certain that an impression is taken. High pressure may be applied to the mold to insure a solid imprint. This may be accomplished by clamping it in a vice or standing on the mold;**
- **The two mold halves should be split apart very carefully while in a vertical plane on a flat surface. If the mold does not come apart easily, the halves must be slowly worked apart with the key facing up;**
- **Lift the key straight up and out of the mold, gently twisting to remove;**
- **Place the mold halves on a flat surface with each of the clay sides facing up, being extremely careful not to damage the impression just taken;**
- **The resulting negative image must be inspected to insure the uniformity of impression and the lack of raised edges;**
- **Create a funnel within the clay, to be used when pouring molten metal into the mold. This is accomplished by cutting away a little clay from each half of the mold, so a narrowed entrance is created at the open end, about 1/4" in diameter. This technique will allow metal to flow quickly into the mold. A letter opener, flat end of a screwdriver, or pen knife may also be used to create the funnel effect;**
- **Dust the impression with one of the lubricants noted above in order to allow release of the target key after casting;**
- **Put the mold together, being certain that the ends**

are aligned properly;

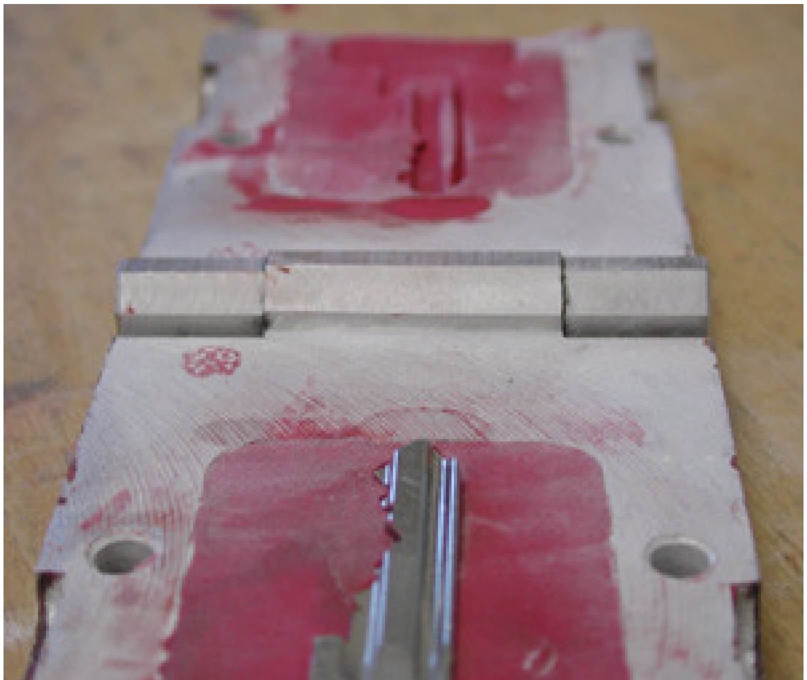
- **Tape the mold together or use rubber bands.**

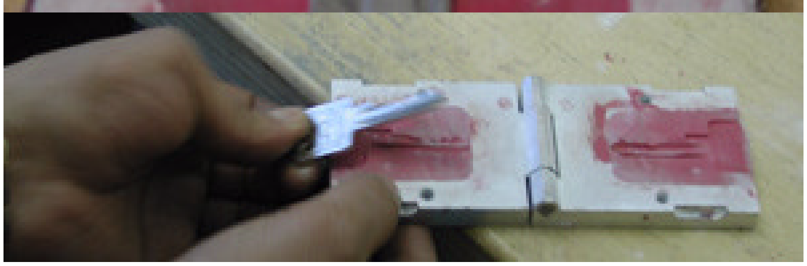




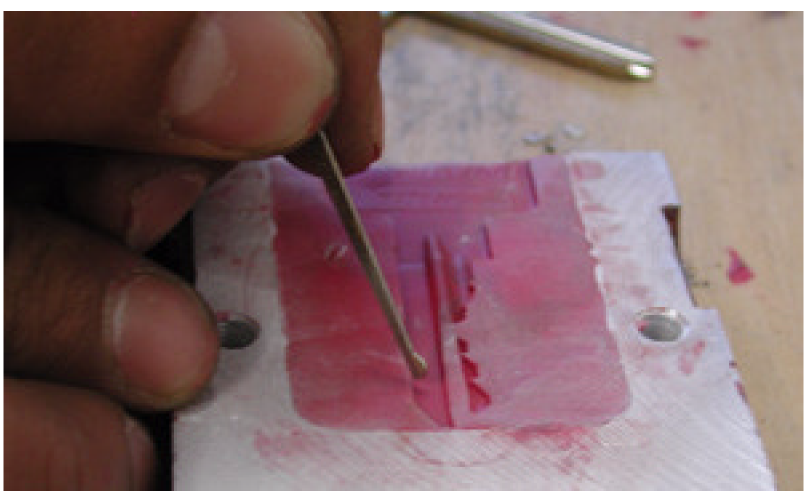
LSS+810 The mold is closed with the source key inserted. Pressure is applied to the closed mold to create an impression.

LSS+811 The mold is then carefully opened.



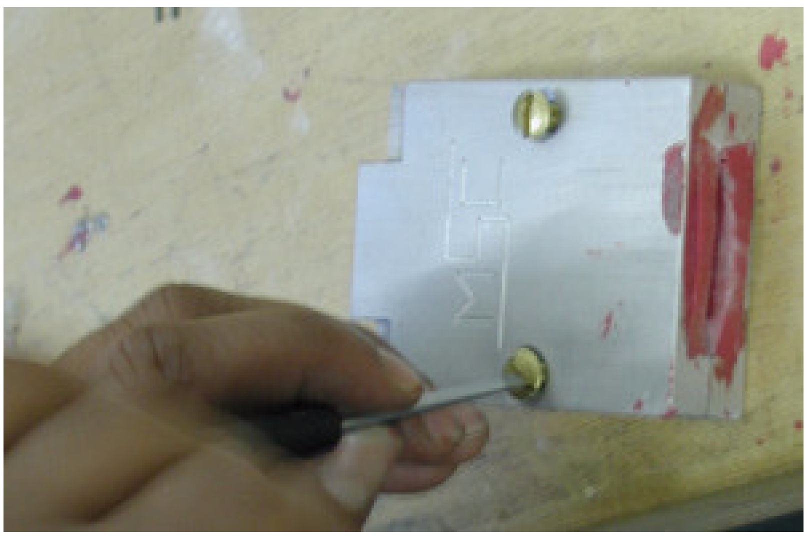


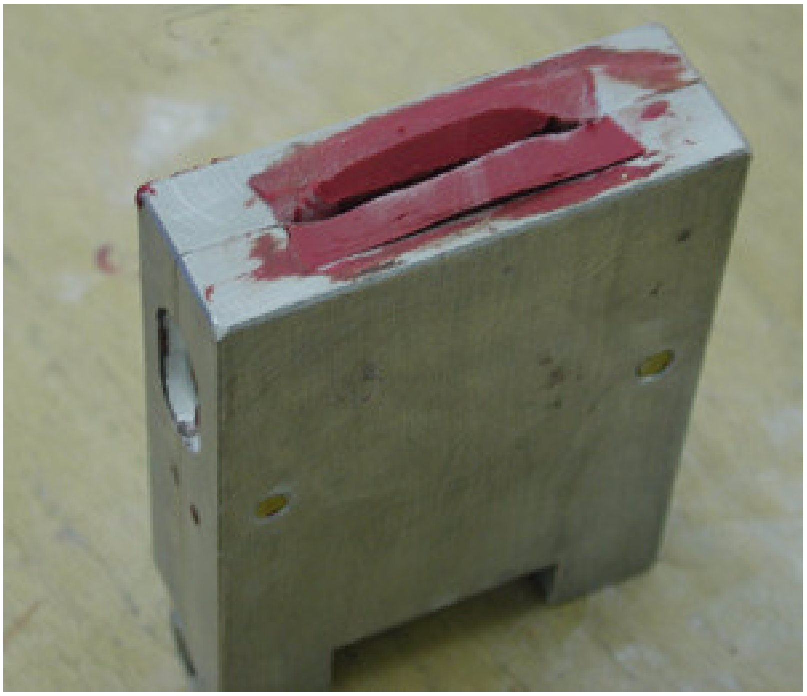
LSS+812 The key is carefully removed from the mold, taking care not to distort the impression.



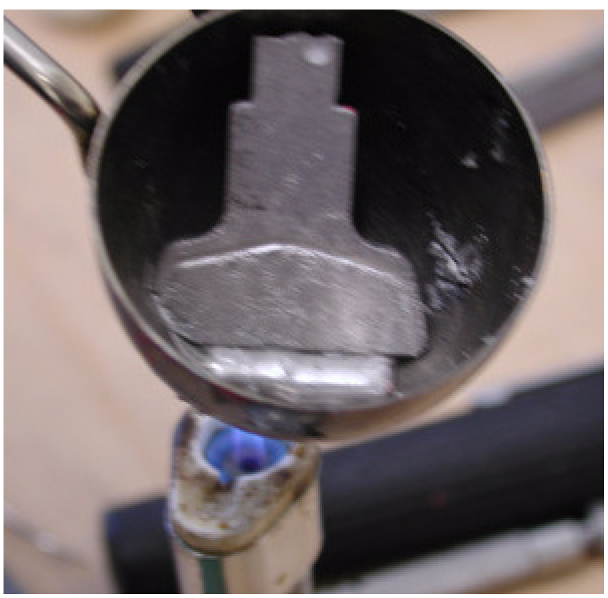


LSS+813 A matchstick or other tool is used to produce a track for the release of hot gasses generated
during the pouring and cooling of the molten metal.

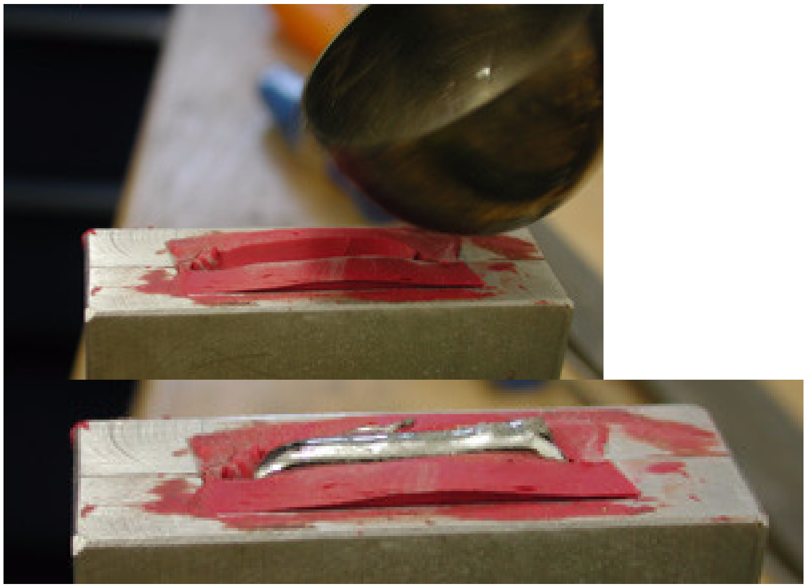




LSS+814 The mold is secured.



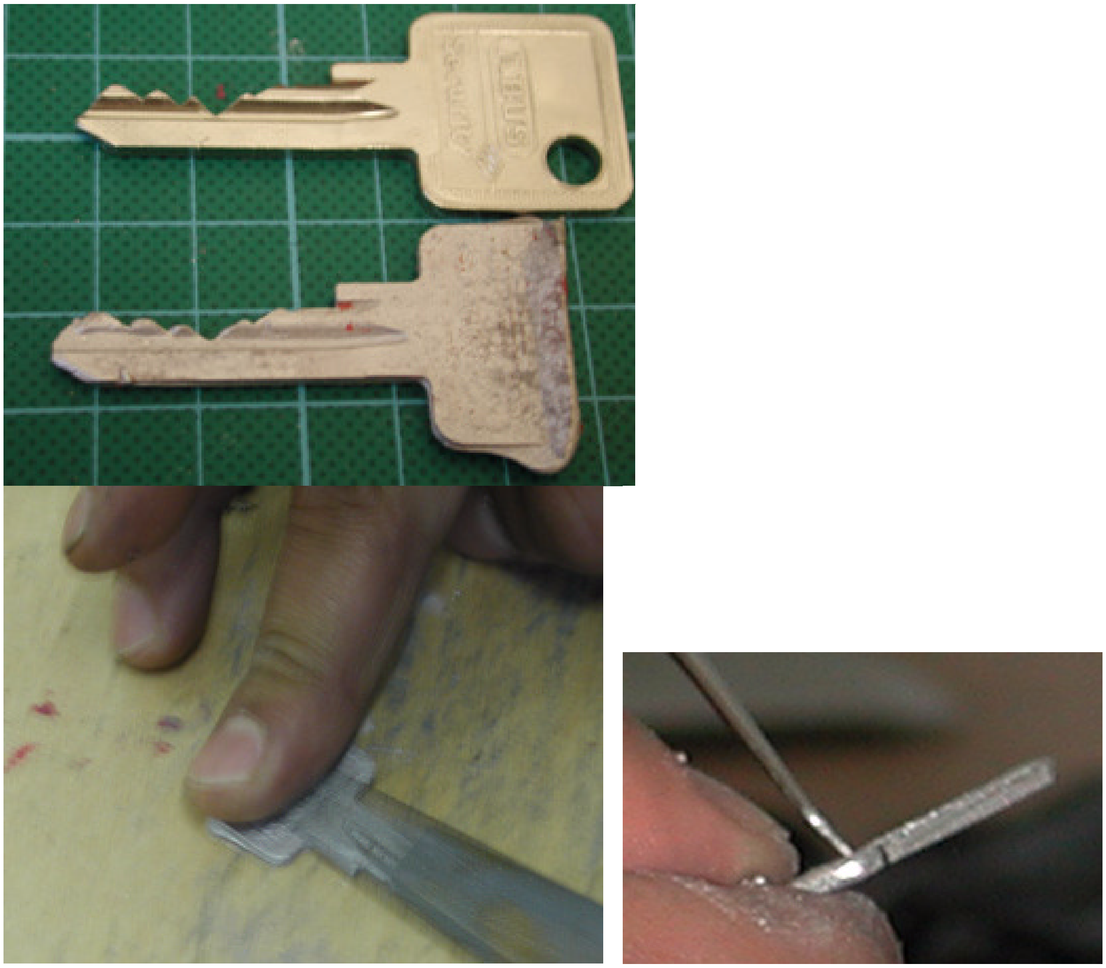




**LSS+815 A small amount of low melting temperature metal is inserted into a crucible
and reduced to its liquid state. It is then poured into the slot of the mold.**



**LSS+816 The mold is allowed to cool. It is then opened, to reveal
a positive copy of the source key.**



LSS+817 The key is removed, compared, and any burnishes are removed from it surface. Milling of the key may be required if the impression was not precisely symmetrical in the mold.

8_7.1.4 Silicone Impressioning

LSS201: Making keys by silicone impression, Courtesy of MSC

Silicone is an excellent impressioning medium; its only drawback is the time required to set. Kerr Extrude is utilized by dentists for taking impressions of teeth and is quite suitable for work with keys. Kerr Extrude and similar materials will harden within seven minutes, although there is a quick-setting formula that will be ready for casting in less than three minutes.

Silicone generally is supplied as a two-chemical process, much

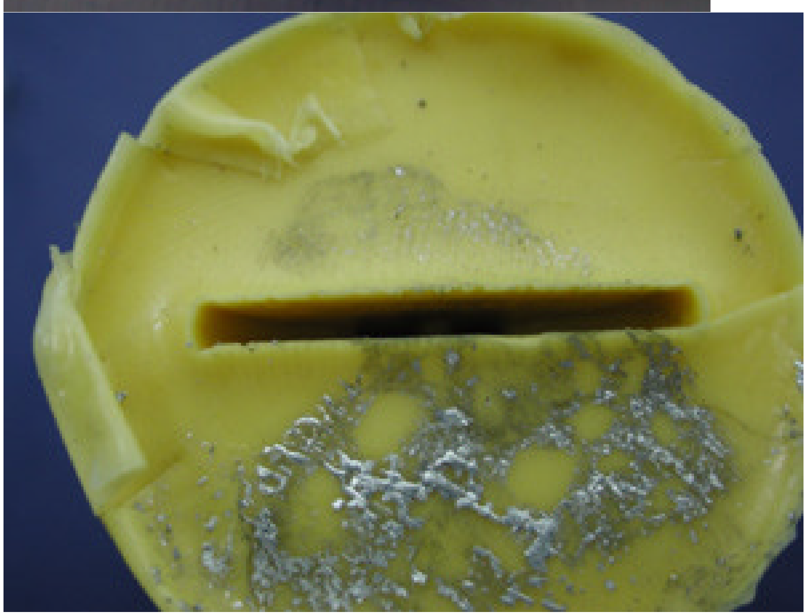
like epoxy. The chemicals are automatically mixed through a syringe gun and are ejected from the tip as a low viscosity liquid, which flows easily around the key.

MSC in Germany produces a kit for the impression copying of keys using a silicone-based product. Their system includes an electric vibrator to insure proper mixing and release of all air bubbles in the silicone material, prior to setup.

The author prefers silicone to clay because of its consistent results and high definition. To impression in silicone, simply:

- **Spray the source key with silicon, light oil, WD-40, or other lubricant, to allow removal from the mold after setup. Although this is not absolutely necessary, it can help when dealing with a complex key design;**
- **Place the source key into a shot glass or other small container. It may be necessary to run a pin, wire, paper clip, or similar item through the head, to suspend the key and prevent it from touching the sides of the glass;**
- **Infuse the silicone into the container until the key is almost fully immersed, leaving a small portion of the head to allow removal when completed;**
- **Lightly rap the bottom of the container on a tabletop several times to release air bubbles, in order to insure proper flow of the material;**
- **Wait for the silicone to harden;**
- **After setup, slightly move the key within the mold to release, and withdraw.**





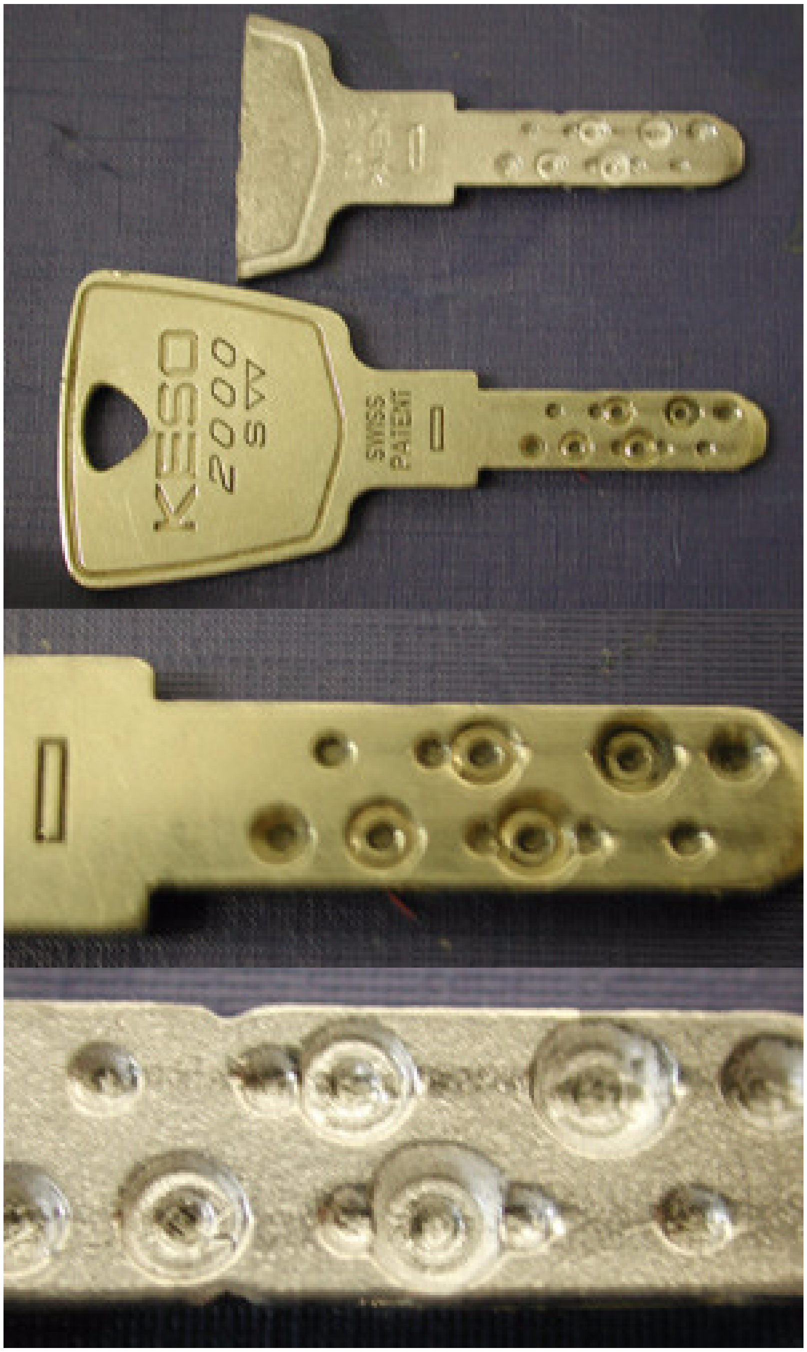
**LSS+818 Silicone is used to create a negative impression of the source key. The key is surrounded
by the material and allowed to set. The key is then removed and molten metal is poured into the
impression. The result if an exact replica of the source key. A 35mm plastic film container or**

shot glass may be used to hold the silicone during the process.



LSS+819 The silicone block has been removed from its container and cut in half to show the details of the impression. Silicone, unlike clay, allows multiple castings to be accomplished.





LSS+820 The source and target key in two different castings are shown. Exact detail is replicated.

8_7.1.4.1 Impressioning Stamped Numbers on Metal

Silicone may be utilized to make impressions of stamped numbers on metal surfaces. This can be a valuable technique in vehicle theft investigations and other cases where minute marks must be preserved and reproduced. High resolution reproductions can be obtained, if the correct materials are utilized. In one homicide investigation involving a two year old child, the author was able to produce a detailed reproduction of bite marks produced by the victim in his arm.

The following instructions are for making an impression of stamped numbers in metal.

- **All casts should be taken before any number restoration is attempted**
- **Casts should be made with a silicone with sufficient resolution (viscosity)**
- **Thoroughly clean the area of any foreign matter All contaminants including paint and dirt should be removed from the stamped area with a suitable solvent (acetone, alcohol, gasoline, commercial paint remover or "Goo Gone"). A toothbrush can be used for this purpose. A wire brush should never be utilized, as it can produce artifacts that can make identification impossible, and also cause evidentiary problems. Naval Jelly or Goo Gone can be employed to remove rust;**
- **After the surface is cleaned, a dam of pliable clay or similar material should be built around the target area to retain the silicone during setup;**
- **Prior to forming the dam, nylon filament tape or masking tape should be applied at each end of the stamped characters and partly within the dam area to facilitate the cast removal.**
- **All voids around the dam should be sealed to prevent leaking and to insure consistent contact with the target area;**
- **Once the silicone has been poured and set, lift up on the ends of the tape to remove the cast. If the silicone contains significant amounts of paint and rust, additional casts should be made for optimum resolution.**

8_8.0 Casting

The following discussion relates to casting, using low-melting temperature metals, in terms of necessary tools and materials, and specific procedures to reproduce a target key.

8_8.1 Potential Problems in Casting

Two primary problems can occur during the casting process that will require a new impression or casting to be made.

8_8.1.1 Absence of Bitting

An absence of bitting in the cast can result from a lack of penetration into the impressioning material by the source key, trapped air causing bubbles, or too rapid cooling of the metal. If metal cools too rapidly, simply heat the metal longer before the next casting attempt. This problem can often be corrected by recasting. Generally, the mold is not damaged.

8_8.1.2 Blurring of Bitting

Blurring of the bitting generally occurs from air bubbles or damage to the impression material during the impressioning portion of the process. Carefully examine the actual impression against the original key, and take another impression if required. If a new impression is made, rework the old clay and add the clay that was scraped from the mold in the setup process.

8_8.1.3 Bitting Includes thin Sheets of Protruding Metal

This problem is caused by the two halves of the mold not being closed tightly enough, which leaves air spaces into which metal will flow. The problem can be corrected by filing the metal from the target key.

8_8.1.4 Under or Overheating of Metal

If the metal used in the casting process is not heated to the correct temperature, problems will occur. These will affect how the metal flows, which can also cause damage to the impression. If the metal is not raised to the proper temperature prior to casting, then it will cool too rapidly when poured into the mold. This will result in uneven flow. In contrast, if the metal is brought to a temperature higher than required, the mold material may be softened, causing distortion in the impression. A candle or other heat source such as a small torch may be used, if attention is paid to duration of heat application.

8_8.2 Tools and Materials

Specific tools and materials are required to produce accurate and useable castings.

8_8.2.1 Tools

- **Cheese slicer;**
- **Candles, boiling water or other heat source;**
- **Thimble with a twisted wire handle, or other container to hold molten metal.**

8_8.2.2 Materials

The following materials are required for casting using low melting temperature metals:

- **Alloy slug;**
- **Mold containing impression;**
- **Ladle;**
- **Heat source, such as matches and candle or boiling water.**

8_8.3 Casting with Low Melting Temperature Metals

Low temperature metals can be melted and poured at a temperature of about 158°F. The proper procedure for producing casts with low melting temperature metals is straightforward:

THE CASTING PROCESS	
STEP 1	**Place a drop of wax on the bottom of the candle to hold in position.**
STEP 2	**Place a drop of wax on the bottom of the candle, to hold in position.**
STEP 3	**Place an alloy slug in the ladle.**
STEP 4	**Melt the alloy slug for about thirty seconds, until molten. ladle should be positioned about 1/4" above the tip of the This will produce the highest and most reliable temperature**

	This will produce the highest and most reliable temperature
STEP 5	A few seconds prior to pouring the molten metal, hold the m the ladle to warm the mold material. This will delay the p cooling of molten metal in the mold;
STEP 6	Pour the metal into the mold. In order to release air bubbl may build-up, tap the mold on a surface several times, allo molten metal to flow evenly.
STEP 7	Do not proceed until the metal has turned to a solid. This generally occur within two minutes.
STEP 8	Release the two mold halves.
STEP 9	Remove the casting from the mold, utilizing the same tech caution as was employed when the source key was removed aft impressioning. This operation is more critical, however, be there is no longer a bow of the key to hold onto. A corner scraper can be used to lift the casting from one edge. The should be inspected for defects. Recast if the positive im appears damaged, distorted, or unusable.
STEP 10	Make a copy of the cast key in brass or nickel silver. Unl is no alternative, the casting should never be used to oper It should only be employed for the production of a duplicat key, because the casting is too soft for actual use.
STEP 11	If the actual cast key is inserted into the lock, a turning should be used to avoid excessive stress on the soft metal Also, be certain to clean any flash or metal ooze that may developed during the casting process.

8_8.4 Casting with Silicone

After an impression has been produced, silicone can be utilized as an excellent casting medium. After the source key has been withdrawn, a low-viscosity epoxy or metal is poured into the mold until full. The casting material is then allowed to harden, and the new key is removed from the mold. A Silca Quattrocode key machine with laser scanner can be used to make a hard metal copy of the soft key.

CHAPTER NINE: GENERIC TYPES OF KEYS

Producing Keys for Specific Locks

Master Exhibit Summary

Forensic implications of using a shim to open a lock prior to analysis. Courtesy of Hans Mejlshede.

9_1.0 Introduction

This chapter provides basic information regarding the design of keys for warded, lever, wafer, and pin tumbler locks. Proper design is required to allow the generation or duplication of a key for each of the basic locking mechanisms. The chapter is not intended as a comprehensive treatise on the subject, but merely to provide the basic skills needed to meet law enforcement and locksmithing requirements. There are many ways to generate keys for locks. In large part, the technique depends upon the design of the locking mechanism, tools available, skill, time, and location.

As has been previously noted, keys can be produced from other keys, from the lock itself, or from information about the key in the form of codes. In **Chapter 8**, the sources for such information were described. They are mainly determined by the type of mechanism. In this chapter, the three most popular methods of producing keys are examined for each type of mechanism. Information is provided about **disassembling the lock, impressioning, and visual decoding.**

9_1.1 Disassembly

Most locks can be disassembled, although this is least likely within warded mechanisms because they are generally fastened by rivets. If the lock is held together by screws, retaining clips, arc rings, or similar devices, then obtaining access to the mechanism is generally straightforward.

Locks may also be taken apart using the techniques of **shimming, picking, and rapping.** Each of these procedures will result in aligning the detainers at shear line, causing the lock to open. Once in the unlocked position, a key can be matched to the specific tumbler configuration. These techniques are more fully discussed in **Chapter 29.**

9_1.2 Impressioning

Locks can be impressioned, producing a working key through the marking of the surface area of a blank. Different impressioning techniques are employed, depending upon the type of lock. These are discussed in **Chapter 30.**

9_1.3 Visual Decoding

Certain locks may be visually decoded in order to determine tumbler combination or location. Decoding is accomplished externally, or from each tumbler or wafer in a disassembled condition. Techniques for decoding are presented in **Chapter 31.** The materials that follow will focus on basic procedures for producing keys to each type of locking mechanism based upon the mechanical configuration.

9_2.0 Warded Locks

Chapter 13 presents a detailed discussion of warded locks and their mechanical functionality.

9_2.1 Introduction

The warded lock has been in existence for several hundred years and was the first "modern" locking mechanism since the Egyptian pin tumbler. Security is a function of the placement of wards, which block the entrance and rotation of all but the correct key. Depending upon the mechanism, keys for warded locks take several forms. Although they may differ in appearance, keys and locks generally have two common traits: warded keys have square cuts,

and, unlike any other mechanism, generic skeleton or master keys can bypass them. Warded padlocks produced by Master and others are popular and very prevalent in low-security applications. These are also the easiest to bypass. A set of five skeleton keys is available for warded padlocks and will open most of them without difficulty. HPC produces such a set (**HPC PKS**).

Keys for warded locks are made of soft iron, cast iron, steel, brass, bronze, zinc alloy, or aluminum alloy. Blanks are usually readily available. Warded keys, however, may in fact be more difficult to cut than other types due to complex patterns. The tolerance and spacing required in a warded mechanism is minimal due mainly to the locks construction and principle of operation. Thus, key generation is fairly simple.

9_2.2 Warded Keys

There are three primary types of warded keys: **mortise**, **padlock**, and **specialty**, such as cabinet and luggage.

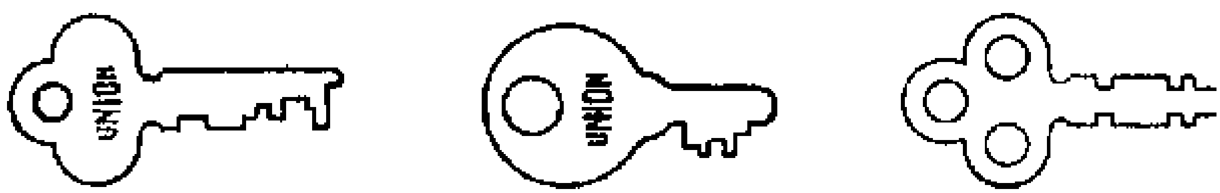
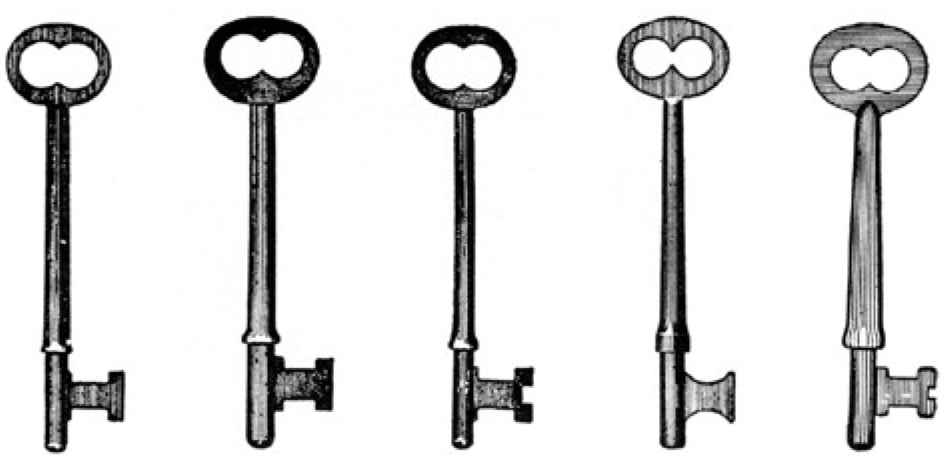


Figure LSS+903 Examples of three warded flat keys. From left, locker key, luggage, and padlock.



9_2.2.1 Keys for Mortise Locks

Keys for warded mortise locks take many forms, often having very complex and artistic designs. The active portion of the key, called the **bitting**, is comprised of cuts and grooves to pass the wards. The names associated with the various parts of the key will slightly differ, depending upon country.

The **bit key** is the oldest form, dating back to Roman times two thousand years ago. It is probably the most popular in the world, except in the United States and Canada. Keys are cast and, thus, low tolerances are maintained. No two keys are identical. The bit key has two basic variations, depending upon whether the stem is solid or hollow, and consists of three primary parts: the **stem**, **bow**, and **bit**.

9_2.2.1.1 Identification and Function of Parts

Bit Key: This actually describes a key with a bit projecting from its shank. There are different variations, generally described as the **pin**, **pipe**, or **barrel** key. Differing slightly in design from the pin key, the **barrel** or **pipe** key has a hole drilled in the post that fits over a corresponding pin or post within the lock. There are generally no shoulders on the barrel key.

Bit: At the working end of the key is the bit. It is the most important and complex part of the warded key. All bits are essentially rectangular and cut in square steps on the bottom and sides.

Bow: The bow, usually oval or round, can be any shape and performs the functional purpose of providing a handle with which to grasp the key for use. Its design is irrelevant to operation.

Bullets: Bullets are grooves cut longitudinally across the bit, to form different keyway designs.

Pin or Post: The pin or post, either hollow or solid, provides an anchor and rotating center point when the key is inserted into the lock. The post, if a hollow pipe, is designed to fit over a pin within the lock and rotate around that pin. If the stem is solid, its tip is intended to pass through a "0" in the keyhole to anchor the key for rotation.

Shoulder or Collar: The shoulder forms a stop point, projecting

ring, or flange, to block further entrance of the key. The diameter of the shoulder or collar is slightly larger than the shank. The keyway will not pass this larger diameter.

Stem, Shank: The stem or shank forms the long part of the key, connecting the bow with the bit.

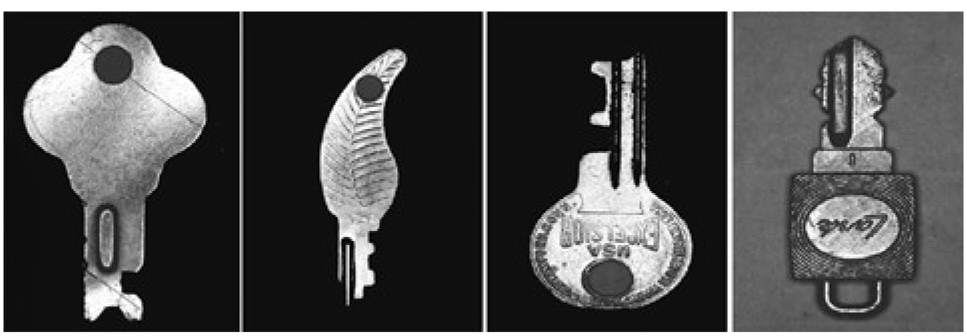
Throat or Neck: The throat is the spacing between the shoulder and the bitting.

9_2.2.2 Keys for Warded Padlocks

Keys for warded padlocks are very distinctive in design. They can be identified by their square symmetrical cuts. These are required to pass the wards in order to release shackle-locking bands. Master Lock is the predominant supplier of these mechanisms worldwide.

9_2.2.3 Keys for Specialty Warded Locks

Luggage, trunk, cabinet, and specialty locks utilize the warded principle and are the simplest form of lock produced today. Many kinds of luggage keys can be ordered precut for specific locks. Flat keys are used in padlocks, letter boxes, lockers, cash boxes, cabinet locks, and safe-deposit lever locks, and are described in Section **9_3.2** below.



9_2.3 Generating Keys for Warded Locks

Keys for warded locks are produced by hand filing from an original or through the impressioning process.

9_2.3.1 Cutting Keys by Hand

Generally, the easiest way to duplicate a warded key is to **smoke**

the source, using a candle, lighter, or match until all of the bitting is covered with black carbon. Then, take a blank key and cut the same pattern as found on the source. Place the target against the original and file until the carbon is barely marked on the source key. Another technique is to press sticky-backed aluminum foil onto the source key, then remove, cut, and overlay onto a blank. Regardless of method selected for key duplication, there are certain guidelines which must be followed:

	GUIDELINES FOR KEY DUPLICATIO
BOW NOT IMPORTANT	**The shape of the bow is not important. correct dimensions will work.**
SHANK AND POST SAME LENGTH	**The shank and post must be the same len target key.**
BIT DIMENSIONS	**The bit on the target blank must be hig or equal to the source key. The thickne same on both keys.**
POST DIMENSIONS	**The diameter and length of the post mus**

Some bit keys can be very complex in design, including a bullet or side groove in the bitting that forms part of the keyway. A depth gauge or micrometer can verify the cuts during duplication.

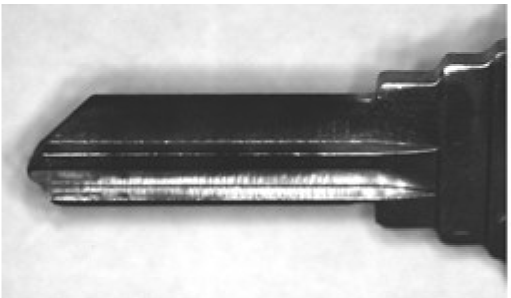
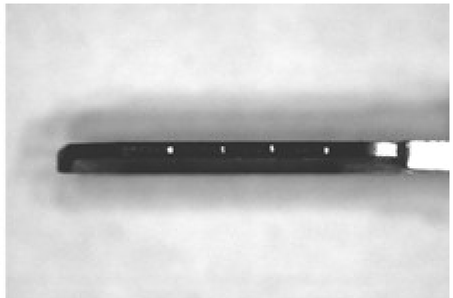
9_2.3.2 Impressioning Keys Using Carbon or Wax

Warded locks can be easily impressioned, thereby eliminating the requirement of disassembly to produce a key. The procedure is based upon distinct markings that are created on the face of the blank. Because the wards prevent a key from turning without the proper corresponding cuts, marking will occur in the absence of such cuts. Torque is required to cause the imprints.

In order to impression the lock, be certain that the correct blank is selected. It must be both long enough and sufficiently wide to operate the bolt mechanism, especially in padlocks. If the key is too narrow, it will not be able to spread the release spring to unlock the shackle.

Smoke the blank key, insert it completely, and turn sharply without actually twisting the metal. This allows the key to partially turn within the lock, making contact with the wards. Upon removal, spots will indicate the position of the throat and

ward cuts. Make the throat cut first so as to allow proper contact with the other wards. Marks will appear because a blank key is blocked from rotating past the wards. Only when metal is removed from the key, corresponding to the precise location of the wards, can the key be turned freely.

Use a triangle file to begin each cut. Place the cutting edge down, and apply pressure in a forward motion. Finer cuts can be produced with the smooth edge down. Draw the file forward to widen the cut angle. Once initial indentations are made, a flat, square warding file should be used to cut the remainder of the key. For padlocks, symmetrical cuts are required. All cuts will be to the same depth and will be in line with the edge of the tip of the key. If a cut is not wide enough, the key will not operate. Simply widen slightly until impression marks disappear and the key operates without binding. If too much of the bitting surface is removed, a skeleton key will be created that will open more than one lock.

9_2.3.3 Skeleton, Pass, and Master Keys

Skeleton keys are created by removing all bitting material, except that which is required to actuate the bolt or shackle-release spring. Because it is so simple to make such keys, warded locks offer little security.

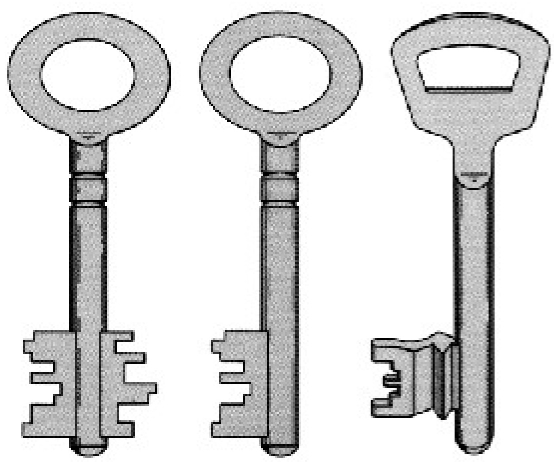
HPC and other companies sell a set of five skeleton keys. These are made of thin metal shim stock and will open virtually every warded padlock. Two keys can be overlaid and inserted into the lock as one composite if **three** shackle-release springs are present. These will bypass all of the wards and only act upon the release mechanism.

9_3.0 Lever Locks

9_3.1 Introduction

In the United States, lever locks are primarily used in safes and vaults, safe-deposit boxes, cash boxes, mailboxes, telephones, and certain low-cost, low-security applications. In Europe and most other parts of the world, lever locks are very popular for use in high-security safes, as well as in mortise configurations for hotel, residence, and business door locks. They are preferred over combination locks on many high-security safes.

Lever mechanisms can offer extremely high-security, and thus, tolerances for key duplication must be precise. Keys for lever locks are generally made of steel or nickel silver and are either flat or double cut. Most safe-deposit locks utilize flat keys.



Double-bitted lever keys can be found in higher security applications on safes and vaults and in prisons. Blanks are readily available, and many of these keys are produced from codes. Keys may be cut either by machine or by hand.

9_3.2 Keys for Lever Locks

Flat keys are generally easy to duplicate. The manufacturer-designated key blank is often not required, because similar blanks can be cut to match the source key. Even a flat piece of metal or plastic can be employed, if necessary. The length of the blank must be correct, and the width cannot be smaller than the source key. Thickness and height should also be comparable in both the source and target.

Warded and lever keys often appear identical, and in fact, a warded lock may be confused with a lever mechanism in many applications. The design of the key requires that for every lever, a corresponding rectangular cut be made. All sides must be perpendicular, and the bottom of each cut is flat and horizontal.

9_3.2.1 Hand Cutting Lever Keys

Lever keys are usually cut by hand with a file. Prior to beginning our discussion of how to make a key for these locks, the method of cutting must be analyzed to insure that the key will work properly. A 6" flat warding file that has a thickness **less than or equal to** the width of one lever tumbler is required for cutting keys by hand. This concept should be clearly understood prior to attempting to make a key.

One must consider the operation of the key in the lock in order to understand the relationship between the tumbler and the geometry of the cut on the bitting. Each individual cut corresponds to one lever tumbler; each cut raises one lever to the correct position. Therefore, if the cut on the key is too wide, more than one tumbler will be picked up. It also follows that if the cuts are too narrow, a tumbler will be raised but not necessarily to the correct level.

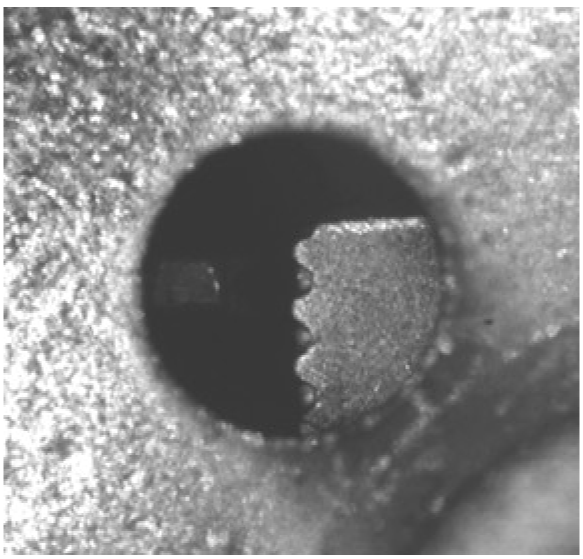
9_3.2.2 Producing Keys for Lever Locks

The following discussion assumes that the interior of the lever lock is available for inspection during the cutting process. If such is not the case, the reader is directed to **Chapter 30** for a discussion of impressioning. The correct blank for the lock is first selected, making sure that it is both long and wide enough to reach all tumblers so that it may lift them to the correct level. The blank is then inserted until stopped by the tip. Several sharp rotations are made, as if to open the lock.

After removal of the blank, there should be fine marks or scratches on the key that will indicate the exact point where the lever tumblers came into contact with the metal surface of the blank. The marks are necessary for the determination of where to file each tumbler cut. If the tumblers do not leave clear marks, the surface of the key may be polished to a mirror finish or be smoked. Smoking is accomplished by holding a lighted match under the key and allowing a thin film of carbon deposit to build-up on the surface. The key is reinserted into the lock and sharp

turning motions are applied. The key is then carefully withdrawn, and marks should be clearly visible.

After the tumbler positions have been precisely determined, one simply files the key to the point where all gates are in alignment with the fence. Because many lever assemblies will have windows or holes cut in the face of the assembly, the alignment of the lever gates with the fence can be observed through these openings or by taking the lock apart. A key can be produced using the viewing window. Insert the blank and determine how much filing will be necessary to line up the first visible tumbler; it will be closest to the bow of the key. Remove the key and file until this tumbler is aligned with the fence. When this is accomplished, the second tumbler can be lined up in like manner, continuing this procedure until all of the levers are aligned with the fence and the lock opens.



This procedure does not require the lock to be taken apart, nor is the tumbler combination disturbed because levers have not been removed. The blank must be inserted in a perfect vertical angle to insure that the key aligns the tumblers correctly. It may be preferred or required to remove the top plate of the lock in order to produce a key or to change the tumbler combination. This is the case when there is no window to view the tumblers. In such instances, the top plate can be lifted by removing a few screws.

With the plate gone, the tumbler arrangement is visible. One then inserts the blank in the keyway, being careful to keep the keyway guide exactly vertical and centered. Each tumbler position on the

key is then filed to the correct level. The proper depth of each cut is determined by rotating the key as if to open the lock and bringing the fence and gate into precise alignment. The tumblers also may be completely removed from the lock and reinserted one by one as the key is produced.

The situation may also arise in which a key must be made for a lever lock that is in the locked position and cannot be removed. In such a case, it may be necessary to drill a small hole in the precise spot that allows a view of the tumbler alignment. A key can then be cut by the procedure outlined above. If the lock is first picked open, it may be removed for keying. A key can be produced by the impression method or the tumblers may be visually decoded with a borescope.

9_3.3 Impressioning Lever Locks

Lever locks can be impressioned, even in cases where serrated levers are employed. In addition, visual inspection of the wear patterns on the bottom of the levers can provide information as to tumbler depth. During the nineteenth century, lock pickers used wax as an impressioning medium for determining the correct lever depths. The subject is more fully discussed in **Chapter 30**.

9_4.0 Keys for Disc or Wafer Tumbler Locks

9_4.1 Introduction

There are several different wafer lock designs, employing discs, wafers, plates, or other similar forms of tumblers. For a thorough discussion of these mechanisms, see **Chapter 15**. This section will provide information relating to the most common wafer locks, although the techniques are generally applicable to most of the mechanisms in use today.

Keys for wafer or disc tumbler locks are usually made of brass, nickel silver, or aluminum. Wafer locks are prevalent in the vending industry and are an inexpensive substitute for pin tumbler cylinders. Most wafer locks are offered in a **cam** configuration and are frequently cast from alloys. The mechanism consists of a plug containing all of the springs and tumblers, which rotates within a shell. Wafer keys can be single, **double**, or **triple**-bitted. The locks usually have from four to six tumblers, and the keys often appear identical to those for a pin tumbler lock, except that the blanks are generally smaller.

9_4.2 Generating Keys for Wafer and Disc Tumbler Locks

Duplicates can be made from a source key, from code information, from visual decoding of the tumblers, from disassembly of the lock, and by impression.

9_4.2.1 Duplicating from Source Keys

Keys can be generated by hand cutting or machine. The same rules apply with respect to hand cutting of wafer and pin tumbler keys. See Section **9_5.0** for information on producing keys for pin tumbler locks.

9_4.2.2 Duplicating Keys by Code

Most wafer keys can be cut by code, either by hand filing, by mechanical punch machines, or with electric code cutting machines. Keys can also be reproduced through a visual decoding process, explained in detail in **Chapter 31**. This procedure involves inspection of each tumbler within the lock, correlation of the viewed tumbler depth with the proper depth code, and cutting a key to match the derived information. A decoder (**HPC HKD-75**) micrometer (**HPC SKM-2D**, KM-60, SKM-1) or various gauges can also be used to measure the depth and spacing of wafer keys. These instruments can verify measurements or provide the data to hand cut keys by code.

9_4.2.3 Keys Produced After Disassembly of the Lock

It is a relatively simple procedure to produce a key directly from the internal wafers. The lock is first disassembled by removing a retaining screw or arc ring located at the rear of the plug. This will allow the complete internal mechanism to be withdrawn.

A blank key is inserted into the keyway, and pressure is applied to the top of each of the wafers. This will mark the surface of the key to determine exact spacing. Then, each tumbler position within the bitting is created, filed, and shaped until the wafer rests at shear line. Once all tumblers are properly aligned, the plug can be turned within the shell.

Double-bitted keys can be produced in similar fashion by first disassembling the mechanism to expose the plug and wafers. The significant difference between single and double-bitted locks is that there are two shear lines, at the top and bottom of plug. The wafers alternate between the two shear lines rather than being aligned only at the top of the plug. The correct blank is selected and both surfaces filed flat until the key will enter the keyway completely. Pressure is applied to each individual wafer in order to establish correct spacing. The key is then filed until all tumblers are at shear line.

Although a key appears to be double-bitted, it may in fact only have one active surface. To allow for customer convenience, certain keyways are designed for the blank to be inserted to allow either vertical orientation of the bitting surface. The bitting will only mate with one set of wafers or tumblers, regardless of the position of the key. Many automobile locks appear to have two sets of tumblers but in fact only have one, although the keys are double cut.

9_4.2.3.1 Decoding of Wafers

The wafers can be inspected and decoded once the lock is taken apart. There may even be numbers stamped on each of the discs to indicate the depth of the cut. A key can be cut by code based upon that information. Although the HPC handheld decoder (**HPC HKD-75**) will not work with double-bitted keys, it is an excellent tool for single-bitted wafer locks.

9_5.0 Keys for Pin Tumbler Locks

9_5.1 Introduction

The modern pin tumbler lock was invented by Linus Yale in 1844 and is used throughout the world in every imaginable security application. Keys for pin tumbler as well as wafer locks are made of brass, nickel silver, or an aluminum alloy. Many high-security lock manufacturers produce their original keys in nickel silver, because it is physically stronger than other metals.

Blanks are inexpensive and easily obtained for most keyways. **Silca** and **Ilco** are probably the world's largest blank manufacturers and maintain complete data on virtually every lock that is produced and sold. In 2000, Silca was purchased by

Ilco-Unican. As can be imagined, there are thousands of different keyway combinations, many of which are very similar. Therefore, care must be taken that the proper blank is identified before cutting a particular key.

Keyways may be restricted to provide a greater measure of security against unauthorized duplication. They can also be made highly pick resistant through a complex design of wards.

Keys for pin tumbler locks can be produced from a source key, from code information, and from disassembly of the lock. Unlike wafer locks, keys cannot be reliably produced from visual decoding of the tumblers **externally** except in rare instances.

9_5.2 Source Key Duplicates

Direct duplicates of source keys can be made either by hand or by machine. Source keys can also be decoded. The information thus derived can then be input into a code-cutting key machine in order to produce the equivalent of a factory original.

Careful attention to spacing and cut angle is required whenever a key is cut by hand. If the V cut angle is greater than the range of 90°-120°, the key will have a tendency to hang up in the lock. This condition is known as **back cutting**; it can result in a great deal of difficulty when attempting to remove the key. Tolerance of the depth cuts is quite close, usually between .015” and .020”, leaving little room for error. Key duplicating machines must be adjusted for a maximum error of no more than .005”. The HPC key micrometer may be used to measure and verify each cut.

9_5.3 Producing Keys from a Disassembled Lock

Keys may be produced by actually taking the lock apart, then filing a blank key, one tumbler at a time, until all tumblers rest at shear line. Through disassembly, we gain direct access to the plug and shell together with all tumblers and springs. Once the lock has been taken apart using one of the described techniques, a key is cut from the information derived from each tumbler.

A pin tumbler lock must be taken apart for one of four reasons:

- **Change combinations;**
- **Make a key for the lock due to loss or other**

reasons;

- **Master key the lock;**
- **Cleaning and maintenance.**

Before one can work on the lock, it must be disassembled. Regardless of the design, the process for taking the lock apart is the same. Through disassembly, direct access is obtained to the plug and shell. We must be able to get at both sets of tumblers and the springs to effectively service the lock.

In the description that follows, procedures will be detailed pertaining to the cylinder lock, for this is the easiest to describe. Most of the other mechanisms can be taken apart in the same manner. Three basic tools are required for working on any pin tumbler lock: a **setup tray**, **follower**, and **pin loading tweezers**.

9_5.3.1 Disassembly Procedures

Locks can be disassembled in several ways, although there are two basic means for directly taking the cylinder lock apart. The first method involves removing the spring retaining strip, then dumping all of the springs and tumblers out of the shell through the chamber holes at the top of the cylinder. The second method requires removal of the plug from the lock directly without disturbing the retaining strip. The first technique is a simple procedure, the second can be made difficult in certain instances.

9_5.3.1.1 Removing Spring-Retaining Strip

In most cylinder locks, there is a flat piece of soft metal, generally brass, which will be crimped or pressed into a slot directly above the springs. This strip seals the pin chambers, thereby providing a stop for each spring so that tension is created for each top tumbler. Tapped setscrews may also be used in certain locks such as Medeco, in place of the spring-retaining strip.

With a pointed instrument such as a small screwdriver, the end of a drawing compass, or an ice pick, the strip can be pried back and withdrawn. Care must be exercised to remove the strip slowly, preferably with the index finger covering the chamber holes as the piece is withdrawn. If removed from the lock improperly, the springs will fly out of the chambers because they are under constant tension. Once the retaining strip is released, the

springs, drivers, and lower pins are carefully removed, the cam is taken off the back of the lock, and the plug is withdrawn.

A word of caution when removing the tumblers: If a key is to be made or if the lock is master keyed, extreme care must be exercised to insure that the tumbler order and stacking is not disturbed. The use of a setup tray is recommended. The tumblers can be individually released from the chambers and put into the tray. They can be replaced in the same order.

9_5.3.1.2 Removal of Plug Using the Correct Key

The plug, containing the lower set of pins, may be directly removed from the lock. The correct key is inserted into the keyway, the plug turned 90°, and then withdrawn from the shell after the cam is released. In order to remove the plug and lower pins without disturbing the driver and master pins, a **follower** or **following tool** is utilized. The follower is a wood or metal rod having the same diameter as the plug.

Followers may be made from wooden dowels or purchased from lock supply houses. HPC makes a following tool kit (HPC SUT-14) that has four different sizes, diameters, and ends. In addition, a spring-loaded, adjustable follower (HPC SUT-22) is available and recommended. Various plugs have ends with different shapes, thus requiring matching followers. However, a flat-ended tool may be used in a majority of locks, if care is exercised during insertion. A kit containing followers with the diameters of .395" (small size Yale and Corbin) .495”, .5" (common plug diameter) and .55" (large diameter plugs) is a necessity.

After the cam has been **removed**, the follower is placed against the back of the plug, and slight pressure is applied so that, in essence, the follower and plug form one continuous rod. As pressure is applied from the rear, the follower forces the plug out the front of the lock. The cylinder is held in the right hand, the follower being pressed into the lock with the left, while the right thumb is used to control the movement of the plug as it is withdrawn.

Applying pressure during the removal process is required to retain the proper order of pins, especially where there are master pins and where pin-stack length may be critical. It will be recalled that the term **“pin-stack”** refers to the total length of driver and lower pins. There must never be a gap between the

follower and end of the plug. The function of the following tool is to prevent the drivers and springs from entering the space occupied by the plug when removed. Remember, the top tumblers are under constant bias: if the plug is simply pulled from the lock without a follower in place, there is nothing to prevent them from ejecting into the void.

This procedure presumes that the correct key is available. Often, however, keys have been lost or a key must be fitted to the lock for other reasons. When this occurs, the initial problem becomes how to remove the plug from the lock. In many instances, the **spring-retaining strip** can be removed, but often this is impossible due to the locks construction, especially in mortise cylinders. Realizing that the drivers must be above shear line in order for the plug to be turned and removed, there are several means to accomplish this. **Shimming**, **bumping**, **rapping**, or **picking** are all options.

Whichever method is utilized to ultimately remove the plug, a note of caution is in order. **Always rotate the plug 90° prior to removal.** Often, a lock with six chambers may only be keyed for five pins. There is thus an extra hole in the plug in the sixth pin position. If the plug is not rotated prior to being withdrawn, the fifth driver and spring will drop into the empty sixth hole. When this occurs, the plug must be withdrawn with the spring jammed between the plug and shell. It will feel as if there is gravel in the lock, and of course, the springs will be destroyed.

9_5.3.1.3 Cam-Retaining Mechanisms

A number of different means are employed to secure the plug within the shell, including spring steel arc rings, pins, screws, and screw-on caps. The arc rings can be removed with the aid of a special set of pliers. Care is required to insure that the rings are inserted with their flat side towards the plug for proper seating.

Spring-loaded pins are quite easily removed and reinserted. They provide a wedge so that the plug cannot be withdrawn from the lock when in position. A number of manufacturers, including Schlage, use a screw-on cap arrangement together with a **spring-loaded pin** to retain the plug. When the cap is screwed tightly to the back of the plug, the pin will lock itself into the cap and thereby hold it in a secure position. Screw-on caps have the advantage that the plug rarely works itself loose.



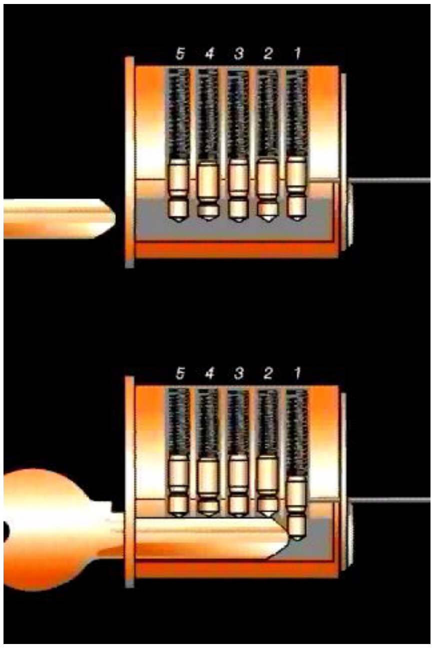

The use of screws is perhaps the most common means of securing the plug. Generally, two screws are present, through a tailpiece. Cam screws must be tight to insure proper operation of the lock. If they are loose, keys cannot be properly withdrawn and it may become necessary to place frontal pressure on the plug to allow removal of the key.

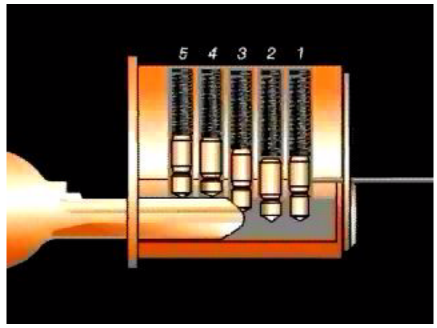
9_5.3.1.4 Disassembly of the Locked Cylinder without a Key

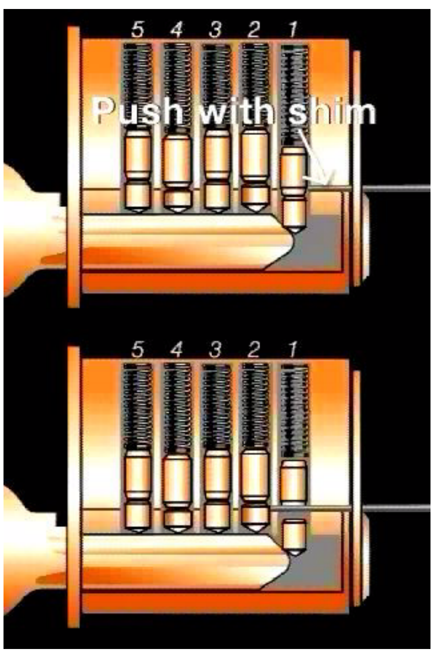
As has been described, locks may be taken apart for a variety of reasons. In cases where the cylinder is locked and no key is available, the plug can be removed using the techniques detailed below. **Chapter 16** provides additional information regarding pin tumbler cylinder disassembly.

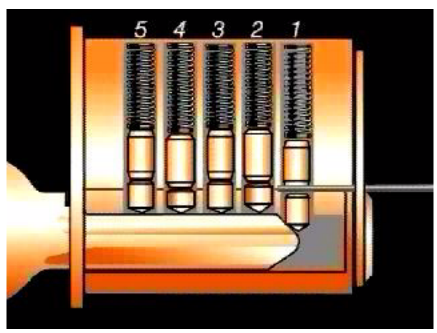
9_5.3.1.4.1 Shimming Open the Lock

Shimming is a technique whereby pressure is applied against the edge of each tumbler, in succession, by a very thin strip of metal called a shim. It is inserted from the back of the lock in the clearance area between the plug and shell. As each tumbler is forced upward, the shim will slip between the tumblers as they cross shear line.


5 4 3 2 1
5 4 3 2 1


5 4 3 2 1


5 4 3 2 1
Push with shim
5 4 3 2 1


5 4 3 2 1

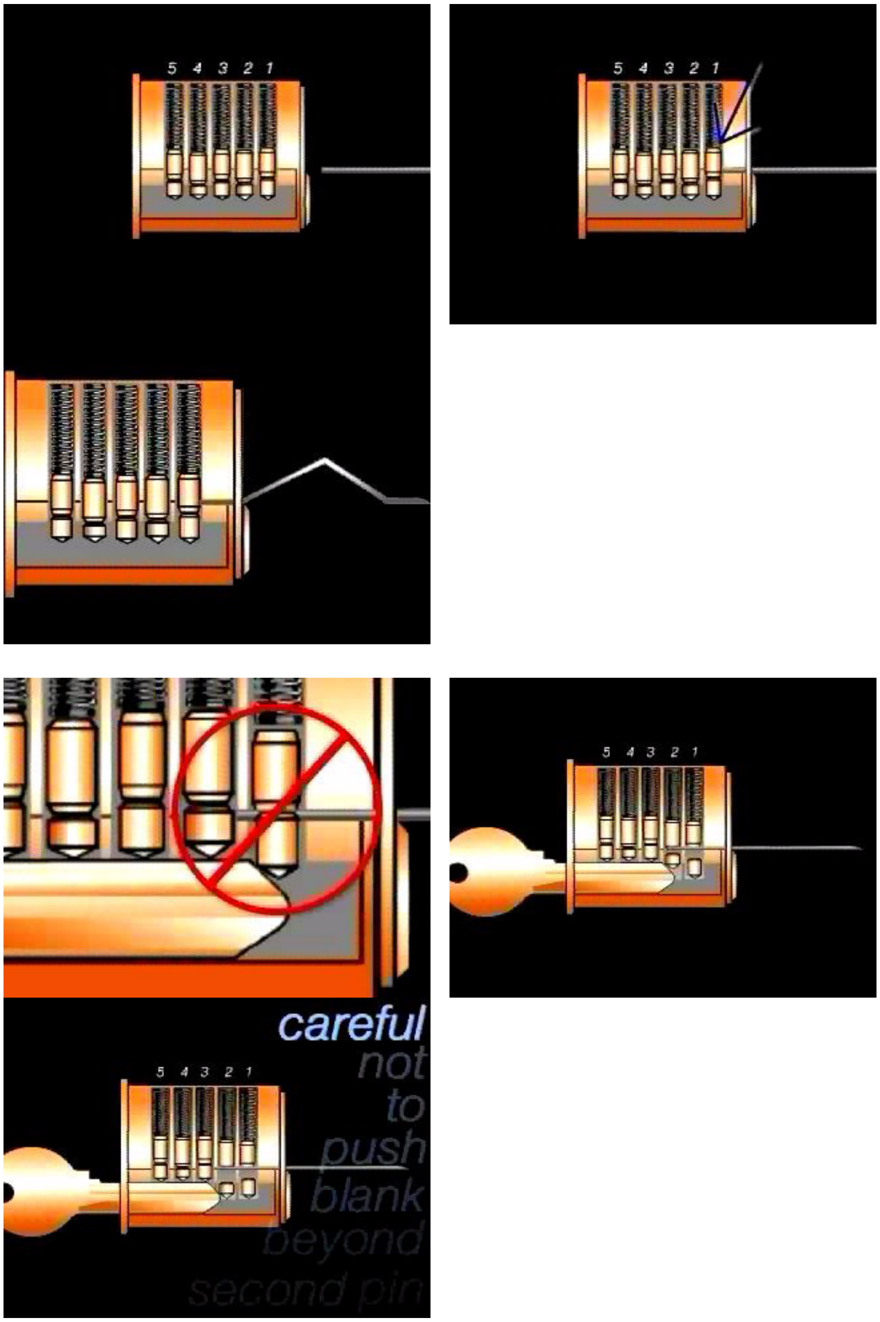


Figure LSS+901 This series of drawings illustrates the proper use of a shim to split the bottom and top pins within a cylinder that is locked. The key is utilized to raise each pin to shear line while pressure is applied with the shim against each pin in sequence. Be certain not to apply too much pressure to the shim, and never attempt to force the key under a pin that has been split by the shim. Courtesy of HPC Interactive Learning Series.

A very thin (<.005”) metal shim may be utilized to **split** the

lower and upper pins at shear line, thus allowing the plug to be removed. The shim may be made of flat or curved spring steel stock, usually between .002″ to .0015", 1/8" wide, and several inches in length. An excellent shim consists of the mainspring or suspension wire from a watch or clock. These may be obtained from most jewelers or jewelry supply houses.

Shims can also be produced from film negatives. The celluloid can be cut into narrow strips. Shims are also made from metal stock. A set of shims with the following thickness will suffice for a majority of situations: .0015″, .002″, .0025″, .003″, .004″, .006″, .008″, .010″, .012″, .015″. A complete set of shims is available from HPC.

The proper procedure to open a lock by shimming requires the following steps:

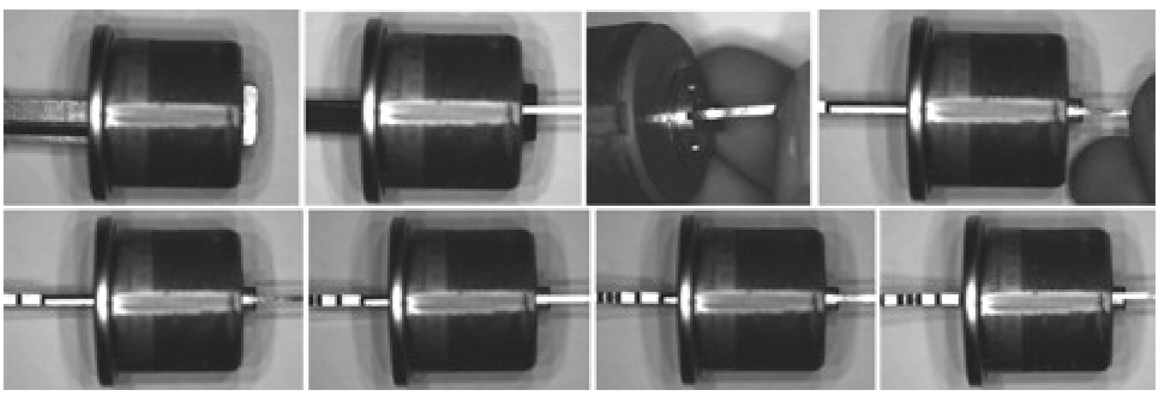
- **Remove the plug retaining screws and cam;**
- **Insert the shim in the clearance area between the plug and shell, from the last tumbler position at the back of the lock;**
- **Exert a forward pressure on the shim until it is stopped by the farthest rear tumbler. The pressure required for shimming is minimal: excessive bias will prevent the bottom pin from falling or will deform the shim. One can feel each tumbler as the shim scrapes its vertical surface;**
- **Insert a blank key from the front of the lock; it is used to raise each of the lower tumblers above shear line;**
- **Retract the blank very slowly. As the first tumbler with which the shim makes contact is lowered to shear line, the thin wire can be pushed between the driver and the lower pin until the wire is blocked by the second set of tumblers. It may be necessary to move the key back and forth slightly in order to engage the shim;**
- **The blank is carefully pulled back, allowing the wire to be slipped between the second driver and lower pin;**
- **Repeat the procedure for each pin-stack. This process is continued until all of the tumblers have been separated. As each tumbler is split, the key will extend that much further from the front of the**

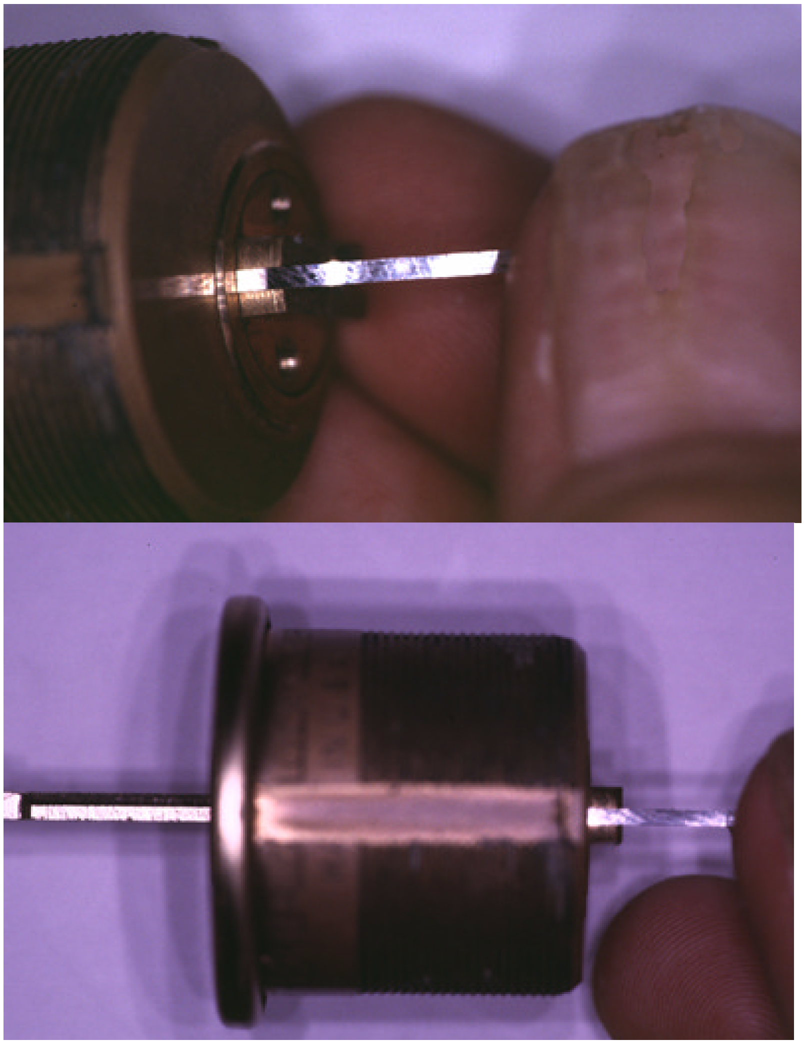
lock;

- Never move the blank over an already split tumbler;
- Once the shim has split every pin-stack, the plug is free to turn, because there are no drivers projecting into the plug. They are held above shear line by the wire. With the wire still in place between pins, the plug is turned approximately 90°, and the shim removed. It is now a simple matter to insert a following tool and withdraw the plug.

Shimming a lock containing security tumblers can present more difficulty. If mushroom, spool, or serrated pins are encountered, pull the shim back slightly in order to clear the indented portion.

Forensic implications of using a shim to open a lock prior to analysis. Courtesy of Hans Mejlshede.





Exploded view of shimming sequence 1, 2, 3, 4, 5.

9_5.3.1.5 Rapping Open the Lock

A pin tumbler lock may be rapped open, through the application of slight pressure to the rear of the plug, after the retaining screws and cam have been removed. The procedure involves the sharp rapping or striking of the top of the cylinder with a rubber or wooden mallet, plastic screwdriver handle, or similar object, while pressure is applied to the plug. Lightly slamming the assembly against a hard rubber work surface, such as a tabletop may also open a cylinder.

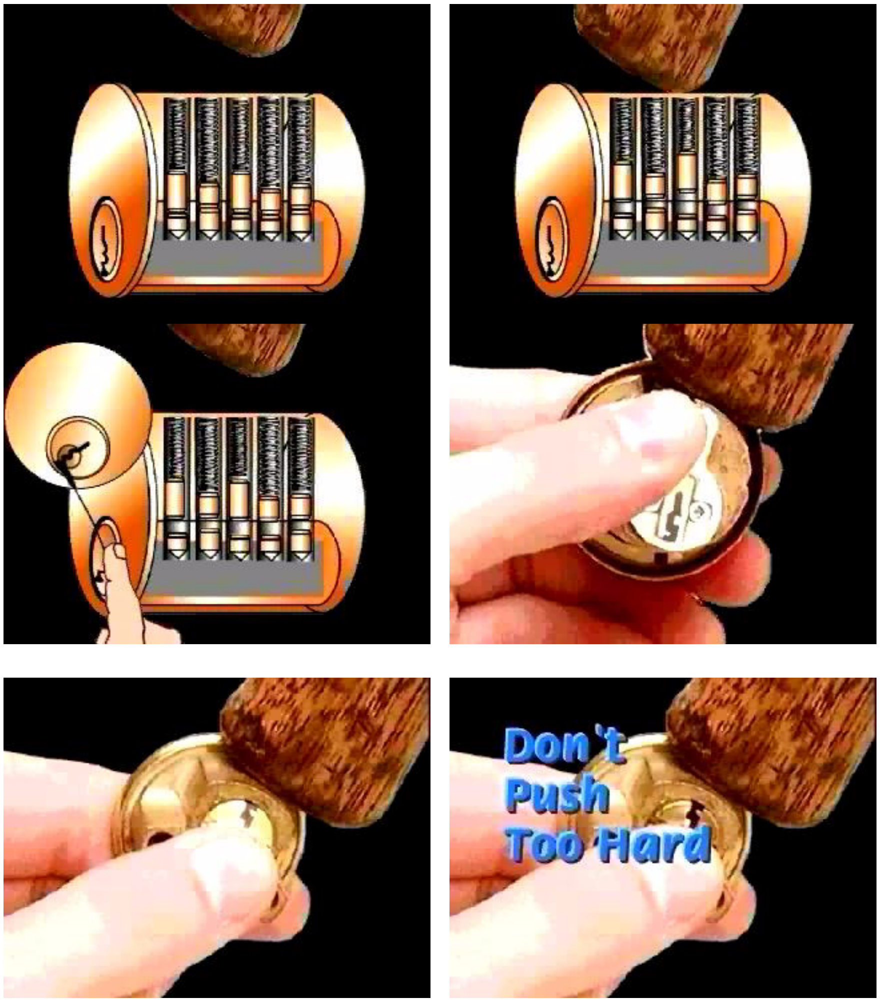


Figure LSS+902 The process of rapping a cylinder requires that sufficient energy be provided to bounce all of the driver pins above shear line. A wooden or rubber mallet may be utilized for this purpose. In practice, the cam is removed from the rear of the cylinder and pressure is exerted to the rear of the plug while shock is applied to the shell to bounce the tumblers. Courtesy of HPC Interactive Learning Series.

In theory, the sudden shock causes all of the upper tumblers to bounce above shear line, leaving a break between all lower and upper pins just long enough for the plug to be free to turn. The driver pins will be moved based upon **Newton's Third Law of Motion:(128)** for every action, there is an equal and opposite reaction. The theory is the same as when using a snap pick gun, discussed in **Chapter 29.**

In practice, the cylinder is held in one hand, with the index finger pressing against the rear of the plug (after removal of

any cam-locking device). The lock is rapped above the springs several times. If done correctly with only two or three hits, the core can be pushed forward to clear the drivers. Care must be exercised that the plug is not pushed too far forward, allowing the drivers to enter the lower pin chambers. If this should occur, removal can be very difficult.

Once the pins are split, the plug should be rotated 90°, the follower tool inserted, and the plug removed. To facilitate successful rapping, the plug should be cleaned, allowing the pins to move easily in their chambers.

9_5.3.1.5.1 "999" Rapping

A modified form of rapping, quite popular in Denmark, is referred to as "999" rapping or bumping. This technique involves the use of a precut key that fits the keyway of the target lock. The blank is prepared by code cutting all tumbler positions to the greatest possible depth (usually a 9 cut). The "999" key is inserted into the lock completely, then withdrawn one tumbler position. A very slight turning pressure is exerted while the head end of the key is rapped with a mallet. In this manner, a shock is applied to all tumblers simultaneously that causes them to bounce the drivers past shear line. With practice, the lock can be opened with one or two strikes. A full discussion of this technique is presented in **Chapter 29**.

9_5.3.1.6 Picking the Lock

The lock can be picked open and the plug removed. In this procedure, the lock is picked, the following tool inserted, and the plug rotated and removed. When picking, special care must be exercised for master keyed locks. Many times, some of the lower pins and wafers will be picked at the same time. The pins must be removed carefully in order to insure that the combination is not disturbed.

9_5.4 Making the Key After Disassembly

Making a key directly from the internal components of the lock is a straightforward procedure. The lock is first disassembled by one of the methods described earlier in this chapter. The tumblers are placed into the setup tray, one chamber at a time, so that the combination is not disturbed. Special care must be taken when master pins are present in order to insure that the

proper sequence of pins is properly transferred. The correct procedure to produce a key from the bottom set of pins requires the following steps:

- **Select the correct blank for the keyway;**
- **Insert the blank into the plug;**
- **Move a sharp-pointed instrument such as the tip of a file or the point of a compass across the surface of the key, through each chamber hole to mark their position on the blade. In the alternative, slight cuts may be made on a blank, using a code- cutting machine, to indicate tumbler spacing;**
- **Insert the first tumbler into its proper position within the plug;**
- **Remove the key and file until the tumbler is at shear line;**
- **Shape each cut for angle and size;**
- **Continue this procedure until all of the tumblers have been reinserted into the plug and are even with the shear line;**
- **The plug may be replaced and the lock reassembled.**

An alternative procedure is to measure each lower tumbler and then determine the depth correlation from manufacturer data. A key can then be reproduced from the information so derived.

9_5.4.1 Master Keys

Making a key directly from the tumblers removed from a master keyed cylinder often requires several different attempts. This occurs because the precise combination may not be readily discernible from the tumblers due to the mix of lower pins and wafers. Difficulty may be encountered because the master key may be a combination of lower pins in certain positions, and lower pins together with master pins in other positions. The problem can become even more complex if there is more than one master pin utilized in any chamber, which is typical in a multilevel keying system.

9_5.5 Assembling the Lock

After a working key has been produced, the lock must be put back together. This is a simple procedure but must be done carefully.

Whether the metal spring-retaining strip was removed prior to disassembly will determine the procedure for replacing all of the tumblers during the assembly process.

9_5.5.1 Replacing Retaining Strip

If the lock was disassembled by removing the metal-retaining strip covering the springs the correct lower tumblers, followed by the drivers and springs, are dropped into each chamber. After all pin stacks have been replaced, the strip is slid back into its original position. Care must be exercised to insure that the strip crimps none of the tops of the springs and is properly seated.

9_5.5.2 Assembling the Lock Through the Center

When a lock is completely taken apart, having removed all of the top and bottom pins and springs, more skill is required to replace the parts. This is especially true if the spring-retaining strip was not used to gain access to the chambers. Each of the top pins and springs can be replaced going through the void in the shell left by the plug. The lower pins can be inserted into the plug without difficulty. The springs and drivers present the problem. For this operation, a following tool and a good pair of long tweezers (HPC TPT-5 or equivalent) are required.

Conceptually, the following events must occur to properly reassemble a lock:

- **Each chamber must be loaded with its spring and top pin;**
- **As each chamber is loaded, the partial pin-stack must be retained in position, using a follower;**
- **When all chambers have been loaded, the plug containing all lower pins and master pins is inserted into the lock, replacing the following tool.**

The proper procedure to reload a cylinder requires the following steps:

- **Replace all lower tumblers in the plug;**
- **Insert the correct key into the plug, and verify that the shear line is perfectly level;**

- **Insert any master pins;**
- **Place each spring and associated driver into an individual chamber, using the following method:**

  - **The following tool is inserted from the front of the lock and pushed back to the middle chamber;**
  - **A top pin is picked up with the tweezers and pressed into a chamber. It is best to hold the driver at a 90° angle to the tweezers and press straight down into the hole. If the HPC TPT-5 is used, a pin-pushing attachment is included for ease in depressing the driver into the chamber;**
  - **As the tumbler is pressed into position, some resistance will be encountered due to spring action. The problem becomes one of how to hold the driver in the hole long enough to force the follower over it. The easiest method is to press the pin into the chamber about halfway, then apply pressure against the pin with the follower tool. With this pressure applied, it is a simple matter to push the pin all the way into the hole;**
  - **After the first driver is seated, the process is repeated, placing a driver in the next chamber toward the front of the lock;**
  - **The follower tool is moved forward, now covering two chambers. In like fashion, the next chamber toward the front is loaded with a driver;**
  - **When all of the chambers, from the middle of the lock to the front, are loaded, then the follower tool is pulled through the lock to the front, exposing the remaining chambers at the rear. These are loaded, from the chamber in the middle to the last chamber at the rear;**

- **After the driver pins have all been inserted into the shell, the plug is put back in place;**
- **The cam screws are then tightened. This last point is very important, because the plug will be pulled out of the lock if the cam screws are not present.**

9_5.6 Keys by Code

Code machines and books are available for cutting keys to fit most pin tumbler locks. Keys can also be cut with a set of depth keys, or by hand using an accurate set of calipers or micrometer. HPC, Reed, Silca, and several other companies offer compilations of codes, both in book form and on computer, allowing the generation of keys for almost any lock.

CHAPTER TEN: SECURITY RATINGS

High-Security Locks and Keys

10_1.0 Introduction

The requirement for high-security in locks and keys is found within both government and the private sector everywhere. As will be detailed, there are different levels of security based upon construction, design, and programming criteria. This chapter will define and provide evaluation criteria for high-security locks, their keys, and keying systems. Combination locks are not included in this discussion; they are presented in **Chapter 34.** High-security locks are also examined in **Chapters 24-27** in the context of forensic investigations.

10_1.1 High-Security: What is it and What Does it Mean?

High-security is an extremely broad term, having no precise definition. Its meaning is dependent upon user requirements and environment. High-security for government, for example, may have an entirely different connotation than for a bank or jeweler. The security objective of a GSA Class 6 container, for example, will be vastly different than for a safe containing negotiable instruments. Whereas the contents of the GSA container will generally be documents and information having no actual worth, the bonds or currency within the safe will have a defined value. The loss of negotiable instruments or money can be calculated precisely. The compromise of classified documents or the information contained therein may be inestimable, especially if the penetration is not detected.

Many aspects and factors constitute high-security in a lock or key system. In its simplest form, the concept simply means that a lock meets certain tests and standards that make it more

difficult to penetrate, compromise, or open than an ordinary lock. The term "difficulty," of course, also has to be defined. The difficulty in compromising a lock relates to physical methods, available tools, skill and time. A lock will receive a higher security rating as these factors increase. Standards for locks are discussed in **Chapter 37**.

10_1.2 High-Security Lock Manufacturers

There are many high-security locks produced throughout the world. Different design schemes are employed utilizing mechanical, magnetic, electronic, electromechanical, and hybrid configurations. There is not one "best" design. In part, this is because different configurations meet varying and unique needs that are based upon the user, location, environment, area or objects to be protected, cost, and other factors.

Major manufacturers of locks that offer or represent that they offer high-security include **Abloy**, **Assa**, **Chicago**, **Chubb**, **DOM**, **Evva**, **Ikon**, **Kaba**, **Keso**, **Medeco**, **Miwa**, **Mul-T-Lock**, and **Schlage**. A detailed examination of many of these locks is presented in **Chapters 17-23**.

10_1.3 Standards and Ratings

In America, Underwriters Laboratory standard UL 437 defines high-security for key locks, and UL 768 for safes. Military standards for locks, safes, and enclosures that are used for storing classified documents may also apply. The reader is directed to **Chapter 37** for a detailed analyses of the provisions of UL 437 and related European/EC standards.

The UL 437 standard addresses both forced and surreptitious-entry techniques and the resistance of a lock to such physical and non-physical attack methods. Specifically, the standard provides tests for picking, impressioning, forcing, drilling, sawing, prying, pulling, and driving. All high-security locks should meet UL 437 or the equivalent European or EC standard.

10_2.0 Evaluation of High-Security Locks

Criteria have been developed to evaluate high-security locks. The following issues are relevant to such evaluations.

10_2.1 Criteria for Evaluating High-Security Locks

High-security locks must frustrate forced and surreptitious attempts to open them. Each manufacturer will define its own concept of high-security. A rating requires certain standard design features, options, methods of construction, and production and distribution controls that must be incorporated into such products. The most recognized of these criteria, relating specifically to keys and keying systems, are discussed in this section. Evaluation of locks, in the context of forced and surreptitious entry, is described in more detail in **Chapters 24-27.**

10_2.1.1 Key Control

Physical design and construction of high-security locks is equal in importance to the ability to rigidly control the production, generation, and duplication of keys. **Key control**, in the context of high-security, has a number of interrelated requirements, functions and purposes. The concept of key control encompasses requirements relating to keyways, blanks, master keying and standard keying options, protection from pirating, key machines, key design, and key codes. Key control also relates in part to the willingness and legal ability of the lock manufacturer to restrict the sale and distribution of keys, key codes, blanks, and key duplicating machines.

Properly implemented key control policies and procedures should address the following issues:

- **Limit unauthorized acquisition of keys;**
- **Control distribution of authorized keys;**
- **Provide organization of keys and key records;**
- **Insure that the premises, rather than people provide the basis for system design. That is, the keying system should be based upon building use or function, rather than individual users;**
- **Will promote the splitting of large systems into smaller, more manageable ones;**
- **Avoid cross-keying and and unintended master keying issues;**
- **Avoid maison keying, if possible;**
- **Define hardware limitations;**
- **Reduce keying levels;**

- **Provide for a method to account for all keys.**

10_2.1.2 Legal Protection for Keyways and Blanks

A manufacturer can take certain legal measures to increase the security of their products against unauthorized copying. Prior to purchase of high-security locks, a buyer should verify whether the keys, keyways, and other proprietary designs have been patented or copyrighted. Keyway sections should always be patented in order to restrict the ability to obtain key blanks or duplicate keys from other than the original manufacturer. In the absence of a patent or copyright, lock and key manufacturers have no legally protected proprietary right to prevent others from making facsimile or knockoff keyways or blanks. If keyways have been patented and/or copyrighted, then reproduction, import, sale, possession, or distribution can be prohibited.

Enforcement of such protection is through injunctive relief and seizure of contraband product pursuant to federal law. Generally, a patent can be valid for 20 years; a copyright for 50 years. Buyers of high-security locks should determine from the manufacturer when patent protection will expire in order to insure against the commercial availability of restricted keys to prevent compromise and duplication.

The first American patent for a keyway design appears to have been issued to Walter Schlage. After that, all high-security lock manufacturers have depended upon the protection afforded by the granting of design and utility patents. That legal protection may, however, be in jeopardy. See later Schlage patents for the Triad-C and Triad-D keyway series (5715717 and 5809816).

In 1992 and 1993, Best was granted utility patents on locks, and design patents on their keyways. In 1994, Ilco, an international key manufacturer, released key blanks with the Best keyways, in violation of the patent. Best sued Ilco for infringement of patent 5,136,869 and lost the lawsuit. In effect, Best patents were ruled invalid, because, said the Court, they contained nothing new or unique. What they described were prior art, already invented, and enumerated in Best patent 1,866,342.

Best Lock Corp v Ilco Unican Corp(129), 95-1528 (Fed Cir, 29 Aug 1996). Best Lock owned design patent 327,636 for the ornamental design for the operative portion of a key blade blank, for use

with Best Locks patented (5,136,869) key blade and cylinder lock assembly using a wider key profile to deter lock-picking. Southern District of Indiana held the '636 design patent invalid as functional, not ornamental. The Federal Circuit affirmed the decision: 'Any aesthetic appeal of the key blade design shown in the '636 patent is the inevitable result of having a shape that is dictated solely by functional concerns.' Judge Newman dissented, saying that 'the fact that the key blade is the mate of a keyway does not convert the arbitrary key profile into a primarily functional design. It is not the design of the key profile that is functional, but the key itself.' This litigation may define the limits of protection for design and utility patents as they affect keyways and key blanks. If Ilco ultimately prevails, then all restricted keyways may be subject to duplication and knockoff.

10_2.1.3 Restricted Keyways

A manufacturer will create what are known as restricted or ***proprietary*** keyways and sections, not commercially available to the public. Restricted blanks for such keyways may be designed for a specific customer or for a class of customers. For example, the White House may have a restricted keyway. The manufacturer in such case would only provide blanks to authorized purchasers, such as the Secret Service. No other customer, anywhere in the world, would have the same keyway or keyway groups for their locks. Each customer may have its own unique restricted keyways.

There can be several levels of restrictions. The lowest level may be a generic restricted keyway that is available to locksmiths who distribute a manufacturer's product for use by any customer of that locksmith. The next level would be a keyway sold to one specific customer in a given area, but repeated in other geographic areas in the country or the world. A higher level of security would provide for a custom-designed keyway for use by one customer only.

Many design variations can be applied to keyway control. For example, Schlage and Assa sidebar pin tumbler locks utilize a system whereby the sidebar portion of the keyway is varied according to dealer or customer. Each locksmith in the world who sells Assa or Schlage is provided with precut blanks with a certain sidebar combination. The local distributor will then cut the vertical-bitting portion of the key to different combinations, but the sidebar combination will remain constant for a given geographic area.

The distribution of key blanks for restricted keyways must be closely controlled by the manufacturer. In many instances, this protection has been rendered ineffective, because unlicensed manufacturers or vendors provide locksmiths with blanks for restricted profiles. Knockoff blanks may also be produced, although patent and copyright infringement occurs. A registration system should be offered by the original manufacturer that will restrict the sale of cut keys only to authorized individuals. Compromise in security may also result if key blanks, similar in design and commercially available, are modified through filing or milling in order to fit restricted keyways.

10_2.1.3.1 Compromise of Multilevel Keyways

Another security issue involves restricted, multisection keyways incorporated within a master key system. The function of such systems, in large complexes, is to provide different sectional keyways, with one master key that will enter each of the individual subkeyways.

Higher security is maintained with respect to cross-keying, because no sectional key can enter any other keyway. The local distributor or locksmith may only stock the master key blanks rather than all of the sectional blanks because of availability and cost. The logic is that it is simply easier to stock one blank rather than ten or fifteen for the different sections. When a customer wants a key copied, it is often duplicated on the ***master*** blank rather than the proper sectional blank. The result of this practice is that the copy may open locks it was not intended for, simply because the key can now be inserted into any keyway in the system.

10_2.1.4 Key Duplication

Key control is enhanced when duplicate keys cannot be made on conventional key machines. Many lock manufacturers design their keyways and blanks to require special key machines to duplicate them. For example, Medeco keys cannot be produced on a conventional machine, because both vertical as well as angled cuts must be made. Likewise, to reproduce an Assa key, special side-milling cutters are required. The difficulty in producing keys contributes to a locks high-security rating.

Because authorized key holders usually want to obtain additional keys locally without delay or inconvenience, vendors will

generally make available to their dealers the necessary equipment to produce and duplicate keys. There are also a number of key machine suppliers who can provide a variety of devices capable of duplicating most keys, irrespective of the wishes of the original equipment manufacturer.

10_2.1.5 Key Codes

High-security lock makers will tightly control the access to direct code data for duplicating their keys. Often, such information will not even be available from the manufacturer. A vendor cannot legally prevent, however, the distribution of such data if it was gathered and published independently. Thus, several companies can provide code data on certain high-security locks. The ability to restrict the distribution or availability of such information should be considered in the evaluation of any high-security locking system.

10_2.2 Key Blank Design and Differing

Key blanks for high-security cylinders are typically made of nickel silver and are of one-piece design. The key blank, and particularly the bitting blade, should not easily bend or break under normal use. The thickness of the blade should be a minimum of 0.090”.

A high differing potential must be available, allowing the capability for millions of different keying combinations. Generally, blade depths are divided into 10 steps of 0.015”. When tolerance at shear line exceeds 0.005”, then bitting steps of 0.015” are too small to prevent key interchange. Bitting steps of less than 0.060” invite cross-keying. Master keying requires several million theoretical key differs to yield only a few thousand non-interchangeable keys for some high-security installations.

10_3.0 Keying System Design

Most high-security locks will incorporate two distinct and independent locking mechanisms. In the Medeco design, for example, there will be conventional vertical cuts and rotating tumblers. Thus, many complexities in multilevel keying must be taken into account.

There are several aspects to keying system design, including the

selection of keyway subsections, individual key bitting design, and the configuration of the master key system. In addition, secure keying techniques are required to prevent persons who have limited access to keys from modifying them, through milling or filing, to operate more locks than intended. Thus, a system must be designed so that individual change keys cannot be cut deeper to create a master key. Ideally, a master key should never have the capability of being generated from a change key.

10_3.1 Modification of Master Key

When an unauthorized person attempts to reproduce a master key, he will take a change key and cut it down to the master. This practice is especially prevalent where a restricted keyway is used and blank keys are unavailable. Typically, a change key is reported as lost then used to make a master, if the system has not been designed properly. For example, a change key may be coded 33308, the master, 80008. To convert the change key to a master, the first three tumblers are cut from 333 to 800. As noted, the way to prevent the practice is to design the master key with at least one cut which is higher than any of the change key depths.

All modern master key systems are computer-designed and generated. Such programs take into account and protect against:

- **Cross-keying;**
- **Adjacent depth-cut restrictions (placing a deep cut next to a shallow cut);**
- **Tolerances;**
- **Number of submaster levels;**
- **Keyway subsections;**
- **Improper conversion of change keys to master keys;**
- **Other parameters.**

All high-security master key systems should be capable of master, grand master, and great grand master levels. To increase security, mushroom-shaped driver pins should be randomly applied to each cylinder. False grooves may also be placed on the bottom pins to provide additional resistance to manipulation.

Some vendors have integrated computer control into master key systems for greater flexibility and security. Such systems can monitor:

- **Access by location as to time of day, day of week, holidays;**
- **Duration that a door can remain open;**
- **Entry or exit control;**
- **Number of times a door may be opened;**
- **Activation and deactivation dates;**
- **Limited number of users;**
- **Alarms;**
- **Door unlock time;**
- **Identify, control, and classify keying levels, such as standard, management, system override, or special needs key;**
- **Other factors.**

All cylinders should be factory master keyed pursuant to owner requirements. All keys and blanks should be sent from the factory, via registered mail, and hand delivered directly to the owner's representative.

10_4.0 Product Flexibility

The flexibility of a product, to meet customer-specific requirements, is integral to the security and functionality of a system. Product flexibility encompasses the following issues:

- **Serviceability;**
- **Functionality;**
- **Depth of product line;**
- **Master keying levels;**
- **Standard keying options;**
- **Keyway restrictions;**
- **Convenience in obtaining duplicate keys;**
- **Factory key control;**
- **Ease in rekeying;**
- **Training;**
- **Widespread government acceptance;**
- **Level of keyway protection;**
- **Keyway restriction to one customer, or reuse in other geographic areas;**

- **Requirement for special key machines;**
- **Cost of key machines;**
- **Availability of key machines;**
- **Difficulty of rekeying cylinders on premises;**
- **Supplemental security hardware available from the manufacturer to allow installation of cylinders in such a way as to resist sharp pulling force that is intended to remove cylinders and expose locking mechanisms;**
- **Cylinders should be capable of immediate rekeying to new combinations or a new system at any time;**
- **Serviceability on location;**
- **Installation of cylinders should require no modification to U.S.-manufactured commercial grade locksets;**
- **Manufacturer's keying should be designed to fit mortise locks, rim locks, knob cylinder locks, interchangeable core cylinders, padlocks, dead bolts, cam locks, and switch locks;**
- **Technical support provided by the manufacturer is extremely important. Technical training should be available, detailing all phases of service, keying, installation, troubleshooting, integration of electronic systems, and other related areas.**

10_5.0 Evaluation Criteria for High-Security Locks

Certain mechanical criteria has been established for high-security locks relating to:

- **Type of mechanism;**
- **Level of security of that mechanism, i.e., number of levers or tumblers;**
- **Availability of keyways;**
- **Number of differs;**
- **Materials of manufacture;**
- **Purpose of lock;**
- **Method of affixing;**
- **Pick resistance;**

- **Drill resistance;**
- **Forced-entry techniques;**
- **Tolerance at shear line;**
- **Key interchange;**
- **Tumbler manipulation;**
- **Decoding;**
- **Impressioning;**
- **Key jiggling;**
- **Progressive compromise.**

See the discussion in **Chapters 24-27** regarding analyses of a lock for bypass potential. The following summary provides a synopsis of evaluation criteria for high-security locks.

10_5.1 Mechanical Manipulation Evaluation Criteria

The following detail of mechanical evaluation criteria relate to the manipulation of internal components.

A. MINIMUM TOLERANCE AT SHEARLINE
B. RESIST KEY INTERCHANGE
C. RESISTS TUMBLER MANIPULATION
D. RESISTS DECODING TECHNIQUES
E. RESISTS IMPRESSIONING
F. RESISTS KEY JIGGLING
G. RESISTS PROGRESSIVE COMPROMISE

C,D,G
Any chambers that permit slight lateral movement of the plug before pins are lifted can permit decoding of bottom pin lengths.

A,B,E,F
Wide tolerances at shear line will facilitate jiggling, impressioning, and cross-combinations.

10_5.2 Forced-Entry Evaluation Criteria

The following tests are performed to determine resistance to the use of forced-entry techniques.

A. RESISTS COMMON DRILL BITS
B. RESISTS SAW BLADES
C. RESISTS HOLE SAWS
D. RESISTS HAND FILES
E. RESISTS THREADING OF KEY SLOT
F. RESISTS RESHAPING OF KEY SLOT
G. RESISTS FRAGMENTING WITH PUNCH, CHISEL, SCREWDRIVER, ETC.

A
Insert full key blank. Drill into cylinder body to engage all driver pins. Remove key blank. Rotate plug with screwdriver.

B,C,D,F
Saw or file between pins for systematic compromise.

E
Drill and tap key slot to pull key barrel with slam-hammer.

CHAPTER ELEVEN: COMPLEX SYSTEMS

Keying Systems

Master Exhibit Summary

11_1.0 Introduction

Specialized keying systems are required whenever there are a large number of locks in use at one installation or facility. Such systems can address complex issues of security, access control, convenience, safety, simplified organization, and executive access. The concept of a keying system relates to a hierarchy of keys and locks and individual access to them. The term can also describe a grouping of different locks for which one or more keys can be used to activate one or more single locks within each such group. A system can be designed so that each lock belonging to a level of keying can only be operated by an authorized user for a specific group or level. Ideally, each person should need only one key to access all locks within his individual sphere of responsibility (group).

Security requirements may dictate that certain locks not be master keyed or included in a master key system. In many institutions, there is a clear distinction between locks in administrative areas and those protecting higher security locations or property. It cannot be overstressed that every master key system suffers from a significant lack of security, regardless of whether so called "high security" locks are installed.

In the following discussion, each primary classification of mechanical lock and how they can be utilized in different keying systems is examined. General levels of keying (including key alike, master keying, maison keying, and construction keying) will be described. Later in the chapter, details regarding each system is presented. Keying systems are designed to facilitate access.

The terms “specialized” or “complex” encompass the following levels or forms of keying:

- **Change key;**
- **Keying alike;**
- **Maison keying;**
- **Master keying;**
- **Complex master keying, including hotels;**
- **Construction mastering.**

This chapter explores various systems of keying and their impact upon security. Detailed information is provided regarding the analysis of conventional master key systems in terms of planning, coding schemes, advantages and disadvantages, and the potential vulnerabilities of each system. In subsequent chapters, techniques and procedures are examined with regard to the compromise of the most common master key systems.

11_1.1 Definitions and General Concepts Relating to Keying Systems and Levels of Keying

Keying systems are designed to facilitate access. Locks and locking systems can be configured to allow access by one key or several levels of keying, depending upon administrative, convenience, and security requirements. Specialized keying systems contemplate any group of locks that provide for the use of more than one individual change key for access to a lock or groups of locks. Each system and level of keying is covered in detail in subsequent sections of this chapter, with a brief definition provided here. Our discussion will focus on pin tumbler mechanisms, although keying levels are also presented for warded, lever, and wafer locks.

11_1.1.1 Individual Keyed

The lowest level of keying requires that one key fits one lock (or a group of locks if they are keyed alike). In this type of arrangement, the lock is not part of a master key system or group of locks that is associated with any other keying level. There are only two tumblers within each pin stack (bottom pin and top pin), and thus, only one virtual shear line.

A lock may also have one change key that operates it, yet be part of a master key system. In such case, the lock may or may not be controlled by one or more levels of master keys, depending upon security and access requirements. Individually keyed locks and locks with an individual change key on a master key system constitute the lowest level of keying. It is simply a question of whether the lock is set so that only one bitting combination will open it as a stand alone lock, or whether a change key and one or more master keys will also allow access. Interchangeable core locks may also be individually keyed at the change key level, but may be master keyed at the control shear line.

11_1.1.2 Keying Alike

Locks that are "keyed alike" all have the same pin combinations and thus are interchangeable. Any number of locks can be keyed alike and can be considered as a subset to locks that have one individual change key. It should be noted, however, that several locks can have the same change key, yet also be master keyed. In this instance, for example, several cylinders within a work area could have the same change key, yet all be controlled by one or more master keys. Key alike systems are the simplest and allow one or more locks to be operated by a common key. Any lock can be keyed in this fashion.

11_1.1.3 Maison Keying

In the progression of keying systems, maison level can be thought of as a mix between keyed alike and individually keyed locks. In a maison system, all locks have their own change key and part of every change key may be common to the maison locks. **Maison** (French, meaning **house**) keying is used in apartment houses, college dormitories, and other communal areas where the individual change key must open both the room lock and also an outside door, garage, cellar, or other common access point. Typically, a resident must be able to unlock outside access doors and an individual apartment. Rather than issuing separate keys for each lock, the management can maison-key all access locks in a way that each change key can open them. Maison keying cannot be classified as a master key system. Rather, it should be thought of as a subset of a keyed alike system. The maison locks are keyed to the identical combination for one or more chambers in one scheme, and multiple virtual shear lines are created in another technique. As shown in the diagram, six tenants can access each of their apartments as well as three common areas in another example of a **maison system**.

It can be thought of as the reverse to a master key system where one key is designed to fit every lock within a certain group or level. In the maison system, all keys will fit one or more locks in common areas, yet allow each individual change key to fit one or more specific locks. A maison system can also be part of a master key system. In such an instance, cylinders are pinned in order to create intentional cross-keys. This concept is explored in later sections. In any installation where maison keying is employed, a significant reduction in security will result. Difficulty can also be encountered if maison-keyed locks must be re-keyed, depending upon which keying technique is employed.

Maison systems can be easily compromised in a variety of ways, including picking, "key picking", and the use of keys that are not intended to open a lock. Key picking, the technique of moving an unintended key in and out of a lock, allows the manipulation of pin segments (much like rake picking) in order to raise each pin stack to a shear line.

11_1.1.4 Master Keying

A master key system in its simplest definition is one that has two or more keying levels. In such a system, the locks can be combinated so that one key will open all of the master keyed locks that are associated within a group, yet allow each individual change key to operate one or more locks that have been pinned to that specific key. In reality, master keying systems are simply a grouping of numbers that correlate to the bitting of keys and locks that are linked or associated by function in one or more groupings. Such groupings can be called master key levels and can provide for access by one key to one or more groups.

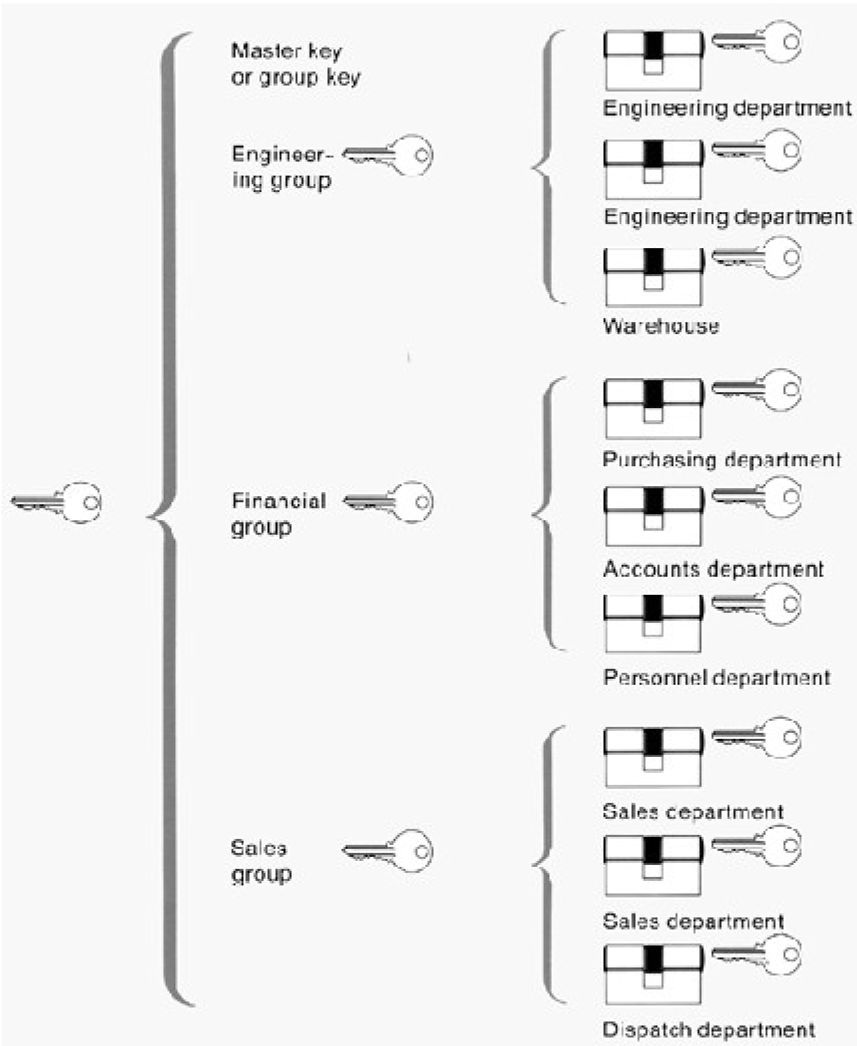
The master key system is the most complex of keying arrangements. The goal is to allow the use of two or more different keys for one lock without a compromise in security from picking, use of skeleton keys, cross-keying, decoding, or a decrease in tolerances. Every master key system establishes a hierarchy of access, dependent upon security, convenience, and need.

The ability to master key a lock depends upon the design of its mechanism. In the warded lock, there are **fixed detainers** that significantly restrict master keying complexity and security. In contrast, lever, wafer, and pin tumbler locks utilize **double-detainer action**, allowing secure forms of master keying in often complex environments. Master keying in the double-detainer type of lock will rely upon certain functions associated with the operation of the individual change key. A second contact point, shear line, or mechanism may also be created for the operation of the master key.

A master system allows one or more locks to be operated by a key having a combination different than that of the change key. There are several levels and techniques applied to master keying. The simplest system level is one in which each lock has its own change key and can also be operated by one master key. This would be designated as a **master keying** level (two level system). A **grand master** offers one level above master keying (three level

system) and is used to open locks in several different submastered series or groups. In other words, a building may have two different wings, where each wing may have its own master key. A master key designed to operate in one wing would not open the locks in the other wing. The purpose of the grand master, then, is to work all of the locks in both wings.

The next step above the grand master is the **great grand master** (four level system). The same principles apply. There is a practical limit to the number of keying levels (generally six levels of keying) that can be established in a conventional system. Limitations are dictated by differs, tolerances, and adjacent cut restrictions. More sophisticated locks, such as the Medeco Biaxial, Medeco M3, and Evva magnetic sidebar system can allow more flexibility in complex systems. See **Chapter 19.**



11_1.1.5 Complex Master Keying

Complex master keying systems can provide up to six levels of keying, allowing for complex access to one lock or groups of locks. Such systems are described in later sections, and would include **hotel keying systems** where several levels of master keying may be required to allow for limited access by maintenance, cleaning, and housekeeping staff, while providing full access to security and management.

The factory will promulgate design specifications for each cylinder in order to insure that the system meets all mechanical requirements and limitations for optimum security. Standard progression techniques (TPP or RC) must be used; otherwise, a

significant decrease in security will result. Failure to adhere to standard keying techniques and resultant use of one progression is the minimum depth increment is less than .023" can result in the improper generation of combinations, leading to the use of master pins that are too thin.

If the spacing between master and change key codes is only one depth-cut apart, a thin wafer can flip sideways in the pin chamber. When this occurs, the lock becomes jammed and will not open. This condition can prove very inconvenient and costly. Generally, master key systems require that there be at least a .023" thick master pin to avoid problems.

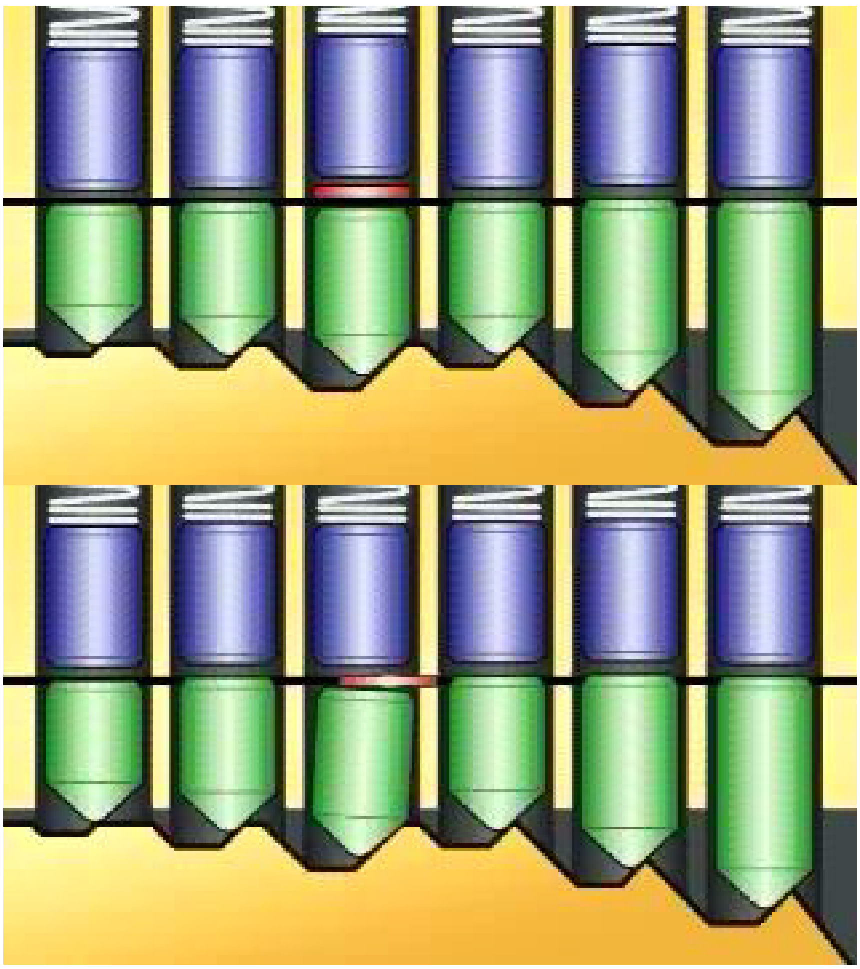


Figure LSS+1102 If master pins are too thin, they can dislodge within the chamber and cause a lock-out. Courtesy of HPC Interactive Learning Series.

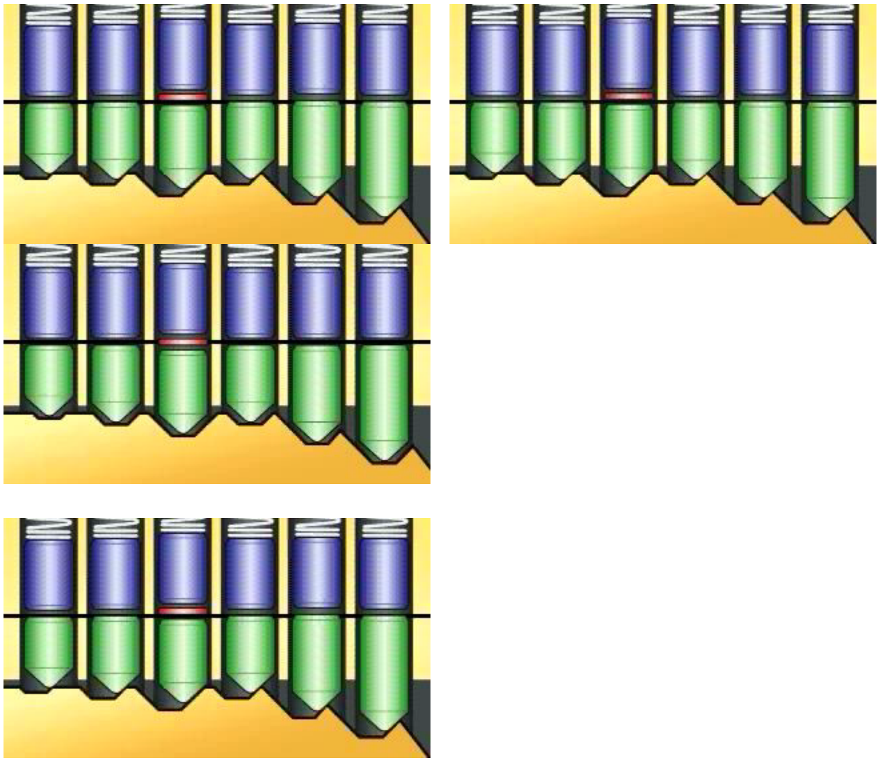


Figure LSS+1103 If master pins are too thin, then a change key can be jiggled back and forth to raise the pin, as shown. Maintenance problems can also be created. Courtesy of HPC Interactive Learning Series.

11_1.1.6 Hotel Keying Systems

Hardware used in the lodging industry must provide both security and enhanced auditing functions. Mechanical cylinders will usually have six or seven pin tumblers and utilize standard keyways. Lockout functions can be activated by guests inside the room, and once activated, only an emergency key can enter the keyway to retract the bolt. Hotel systems have unique keying requirements with multilevel access for different staffing functions. Generally, total position progression systems are employed in these installations. It must be noted, however, that hotel keying systems are extremely vulnerable to decoding and compromise of the TMK because it is easy to obtain a change key in order to derive the codes for the top level master key. This subject is thoroughly examined in subsequent sections.

Many ingenious systems have been designed for the hotel industry. One of the most unique was patented by **Winfield(130)**. The Winfield **cylinder** contains two distinct keyways: one for the

guest and one for the maid or maintenance staff. These locks have also found limited acceptance within colleges and other complexes where instant reprogramming is desirable. See **Chapter 23** for a thorough discussion of hotel locks and those produced by **Winfield.**

11_1.1.7 Construction Master Keying

A **construction master** system allows one or more keys to open all locks within a building site during construction. In order to prevent workers from later using these masters, the system is converted automatically at the conclusion of the project so that the construction keys will no longer function. Certain cylinders have been designed to meet the security needs inherent in buildings under construction. Their function is to prevent the compromise of master keys by project workers while offering the needed job site access to different areas. Workers can be granted access during the project, but denied after completion.

Initially, they provide for the operation of all locks using special keys or inserts, allowing workers to enter all areas without restriction. When a building is completed, the special inserts are removed or the tumbler combinations reset or cores exchanged so that the locks are ready for use by the tenants. The original keying scheme no longer exists, thus rendering all construction keys inoperable. There are several schemes for construction mastering that are based upon different fundamental design configurations. Keyway lockouts, second shear lines, removable cores and unique parking of tumblers are all in use. Examples of construction keying systems are presented later in this chapter.

In large tract construction sites where hundreds of homes are built by one contractor, locks are often master keyed for worker convenience. No special construction keying systems are employed in such instances. At the conclusion of the project, homes are turned over to buyers with individual change keys. Unfortunately, the locks are still master keyed and are subject to compromise through disassembly or by the extrapolation and decoding of the master key through procedures detailed in **chapter 31**. In burglary investigations in townhouse communities, for example, it would be well to examine one or more locks to determine if the complex has been master keyed. Such information may provide a clue as to entry techniques.

11_2.0 Warded Locks

11_2.1 Introduction

The warded lock is the most primary of all mechanisms. Because of its extremely simple construction, it offers a very limited range of keying options. The warded lock may be keyed alike or master keyed for two keying levels, but the number of wards will limit the number of available combinations.

11_2.2 Warded Master Keying

Master keying schemes generally rely upon an alteration of the design of the key rather than the wards. In some systems, different keyways may also be employed. It will be recalled that wards are fixed obstructions and thus cannot be changed. A **skeleton key** may be produced to open all warded locks within a series. Complex master keying, in the practical sense of the word, is not possible. For this reason, warded locks have a very limited use in any environment where security is at issue. Except in hotels and prisons, few warded locks are master keyed. In these instances, special locks can be used that are designed to accommodate higher level keying. They are still vulnerable to skeleton and pick keys, however.

11_3.0 Lever Locks

Lever locks can be individually keyed, keyed alike and, in some cases, master keyed to allow a total of two keying levels. The instance of high-level keying is rare, however. There are four primary uses for lever locks in the United States: lockers, **safe-deposit**, **mailbox**, **pay telephones**. Everywhere else in the world, they are quite popular in all applications.

Safe-deposit boxes generally utilize double cylinders; the customer (renters) lock is keyed individually, the bank lock (guard) is keyed alike. Coin phones are generally keyed alike for the electronics (upper) housing, with individual keying of the coin box vault. All U.S. mailbox collection points are keyed alike in groups, geographic sectors, by city or zip code, or by specific location. Standard keyways for mailboxes, drop boxes, and certified or registered mail pouches have been adopted throughout the United States.

11_3.1 Master Keying Schemes

There are many master keying techniques for lever locks, some dating back 150 years. The most accepted methods are:

- **Two sets of levers;**
- **Two sets of gates in one lever;**
- **Wide gating;**
- **Two keyholes;**
- **Two points on which the keys bear on a set of levers;**
- **Special slots on the bottom of levers;**
- **Butters' System**
- **Special master lever that picks up some or all of the other levers.**

11_3.1.1 Two Sets of Gates in One Lever

The simplest technique provides that each lever tumbler is cut with two slots or gates. In the **spring-biased** lever, one gate will be used for the change key, the other for the master key. In the **dead bolt lever**, however, this scheme is more difficult to accomplish. It will require removal of most of the bar separating the pockets, thereby severely reducing security. The preferred method is to utilize wide rather than double gating.

11_3.1.2 Wide Gating

The wide gating of ordinary levers is one of the more practical methods to accomplish master keying. In practice, the gating on one or more of the levers is made wider than the thickness of the bolt stump. This will allow the stump to pass through, regardless of whether the change or master key is used. The technique severely limits differing potential and is not recommended.

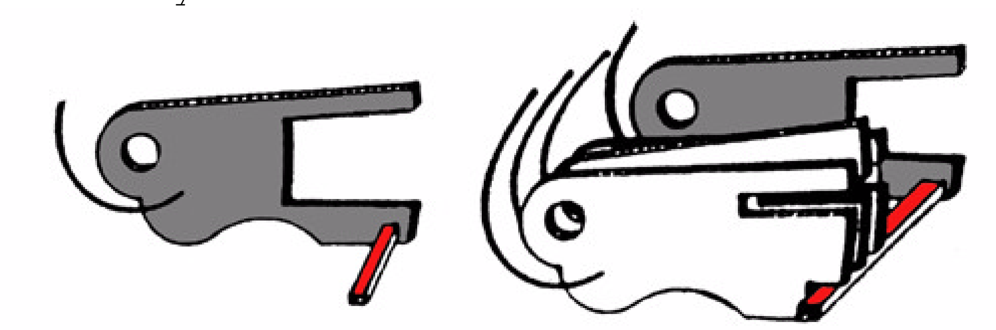
11_3.1.3 Slots on Bottom of Levers

The master lever is one of the most popular approaches for keying lever locks. It consists of placing a slot on the bottom of each tumbler, rather than at the end where the normal gate cuts are made. In this way, the master key is allowed to bypass all but the master lever tumbler. This special tumbler will lift all of

the regular levers to the correct alignment position in order for the fence to slide into the gating. This method of master keying is commonly used in such applications as lockers, cabinets, and desks. No resulting loss of security occurs from cross-keying using this method.

The master key will be cut so as to bypass all of the standard levers, much like a skeleton key does in a warded lock. All bitting positions other than for the master lever tumbler are cut to their deepest position on the key. The master key bitting will only make contact with the master lever tumbler, thereby causing the bar or rod, shown in the illustration below, to raise all of the remaining levers simultaneously so that all gates are aligned with the fence.

The master lever can be positioned anywhere in the lever pack; the pickup bar can extend in one or both directions. This system allows for great versatility, in that two different master levers can be utilized for progression of change keys under different master keys.



11_3.1.4 Two Keyholes

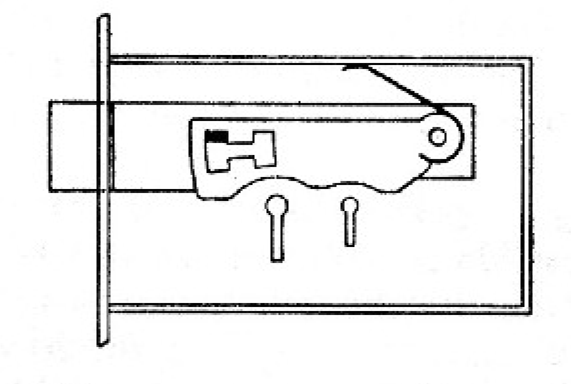
A number of schemes have been developed using two keyholes to accomplish master keying. In the most common form, found in safe-deposit boxes worldwide, there are actually two sets of levers operating more or less in tandem. Each set must be lifted to allow clearance of the stump to permit retraction of a single bolt. In this design, one set of levers is operated by the bank guard key and the other set by the renter's key.

In a design that was first patented in 1898 in Britain, elongated levers were provided with curved bellies in two positions corresponding to the keyholes. Either one of two different keys with unique combinations could thus be used to lift the levers to

the correct position to clear the stump. No cross-keying results.

11_3.1.5 Two Contact Points at Bottom of Levers

A compound lever, first patented in England in 1922, has two contact points or bellies. The change key and master key actually make contact with and raise the lever at different points created by different radii of the bellies. A similar system is used in wafer locks.



11_3.1.6 Butter's System

In the Butter's system, gating on lever-like detainers consists of a small, shallow slot on the edge of each lever. This creates **double gating** using two slots. Because the slots are shallow and bear no relation to the length of travel of the bolt, two sets of gates at different positions can be placed on the levers to match the lift of two different keys. The lock is particularly suitable for master keying because it provides a relatively large number of differs.

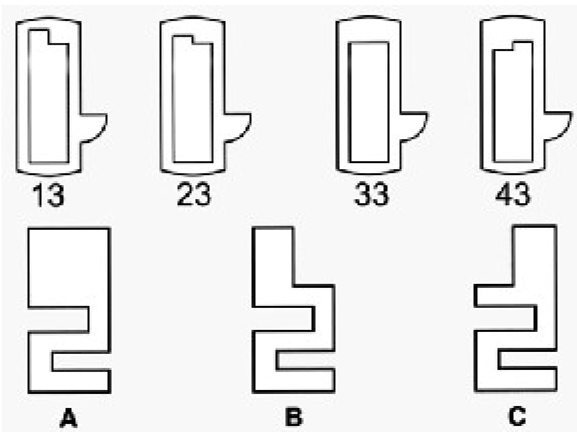
11_4.0 Wafer Locks

Wafer locks, both single and double-bitted, can be master keyed without difficulty, using a specially designed tumbler.

11_4.1 Standard Single-Bitted Wafer Configurations

Master keying of these locks is accomplished through the creation

of a wafer with two steps or contact points. The individual change key lifts the wafer by contact at one point, while the master key raises the wafer at a different contact surface. In order to rotate the plug within the shell, the wafers must all be lined up at shear line. In operation, the change key lifts the left step or contact point on the wafer; the master key lifts the right step. Blanks with left and right orientation are used for change and master key to create the correct pickup angle.



11_4.2 Double Bitted Wafer Locks

The double-bitted wafer lock can be master keyed in the same manner as the single bitted type described above. The bittings on the blank picks up a different portion of the tumbler, depending on whether a change or master key is used.

11_4.2.1 Schlage Wafer Lock

Master keying for the old but very popular Schlage double-bitted wafer lock was described in detail in **Chapter 7** of the first edition of this text, and, therefore, it will be dealt with only briefly here.

The Schlage wafer lock can be very simply and quickly master keyed. The theory is based on the fact that there are only two levels of cuts (binary) in the Schlage system. A "no cut" is used for the master key, a "full cut" for the change key. A master pin can be placed in any one of seven positions within the Schlage plug. The locks were once used extensively in schools, hotels, motels, and other large complexes and can still be found in operation throughout the United States. Interestingly, this lock has now been reproduced in Asia and imported into the United

States. They may indeed become popular again in this country.

11_5.0 Pin Tumbler Lock

The pin tumbler is perhaps the most versatile mechanism for master keying. Therefore, a detailed description of keying theory will be presented here. Many schemes have been devised since the introduction of the Yale lock. The simplest form required the use of two distinct cylinders: one keyed individually, and one keyed alike with all other cylinders. Other systems described within **LSS+** include pin subsets (master pins) that create different virtual shear lines, master rings, and positional systems.

11_5.1 Introduction

Pin tumbler locks can be individually keyed, keyed alike, maison keyed, and master keyed. Their design allows for complex keying, and, in the case of high-security cylinders, such specialized keying will not affect or reduce security, although the overall integrity of many master key system may be compromised through techniques discussed later in this text. High- security locks do not guarantee that the system cannot be compromised; they simply may make it more difficult. This section will describe different keying applications for which the pin tumbler mechanism is so ideally suited. The following discussion presents information regarding the theory of each keying level.

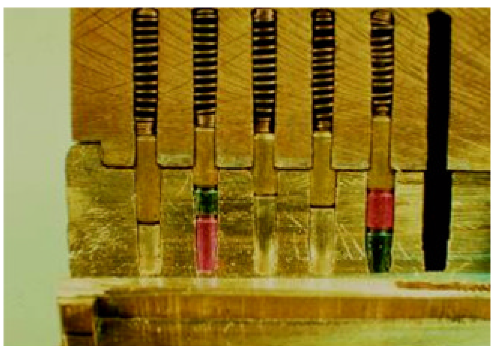
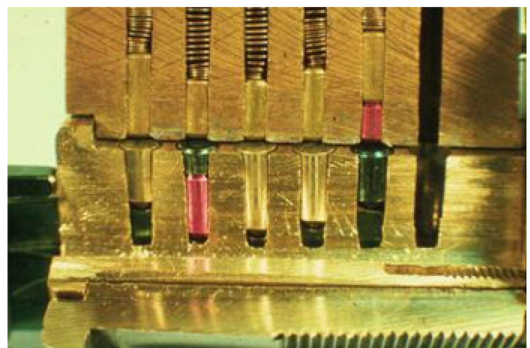
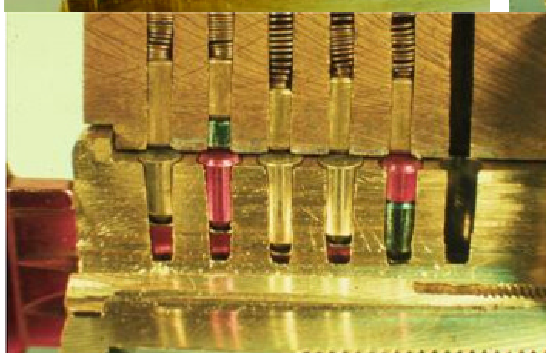
As previously described, there are several levels of keying available for the pin tumbler mechanism. Whatever the requirements, the underlying principles will remain constant in conventional systems. **Positional** master key systems are based upon a different scheme and are discussed later in the chapter.

All conventional keying systems will require a configuration of the pins to create one or more virtual shear lines. This may be accomplished with split pins, called master pins, or with a master sleeve or ring that creates a second physically distinct shear line. A unique rotating piston master keying system was invented by Lipschutz in 1983 (**4409807(131)**). This technique relies upon the rotation of tumblers in conjunction with the bitting of the key.

There are two primary schemes to define the combination for master keys and the security of master key systems in conventional pin tumbler cylinders. These are identified as **Total**

Position Progression System (TPP) and **Rotating Constant (RC).** Each master key scheme protects against certain vulnerabilities inherent when multiple virtual shear lines are created. Modern master key systems will contain a maximum of two pins per chamber below the the top pin (bottom pin and master pin) in order to minimize the number of incidental master keys, cross-key combinations, and to increase the security of the cylinder. Pin segments may be added to meet special keying requirements. This rule, of course, does not apply to IC locks and master ring.

In the photographs below, multiple virtual shear lines are created by the introduction of additional pins.

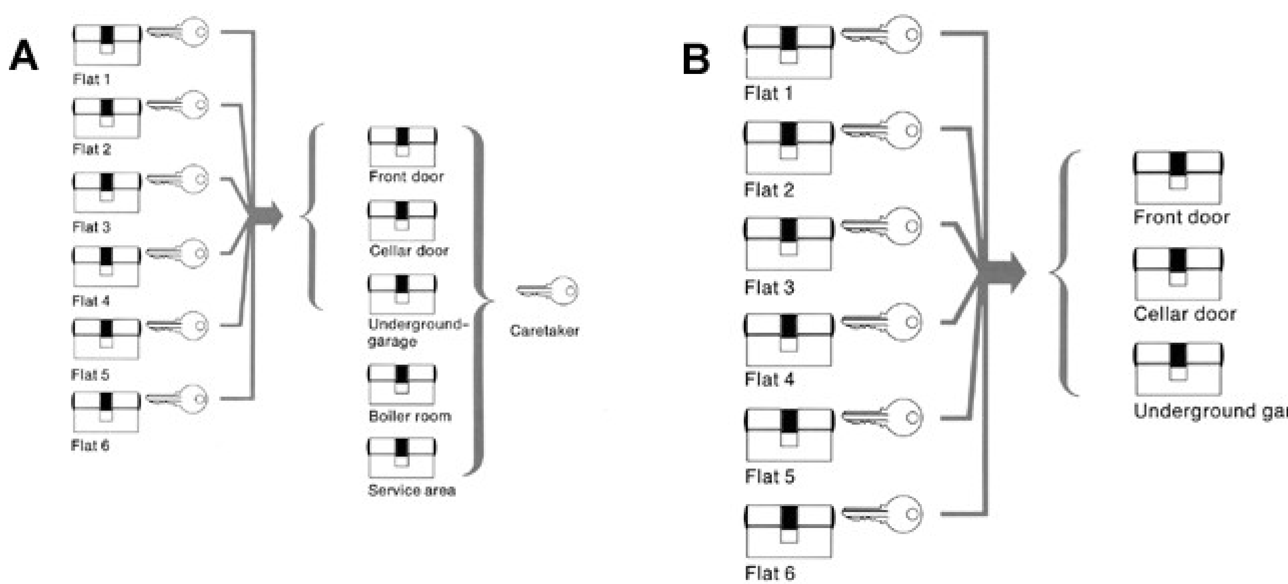




Certain keying systems and hardware can present security problems, resulting in cross-combinations, compromise of master keys, and reduced resistance to picking. If sectional keying is employed, added security issues can result from alteration of blanks, thereby allowing unauthorized access to one or more sections. In those systems where sectional keyways are employed, there is always a risk that a local locksmith may only stock higher section blanks, thus defeating the purpose of sectional keyways. In such an event, a key that is duplicated on the wrong blank would allow entry into unintended keyways. If the same combination was utilized for a different section, the key would enter the lock and open it. The Medeco M3 system offers a unique

alternate or enhancement to sectional keyways by adding a third level of protection through the use of sliders that control a sidebar for change key or master key. See the discussion in **chapter 17.**

11_5.2 Maison or Central Locking Systems

Maison keying is used in situations where a number of different keys must all operate individual locks and one or more central or common locks. In the apartment house complex, for example, each tenant's key will fit the individual apartment in addition to the entrances to the building, garage, utility room, exercise facilities, and laundry. This form of keying is done primarily for convenience. Two methods can be employed to implement a maison system: they both significantly reduce security.



11_5.2.1 Maison Keying Security

Conventional mechanical locks that have been maison-keyed are subject to picking, raking, key picking (jiggling), and key interchange. Unless a magnetic system, sidebar, or other more sophisticated cylinder is utilized, security is severely compromised. In one scheme, the number of pin combinations within these cylinders is usually reduced so that, in many cases, keys for other systems will work. In addition, individually-keyed tenant locks have fewer differs, thereby increasing the potential

for use of unauthorized keys either within or from outside the system (key interchange). This results when all tenant locks have one or more common bitting depths to the maison-keyed common locks. Resistance to picking is also greatly diminished. This can be readily appreciated when it is considered how a lock with two or three tumblers (or multiple shear lines) can be picked, in contrast to a lock having five of six pins and only one master pin in each chamber. The security of a maison system is still further diminished when master keying is also employed.

In any burglary investigation involving possible surreptitious entry, the use of maison keying should be determined. Questions that may be raised in conjunction with any analysis of maison systems include:

/• **Have keys been lost? One of the major drawbacks to maison keying is the inability to change common access locks if keys have been lost or compromised. Access cannot be prevented for any key, once granted;**

- **What type of maison system has been implemented? Are there active pins in every chamber, rather than having only two or three chambers populated;**
- **Has the system been designed so that it cannot be easily key picked? This means that keys cannot be jiggled or manipulated in the cylinder to effect an opening;**
- **What is the policy with regard to changing common locks in the event that tenants leave. Usually there is no such policy, which means that there is no security in the system;**

Security in such systems is reduced because of the following issues:

Added master pins:

- **Reduce pick resistance;**
- **Increase the likelihood of key interchange;**
- **Create more keys that will open the lock (cross-keys);**
- **Increase the ability to key pick or jiggle a key to manipulate tumblers to shear line;**
- **Increase the probability that a blank key, paper clip, or pocket knife can be used to open the lock by simulating the right bitting combination or manipulating each tumbler to shear line;**

- **Increase the ability to rap the lock using a "999" or bump key;**

Reduced number of pins or active chambers:

- **Reduce pick resistance;**
- **Increase the likelihood of key interchange;**
- **Increase the ability to key pick or jiggle a key to manipulate tumblers to shear line;**
- **Increase the risk that a key may be withdrawn while the plug is in the turned position;**

11_5.2.2 Maison Keying Theory

Maison keying can be considered as master keying in reverse, in that a number of **different keys** must open a common lock. Locks can be maison keyed in three ways: they may contain a fewer number of pins that are common to all locks within the complex, use of segmented pins, or a combination of the two approaches. Maison keying generally requires that additional master pins are required, creating cross-keying to allow multiple keys to operate the lock. Whether double pinning or the pinning of fewer chambers is implemented in such a system, security is drastically reduced.

11_5.2.2.1 Cylinder with Two or Three Pins

The maison cylinders may only have two or three pins that are common to all locks in the system. This means that at least two cuts will be the same on all keys, and then the maison locks are combinated to these two pins only. In an apartment complex having four different tenants with keys that must all open a common cylinder, the individual apartment locks could be set to the following combinations:

Apartment one	***62804***
Apartment two	***62738***
Apartment three	***62887***
Apartment four	***62534***
Entry Lock	***62---***

Note that each apartment key has the same cuts for the first two tumblers, **62**. The entrance lock then matches the first cuts. No other pins are used in the entry lock. If a master keyed system

also incorporates maison-keying, it is important to verify the actual number of active chambers if the cylinder is to be decoded through the use of a change key to derive the TMK. A detailed analysis of the procedure to extrapolate a TMK is presented in chapter 31. The validity of the decoding process can be affected if the target cylinder has been maison-keyed.

11_5.2.2.2 Segmented Pins

In order for many keys with different combinations to all operate one common lock, the pin sets must create several virtual shear lines. This is accomplished by a number of small tumblers being stacked one above the other to create the different splits. These are called master pins and are more fully discussed below. In our example, let us assume we have a large apartment complex with three levels of keying and maison keying. Thus, there is a change key for each apartment, a master key for a specific complex, and a top level master key that will open several different buildings within the complex. The common area locks must allow the TMK, master key, and the five tenant keys to open the front, back, and garage door locks:

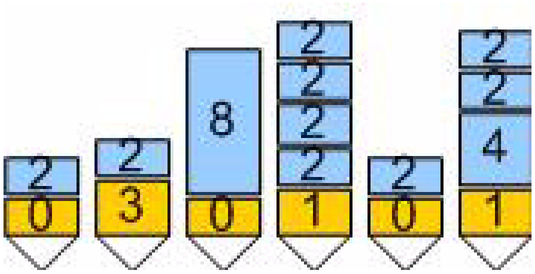
258307 TMK
030307 Master key

030121 change key
030125 change key
030521 change key
030725 change key
030929 change key

In order to allow all of these keys to work in common access areas, chambers four and six must have three extra master pins. This process is referred to as double-pinning and should be avoided whenever possible. In our example, intended cross-keying is implemented. The tables below show the required depths for each position in order to allow all of the keys to open the lock, and the bottom and master pins that are required to implement this scheme. We are utilizing a Schlage cylinder with ten depths (0 = most shallow, 9 = deepest cut). The table shows the pins as they would be inserted for each chamber and pin stack order. The diagram shows the actual pinning. This lock would have a total of 128 cross-keys that would open it. Note that in this example, the code 030929 would not actually be utilized for a Schlage with a

code 030929 would not actually be utilized for a Schlage with a MACS of 7.

MAISON KEYING SYSTEM: DEPTHS REQUIRED FOR EACH CHAMBER					
#1	**#2**	**#3**	**#4**	**#5**	**#6**
			9		
			7		9
			5		7
2	5	8	3	2	5
0	3	0	1	0	1

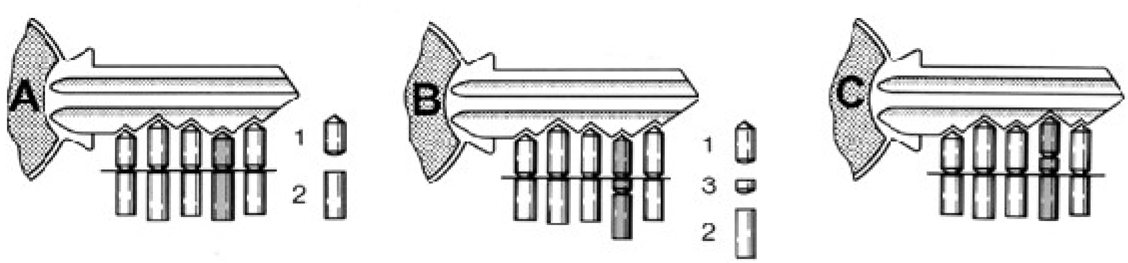


11_5.3 Master Keying Pin Tumbler Locks

11_5.3.1 Introduction

Pin tumbler locks can be effectively master keyed to six different levels, can contain sectional sub-systems and incorporate both schemes for a complex keying system. Master keying is generally done at the factory when locks are first produced for a customer; most combinations are generated by computer program within carefully defined guidelines for the selection of top level master keys. Software is so sophisticated today that all parameters relating to TMK bitting, levels of keying, tolerances, differs, adjacent cut specifications, cross-keying, and other customer requirements can be factored into the output.

Conventional pin tumbler locks are usually keyed to a maximum of four levels of complexity: **master, grand master, and great grand master.** In the simplest system, a number of locks with different change keys can all be controlled by one master key. In the more complex levels of keying, several different series of locks, all with their own submaster key, may have one grand or even great grand master key.



As detailed in the text that follows, there are a number of variables that affect the design, operation, capabilities and

security of any master key system. These concepts are examined in subsequent sections and must be understood in order to effectively analyze a system for security and for covert operations, in order to compromise the TMK as discussed in **chapter 31.**

11_5.3.1.1 Underlying Concepts

- **Method of progression: total position progression or rotating constant;**
- **Type of progression: one or two-step;**
- **Parity;**
- **Keyway design;**
- **Division of the key;**
- **Sequence of progression (SOP): shallow to deep, odometer method, scrambled;**
- **Levels of keying;**
- **Mechanical design of the lock;**
- **Number of chambers that can be progressed.**

11_5.3.2 Definitions

Specific terms have been developed by the locksmithing and manufacturing industry to describe locks, keys, keying levels, keying schemes, bitting, measurements, and associated hardware technology. The following reference provides a comprehensive glossary of accepted terminology.

Abbreviations for Locks and Keys within a Master Key System: See **Standard key coding system.**

Associated Change Key: A change key that has common bitting with the master key to which it belongs. In like fashion, the **associated master key** has common bittings with the change keys below it. In contrast, an **unassociated change key** does not have common cuts that relate it to a master key, and likewise for the **unassociated master key** to the change key.

Bitting List: A comprehensive list or inventory of all keys and their bitting codes that are associated with a master key system.

The list may be sorted by blind code, direct code, or key symbol.

Bitting Position: The location of a cut on a key.

Block Master Key: Within a standard progression format, the one-pin master key for all bitting combinations that comprise a block.

Building Master Key: The key that can operate most, if not all of the locks within a building.

Build-up Pin: See master pins or top pins. The pin is used to "build-up" or make up the difference in height within a pin stack between the change key and control key shear line. The primary definition relates to interchangeable core locks such as Best, and Corbin and Russwin master sleeve cylinders. The build-up pin can usually be found immediately below the top pin.

Chamfer or Radius of Pin: The top of the bottom pin should be chamfered or radiused to conform with the surface of the plug to assure smooth operation. If the top of the pin is flat, it will catch or interfere with the turning of the plug.

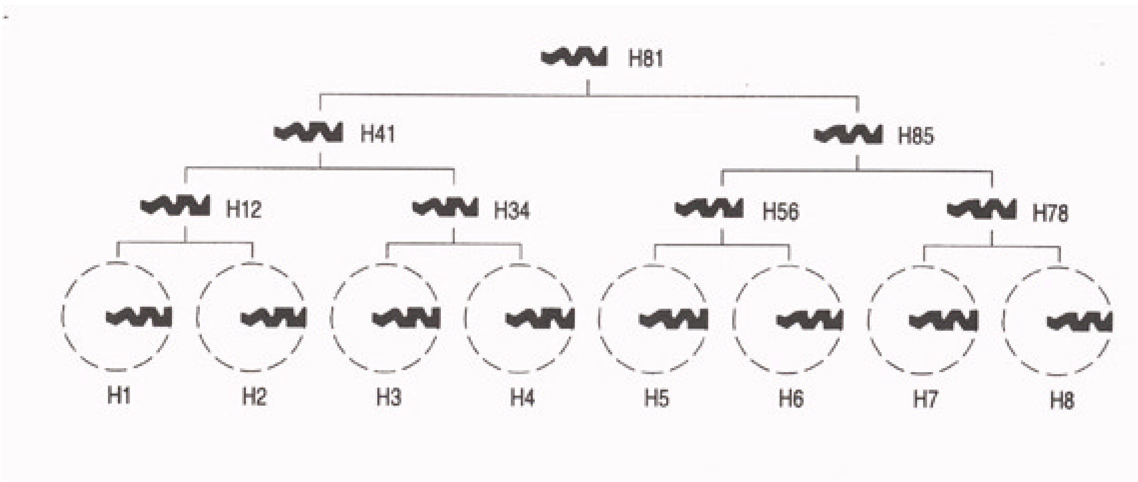
Change Key (CK): The individual change key is the lowest level of keying for any cylinder within a keying system. Change key, guest key, servant key or similar term denotes the base unique individual combination of pins that will allow one or more locks (if keyed alike) to be opened by only one key. Such locks may also be controlled by one or more master keys. The two concepts are not mutually exclusive.



Figure LSS+1104 The change key is the lowest level of keying. One key fits one lock. Courtesy of HPC Interactive Learning Series.

cmk'd: Construction master keyed.

Complex Keying Systems: A *complex keying system* utilizes one or more levels of master keying and may also incorporate sectional keyway assignments for added security and organizational control. Systems implementing sectional keyways may also be referred to as **multiplex keying systems.** The Medeco M3 can implement advanced sectional keyways through the use of sliders for different keying levels.



Complementary Keyway: This term usually refers to a disc or wafer lock that is part of a master key system. As described earlier in this chapter, the wafers are manufactured to provide two contact surfaces for different key sections: one to operate the lock as a change key, and one for the master key.

Constant Cut: This term refers to one or more bittings that are common and identical as to depth and position within different keys within a keying system. Such commonality can provide grouping between keys and levels. As shown in the detailed description of the rotating constant system, **figure LSS+1126**, one or more chambers in groups of cylinders have pins of the same length.

Construction Breakout Key: A special key that is employed by some lock makers to render inoperative upon project completion a cylinder that has implemented a construction master key system.

Construction Core: A removable core, usually keyed alike, that is utilized at a construction site during the project. Cores are removed at the conclusion of construction and replaced with ones that are keyed for the facility.

Construction Master Keying: A specialized keying technique used in new building sites to control the distribution and compromise of master keys during and after construction. It is a unique keying system that is designed for the convenience of workers, managers, and other persons who require free access to the site. Such systems will allow for the programming of a special tumbler combination for a master key that will only function prior to building completion.

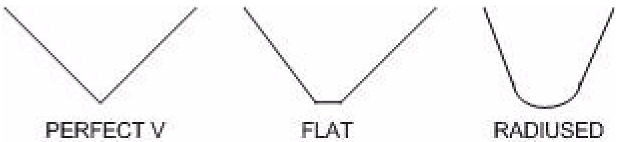
Controlled Cross Keying: When two or more change keys associated with one keying level and under the same higher level are allowed to operate one cylinder **by design**, then controlled cross-keying has been implemented. This would be demonstrated by cylinder XAA3 operated by AA4, but not by AB1. Cross-keying can present serious security issues, detailed in later sections. In contrast, **uncontrolled** cross-keying would exist in a situation where two or more different keys under **different** higher level keys can operate one cylinder. Thus, XAA3 can be operated by AB, AB1, etc.

Cross-Keys: "Cross-keying" can denote the introduction of multiple pin segments within the chamber of a master keyed cylinder that will create different combinations that will open the lock. Traditionally, the term referred to the different combinations that were created with the introduction of multiple pin segments. Many virtual shear lines can be created when master pins are introduced. The industry has refined the definition for cross-keying, as shown below. The correct nomenclature to define the composite combinations that will open a lock in a master keyed environment is "incidental master key."

Cross-Keying: *Cross-keying* is the intended or unintended and undesirable product of conventional master keying systems and results from the introduction of multiple pin tumbler segments within each pin chamber. For each master pin segment within a chamber, there is created another or virtual theoretical shear line. The result is a different key combination that will open the lock. To compute all the possible permutations, the number of pin segments are factored by the number of chambers. Thus, in a five-pin lock with three pin segments within each chamber, there would be 3^5 possible combinations, or 243 different keys that theoretically could open the lock. See the definition for **controlled cross-keying**, above. Locks employing **master rings** or **sleeves** can reduce the problem of cross-keying. However, if

chambers are double-pinned below the master ring or sleeve, then cross-keying can still occur.

Cut Root Shape: The geometric design or shape of the root or bottom of a key cut. The shape may be flat, V, or radiused.

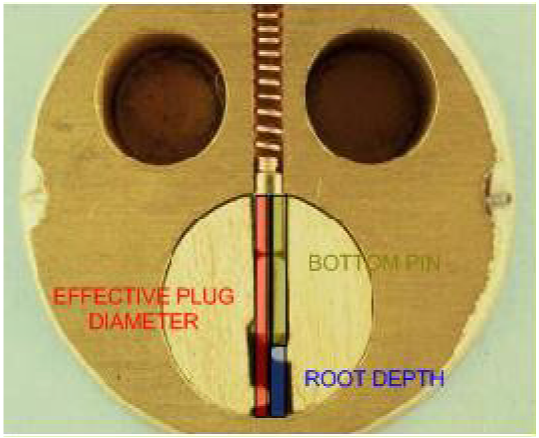


Department Master Key: A master key that is designed to open many or all of the locks within a specific department.

Display Key: Within a hotel keying system, a special key that is designed to open one specific guest room, even if the lock has been set to prevent access by a normal key or master key. A display key may also be considered as a shut-out key.

Double Pin: The practice of double pinning means to insert more than one master pin in a pin stack within a given chamber. The practice is more fully explained later in the text, and is not the correct way to implement a master key system except in very limited circumstances, such as controlled cross-keying, master ring, and IC.

Effective Plug Diameter: The effective plug diameter is slightly less than the actual diameter of the plug. It is comprised of the lower pin tumbler and root depth to the bottom of the key blade. The effective plug diameter is affected by the blade radius and the shaping of the top of the bottom pin to conform with the curvature of the plug. The more that the radius of the blade and the pin tumbler conform to the plug, the closer will be the effective plug diameter to the actual plug dimension.



Engineer's Key: This is a multilevel master key utilized by maintenance personnel than opens locks within a master key system that contains three or more levels of keying, and which will operate locks that are each controlled under different master key levels.

Expansions Specification: A detailed analysis of a system's functionality requirements will dictate how many locks will be needed. The expansion specification defines the potential number of required combinations for each specialized keying level.

Floor Master Key: A master key that controls or operates most or all of the locks on a specific floor of a building.

Grand Master Key (GM): This term generally describes the second level of keying above the individual change key and one level above master key.

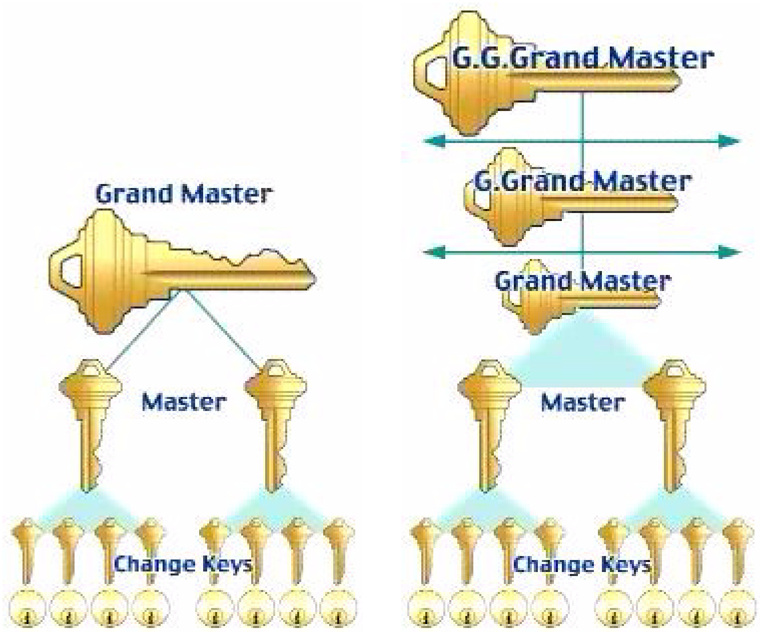


Figure LSS+1105 Great grand master key diagram. Courtesy of HPC Interactive Learning Series.

Great Grand Master Key (GGM): The GGM keying level defines the third step above the change key. It may also be referred to as the TMK. Generally, most systems will rarely be keyed above the great grand master key level, except in those instances where high-security hybrid locks, such as Medeco or the EVVA magnetic sidebar are employed.

Guest Key: A guest key is the equivalent of a change key within a hotel master key system. It is designed to open one guest room when the lock is in the normal (not lockout) mode.

Horizontal Group Master Key: Within a standard progression system list, this is a two-pin master key for all combinations in all blocks in a line across the page.

Housekeeper's Key: A special master key within a hotel keying system that is designed to operate guest rooms as well as those areas that must be accessed by housekeeping staff.

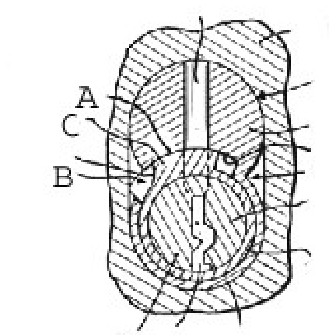
Incidental Master Key: When a cylinder is combinated to a change key and a top master key, a key may be cut to a **virtual shear line;** a composite of bottom and master pin combinations in the different chambers. The matrix of bottom and master pins provide certain bitting combinations that were not intended to be used

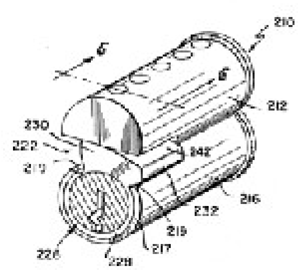
within the system, but for which a key could be produced to open the lock. Incidental master keys are used in complex keying systems as block, row, horizontal group, vertical group, and page master keys. In a total position progression system that utilizes cylinders with six chambers and one master pin per chamber, there are a total of 41 incidental master keys, and a total of 64 keys that will open the lock. In this example, there would be:

1 page master key (PM)
16 row master keys (RM)
16 block master keys (BM)
4 vertical group master keys (VGM)
4 horizontal group master keys (HGM)

Individual Key: The simplest form of keying allows for one depth per bitting position, created by one bottom pin. In this configuration, only one key will open the lock.

Interchangeable Core Nomenclature: The **control cuts** (A) within the **control key**, raise the pins to the control shear line that is created by the **sleeve** (C), in order to remove the core by withdrawing the **control lug** (B).





Key Alike (KA): Two or more locks or groups of locks may be keyed alike within any keying system and at any level. This means that all such locks will have the same individual key combination. Any number of locks can be combinated alike so that one key will open them all. Locks can only be keyed alike if the keyways are identical or use the same keyway section within a multiplex system.

Key Bitting Array (KBA): The KBA provides a graphical method of defining every available bitting depth for each chamber in any pin tumbler lock within a master key system. It is based upon the

number of available depths, the keying scheme, number of chambers, and the spacing between depths (which in turn translates to a one or two-step progression).

Key Bitting Specifications: Each manufacturer provides precise specifications regarding all matters pertaining to bitting depth, spacing, cut angle, cut root shape, key cut profile, degree of rotation, and how bittings are applied to the key blank during the cutting process (bow-to-tip or tip-to-bow). Spacing will generally provide two dimensions: stop to the center of the first cut, and center-to-center between adjacent cuts. Depths are correlated to depth cut numbers and are generally computed from the bottom of the blade to the root of the cut, although some manufacturers have measured from a register groove on the side of the blank.

Key Cut Profile: The geometric shape of the composite cut, including the root design and cut angle.

Keyed Different (KD): One or more locks that may or may not be part of a keying system that are combinated differently from each other. It is the opposite concept of keyed alike.

Keyed Random: Duplicate bittings may occur if a cylinder or group of cylinders is selected from a limited number of locks that present only a few different key combinations of no specific order or progression.

Keying Schedule: A detailed listing or inventory of all keys and cylinders within a keying system that provides the specifications as to their quantity, markings and shipping instructions.

Keying Symbol: See standard key coding system.

Keying Levels: See **standard key coding system.**

Key Interchange: See the definition of cross-keying and incidental master key. This is an undesired and unintended condition that occurs when a key is able to open a lock for which it was not designed, and can be caused by poor tolerance, pinning error or mistakes in the definition of the KBA.

Key System Schematic: A diagram representing the hierarchy of keying levels, where locks and keys are defined through the use of letter designations (symbols), circles (for change keys), and boxes (for master keys). Interconnecting lines are used to

display the relationship between locks and keys within levels.

Levels of Keying: A uniform method of expressing levels of keying defines change key, key alike, maison keying, and master keying systems using the **standard key coding system**, below. A **two level** system, for example, allows for one or more change keys and one master key. Added levels of complexity can be defined, as shown in the accompanying table. Diagrams representing the standard key coding system are hyperlinked for each **level of keying**.

Level of Keying	Key Name	Level ID	Abbreviati
1	Change key	Level I	CK or k
2	Change key Master key	Level I Level II	CK MK
3	Change key Master key Grand master key	Level I Level II Level III	CK MK GMK
4	Change key Master key Grand master key Great grand master key	Level I Level II Level III Level IV	CK MK GMK GGMK
5	Change key Master key Grand master key Great grand master key Great great grand master key	Level I Level II Level III Level IV Level V	CK MK GMK GGMK GGGMK
6	Change key Sub-master key Master key Grand master key Great grand master key Great great grand master key	Level I Level II Level III Level IV Level V Level VI	CK SMK MK GMK GGMK GGGMK

Maid's Master Key: A limited-use master key within a hotel keying system that will allow the maid to access guest rooms and certain special areas such as linen closets.

Maison Keying System: A specialized keying system (generally in apartment complexes) that allows common-access locks to be operated by each tenant. In theory, it is the reverse of a master key system.

Master Key Changes: This term defines the number of useable combinations for change keys that are available under each master key.

Master Key System: Any keying system that allows two or more levels of keying. The term "master key" is also used to designate a two-level keying system (as opposed to grand master key, for example, which denotes a three-level system).

Master Pin: This is the preferred definition for the older term of **master wafer.** See also **build-up pin.** A master pin is a lower pin segment that is inserted into the pin stack to create an added virtual shear line to allow more than one key to open the lock. A master pin may be inserted in one or more chambers, depending upon system design, master keying scheme, and the number of master keying levels. In modern keying systems, there will rarely if ever be more than one master pin in any chamber, unless done to create intended cross-keys (or in master ring or IC locks). If more than two pin segments are present in any chamber, then many **unintended cross-keying** combinations can result. The practice is known as "double-pinning" and is more thoroughly explained later in the text.

Master Disc: See **master pin.**

Matrix Format: A high level method of displaying key combinations and assigning keysets through the use of a matrix rather than in a chronological list. See the detailed discussion in a later section.

Maximum Adjacent Cut Specifications (MACS): This term refers to the maximum degree of vertical separation that is permissible between adjacent cuts and which will allow the pins to move freely up and down as the key is inserted and withdrawn. If the adjacent cuts create too steep an angle, then the tumblers will bind, not seat properly, or form an imperfect geometric shape for the root. MACS rules will also limit the number of useable differs. Adjacent cuts that violate MACS cannot physically be cut.

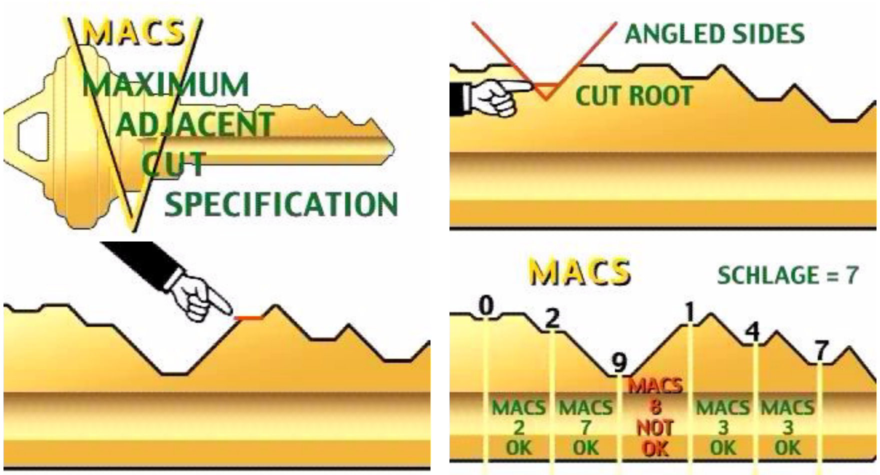


Figure LSS+1106 MACS specifies the maximum root depth and angle that will allow the proper insertion and removal of the key, and the proper root dimensions. By defining the maximum difference in depth between adjacent cuts, the manufacturer controls the ramp angles and root shape for optimum operation. In the diagrams, the proper angle of cut is shown. In the Schlage key with a MACS of 7, it can be seen that the difference between a "1" and a "9" cut is not allowed because the ramp angle causes a reduction of root dimension of the adjacent "1" cut. The diagram to the left of the Schlage key shows the proper amount of bitting that must be present for each root. Courtesy of HPC Interactive Learning Series.

Master Key (MK): A master key is generally defined as the first level of keying above the individual change key. It represents a second common key that will open all cylinders within a group.

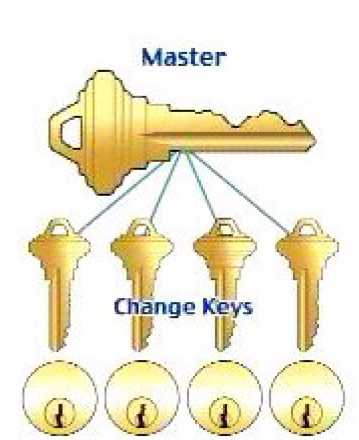


Figure LSS+1107 A master key is one level above the change key. In this diagram, the master key fits all four of the locks for which there is an individual change key. Courtesy of HPC Interactive Learning Series.

Master Sleeve or Ring: A ring is made in the form of a brass tube

to fit snugly around the plug and within the shell of the lock. The purpose of this device is to create a second physical shear line. The ring forms a plug with a slightly larger diameter. Certain pin segments are aligned to the second shear line created by this added ring. Cross-keying problems can be eliminated by this technique because **all tumblers** must be raised to the shear line created by the plug **or** to the sleeve. It is thus impossible to produce split combinations (cross-keying) that will open the lock as with conventional master keying, unless double pinning is used for higher keying levels.

Master Wafer or Master Pin: The middle segment(s) of a pin tumbler set, sandwiched between the top pin (driver) and bottom pin, that will allow the creation of multiple virtual shear lines. Each manufacturer assigns values for standardized lengths for both top pins and master pins. Master pins are usually flat-cut at each end.

Method of Progression: There are two primary *methods* of progression: **total position progression**, and **rotating constant.** These should not be confused with the type of progression: **single-step** and **two-step**. These terms, method of progression and type of progression, are often confused. They denote very different concepts discussed throughout this chapter.

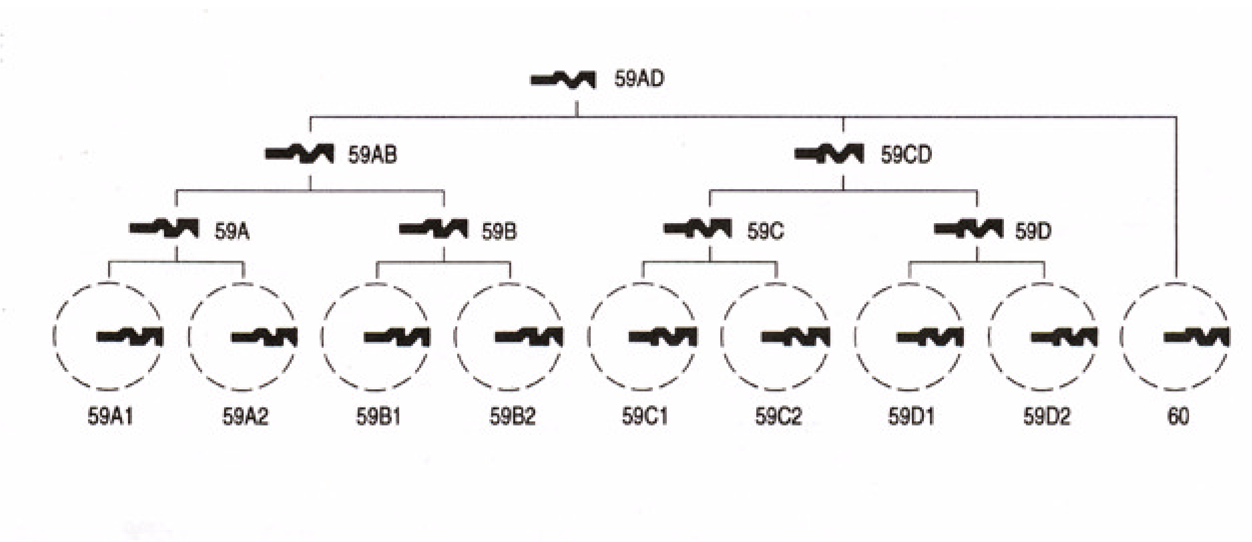
Minimum Safe Increment: This term refers to the depth increments that are required for progression within a master key system. It is based upon the difference between effective plug diameter and actual plug dimension, and tolerance build-up. Cumulative tolerance errors, discussed elsewhere in this text, can result in key interchange and unreliable mechanical operation if a minimum increment between depths is not maintained.

The industry standard requires a minimum of .023" between each depth for master keying and thickness of master pins. This increment will control the available depths that can be written into the KBA and the resulting combinations that are produced by progression of each value in each chamber. Thus, if the manufacturer utilizes .015" steps, a two-step (.030") progression would be utilized. This means that **every other** depth is actually available for use in defining the master key system. It is critical that depth increments never be mixed between manufacturers.

MK'd Only: Master keyed only.

Multiple Gating: In lever tumbler locks, more than one gate for each tumbler is provided to allow master keying.

Multiplex Keying Systems: See **Complex Keying Systems.** The diagram shows a Corbin 59 series keyway system. 59AD will open every keyway in the system.



Odometer Method: In a progression systems, it describes a method of deriving (progressing) bitting combinations in ascending or descending order from right to left, resembling the action of an odometer in accruing mileage. The least significant digit is farthest to the right. The term also describes one of the methods of entering available depth increments into the KBA.

Operating Shear Line: The physical shear line within a pin tumbler lock that forms the gap or break between the shell and plug. It is the precise location where each pin tumbler within each pin stack in each chamber must split in order that the plug might rotate. It also identifies the lower shear line in a removable core lock and in a cylinder employing a master ring.

Page Master Key: In the standard progression format, it is the three-pin master key for all combinations listed on one page. A "page" is a notation of sixty-four change keys under one master key within the progression format.

Partial Position Progression: A hybrid system that contains some of the attributes of a total position progression and rotating constant system. In the PPP, one or more columns are held

constant, allowing the sharing of bitting values between the TMK, MK, and CK. The distinction between rotating constant and partial position progression is subtle yet simple. In RC, the "held" positions are rotated for new progressions; in the PPP, held positions remain constant. There is simply a common bottom pin that is used for the change key, master key, and TMK.

Positional Master Keying Systems: A positional master key system relies upon a different theory than the split tumbler found in conventional cylinder locks. These systems are used by Schlage wafer (obsolete), Kaba, Keso, Corkey, Schulte, Miwa, Showa, and other dimple and magnetic card locks.

Traditional master pins are not utilized; rather, detainers are placed within **one or more chambers**, following a defined keying scheme. Other chambers are left open or inoperative. The master key in a positional system is the **composite** of all of the change keys. In the conventional split pin system, by contrast, the master key is derived through a mathematical computation of bitting depths for each chamber.

Privacy Key: A special key that is used to open a lock that has been single-keyed. It may also be referred to as an **emergency key**.

Progress: To choose possible key bittings from the KBA for each column.

Progression: The logical or orderly sequencing of key bittings that are used within a keying system. The sequence of numbers is usually taken from a **progression column** that represents one bitting position within the key bitting array and occurs in some predetermined order. Each column is progressed to obtain added bittings. The number of columns provide the basis to define the number of bitting combinations that are theoretically available for a system. Progressions are defined by the number of columns that are utilized in the KBA and the commensurate number of pin chambers and depths that create all associated master keys. Of course, the number of pin chambers within the lock will ultimately determine how many chambers can be progressed, and how they are divided between master keys and change keys. If three pins are progressed and used for defining master key bittings, for example, then it is said that it is a three pin master key. The term that designates, for example, a "two-pin" or "three-pin" master key also relates to the hierarchy of master keys within a system, and which locks are associated to that keying level.

In our example, we shall assume that the system utilizes a two-step progression, and that there are four depths available for each position. (Originally, there were five depths in our hypothetical, but one depth was reserved for the TMK in a TPP system). The table shows the correlation between the number of positions progressed and the number of available key combinations. The table also defines the master key designation within the progression.

MASTER KEY DESIGNATION BY NUMBER OF PINS		
Master Key Name or Designation	Columns Progressed,	Available Combinations
Row master key **Block master key**	**1**	**4**
Vertical group master key **Horizontal group master key**	**2**	**16**
Page master key	**3**	**64**
16 groups of 4 pages	**4**	**256**
4 groups of 16 pages	**5**	**1,024**
TMK: 64 pages	**6**	**4,096**
	7	**16,384**

Progression List: A bitting list for change keys and master keys that is presented in a chronological sequence.

Progressive: A bitting position that is derived through a progression of available depths (rather than being held constant) would be considered as a progressive. The term also denotes the number of depths within a chamber that can be progressed. For example, the Corbin System 70 system has a total of six depths, with a depth increment of .028". Thus, a single-step progression can be utilized for generating master keys. There would be a total of five progressives available, because one progressive would be reserved for the TMK.

Random Master Keying: Any scheme for deriving master key combinations that is not based upon a logical progression of bitting depths and that does not correlate keying levels to each other.

Register Number: Most lock manufacturers will asign a code or

identification number to a master key system or to higher level keys within the system.

Root Depth: The measurement from the base or bottom of the cut (root) to the bottom of the blade of a key constitutes the root depth and would equal the bitting value.

Rotating Constant (RC) Systems: This is a common keying progression scheme for defining master key systems. It allows one or more TMK depth and positions to be shared with the change key and master key. It is an algorithm that establishes patterns of progressives that are rotated in different key bitting arrays. Within each different KBA, some columns are constant and some are progressed.

Row Master Key: The one-pin master key that denotes all combinations that are listed on the same line across a page within a standard progression format constitutes a row master key.

Sectional Keyways: A sectional keyway is one that is specially designed to be used in a **family** of similar keyways within a complex keying system. One or more sections will be included within the keyway family and will allow the repeat use of individual and master key combinations in the system without loss of security. They will block access to keys that are not defined within a specific keyway family. Note that if the wrong sectional blank is utilized when cutting a key, then the security of the system can be compromised because the key may allow access to more than one section in different locks in the system. It is typical for certain key shops to maintain a limited inventory of blanks. Thus, in Figure 11-7, the master keyway LN would open all other keyways. If the specific change key that utilizes section LA, for example, were cut on the LN blank, then the security of the system could be compromised if the bitting combination for the LA change key were repeated in other locks throughout the system, because LN would enter all of those keyways. The **Easy entrie** key machine, described elsewhere in this text, can create restricted sectional blanks that can bypass the inherent security in a multiplex system.

Selective Key System: A system that is designed so that every key can be a master key. Certain installations may require a limited number of keys and extensive cross-keying.

Selective Master Key: In certain systems, an unassociated master

key can be made to operate one or more specific locks throughout the system. These keys would act in addition to the regular master key and change key without creating cross-keying issues. They are created by double pinning and are a subset of the TMK.

Sequence of Progression: The specific order by which bitting positions are progressed to generate different change key combinations. The SOP is noted at the bottom of the KBA.

Simple Master Key System: A keying system that contains only two levels (change key and master key) can be referred to as a simple MK system.

Single-Step Progression: Depending upon the manufacturer, a one or two-step progression may be utilized for master keying. In the single-step system, every depth increment can be utilized to progress change key bittings in the KBA. Generally, the difference between depths must be a minimum of .023". If the minimum depth increment is less than .023", then every other depth can be used to derive combinations.

Spacing: The specification that provides the dimension from the shoulder or stop to the center of the first cut, and center of cut to center of cut for adjacent depths.

Split Pin Master Keying: The method that allows master keying of pin tumbler locks by introducing master pins in one or more chambers to create additional virtual shear lines.

Standard Key Coding System:(132) Originally developed by Thomas Hennessy at Emhart in the 1960s, the SKCS has been adopted by the lock manufacturing industry and practitioners to define and designate in a uniform manner all keys and locks within a master key system, according to a hierarchy of access. Key symbols denote **relationships.** Use of these letter and number designations (referred to as keysets) will allow any knowledgeable professional to determine the precise function and keying level of locks without any further information. The definitions can be likened to the symbols that are utilized by electrical and electronic engineers within a schematic. All SKCS symbols have been grouped within one table for easy reference. There are certain **rules(133)** that are followed with regard to the system in order to avoid confusion in large systems.

LSS204: Brian Chan on master keying rules

Standard Progression Format (SPF): An orderly and systematic method to list and relate each change key combination to all master key combinations in a master key system. The derivation of bittings is defined and grouped by segments called blocks, horizontal groups, vertical groups, rows, and pages. Each of these allow or provide for a specific level of access within the keying system.

Sub-Master Key: Within a keying system that has six or more levels, it is the master key level immediately under the level that is defined as "master key."

Theoretical Combinations: The number of combinations that can be derived from the available depths and number of chambers within a cylinder will provide the maximum number of different combinations that can be generated. The actual number may be greatly reduced.

Top level Master Key (TMK) or Top Master Key: This is the highest level within the keying system. It may be a master key, grand master key, great grand master key, or great great grand master key.

Total Position Progression (TPP) System: This is the most common master keying scheme. It relies upon a progression of useable depths, as defined in the key bitting array, to generate combinations for master key and change key levels.

Type of Progression: This term identifies whether a single-step or two-step progression is utilized in generating combinations within the KBA.

Uncontrolled Cross-Keying: See **controlled cross-keying**.

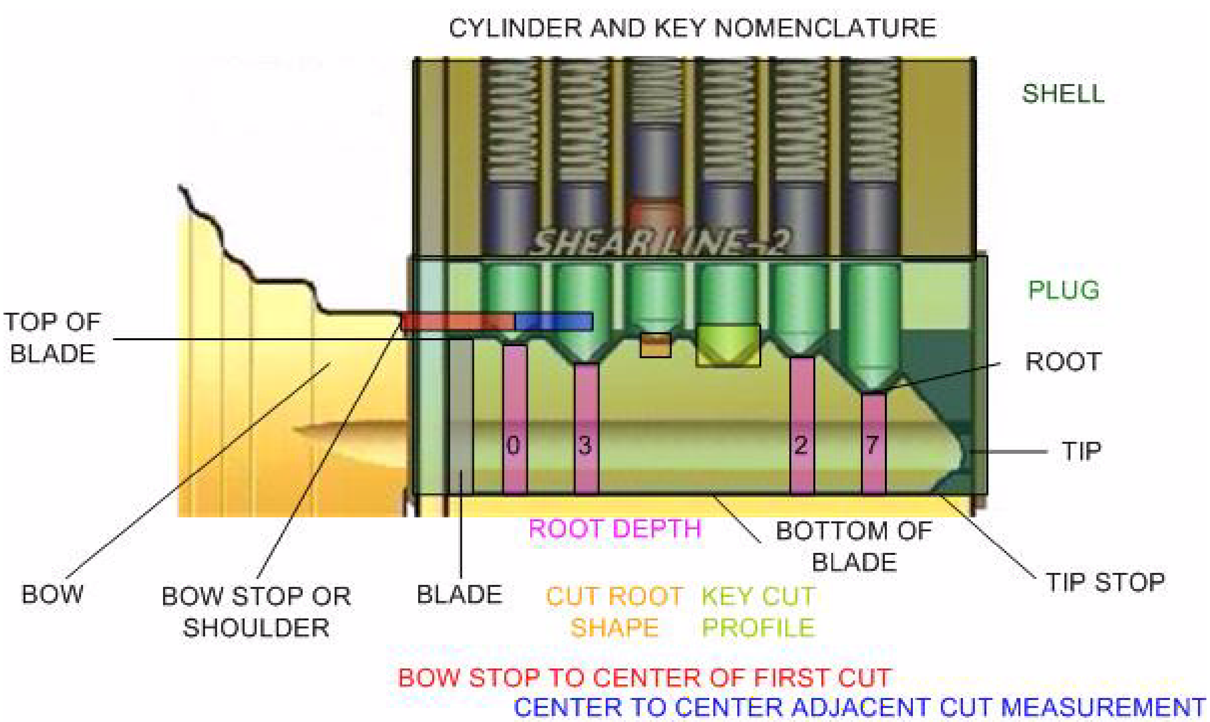
Vertical Group Master Key: Within a standard progression format, the two-pin master key for all combinations in all blocks in a vertical line, down a page.

11_5.3.3 Technical Specifications and Documentation

Master keying systems are described and defined in terms of accepted industry standards and specifications. In this section, the nomenclature and technical details of master keying systems are examined.

11_5.3.3.1 Nomenclature, Measurements and Tolerances

Basic measurements and tolerances of plug, shell, and key are important in order to understand their interaction and affect upon the design of a master key system. Manufacturer specifications for cylinders and keys will provide basic design criteria for a master key system in terms of the KBA, progression technique, and available combinations. Although described elsewhere in this text, the diagram below identifies all critical parts within a cylinder together with proper nomenclature. The manufacturer will assign values to each component that will form the basis of all master key systems. The relationship between each component and their measurement must be understood in order to properly design and implement a multilevel keying system. Tolerance build-up is directly related to specifications, and thus the minimum depth increment for progression must exceed the total tolerance error, or key interchange will occur.



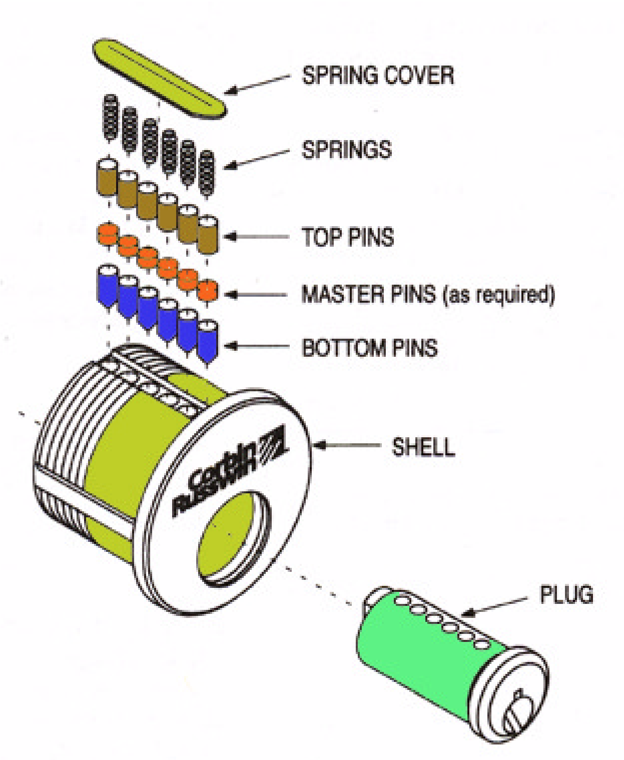


Figure LSS+1127 Identification of critical components within the cylinder. Various root depths are shown (0,2,3,7) for a Schlage lock (left).

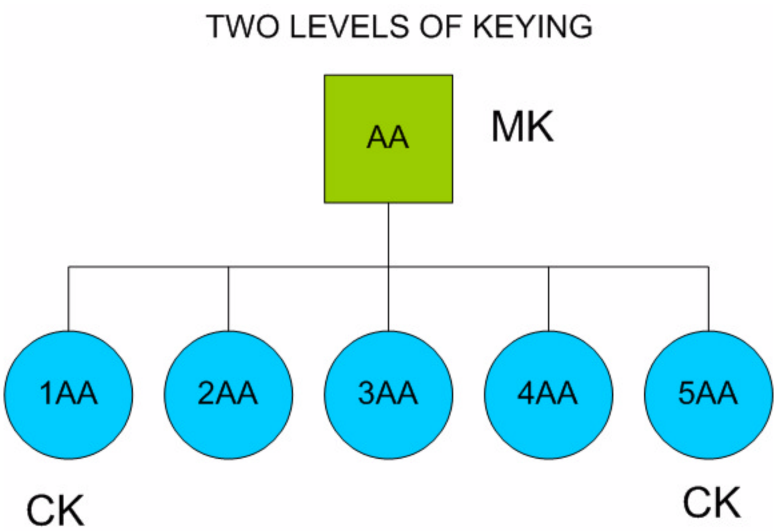
The components in the diagram are described in the preceding definition section of this chapter, and in **chapter 3**.

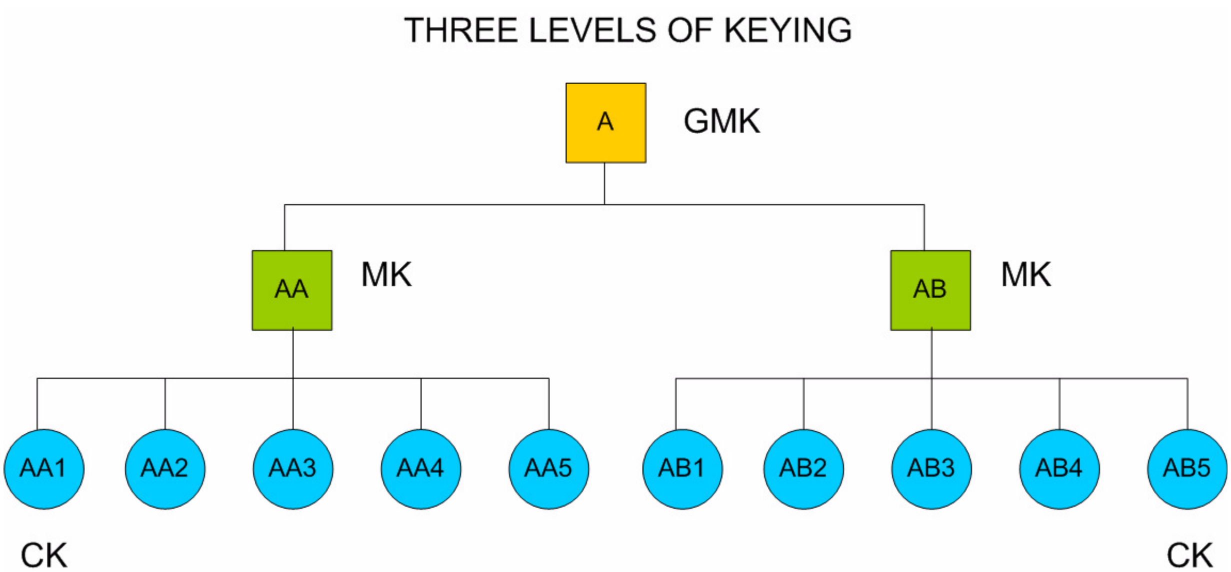
11_5.3.3.2 Levels of Master Keying

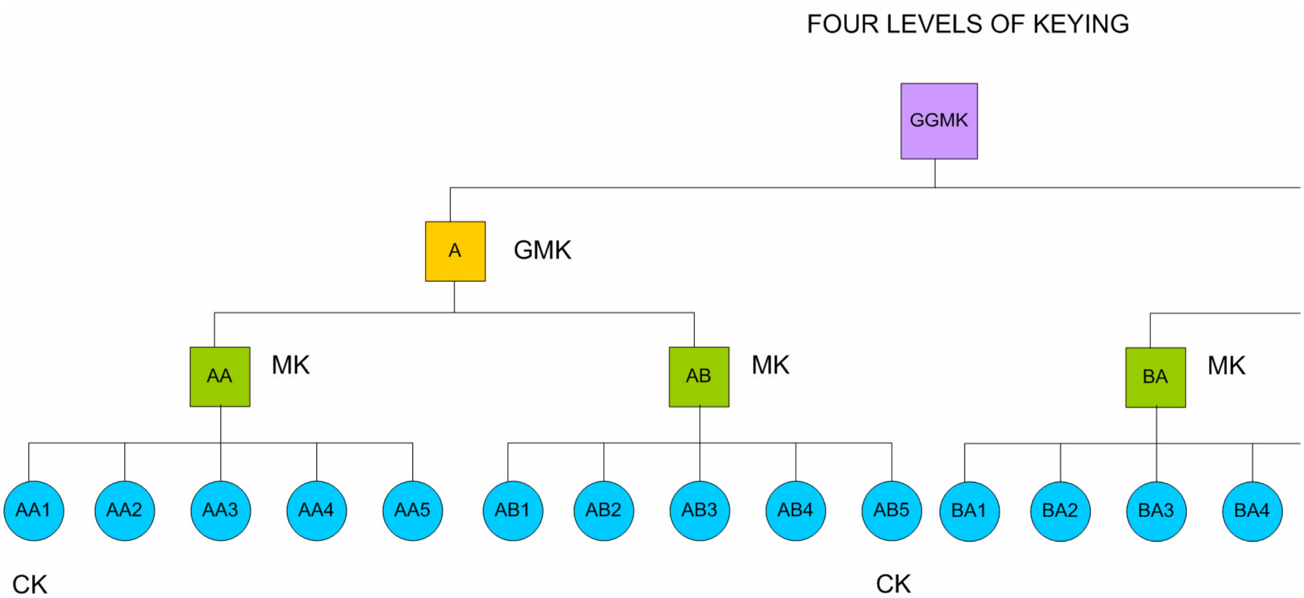
Master key systems are defined by an expansion specification that will delineate keying levels and associated cylinders. In this section, these concepts, as well as system documentation, definition of specific types of keys, and certain design limitations (MACS) are discussed. Pin tumbler keying theory is examined in the sections following this discussion.

Locks can be pinned for several levels of keying, depending upon the requirements of the location, as defined in the expansion specification. The lowest level is the change key. Generally, systems are not programmed for more than six levels (as defined elsewhere in this chapter). Diagrams of two, three, and four keying levels appear below. A five-level system is shown in the definitions of keying levels, above. Standardized coding (SKCS)

for each level is utilized in the diagram.







11_5.3.3.3 Expansion Specification

When designing a system, the starting point is the **expansion specification.** This delineates the total number of theoretical bitting combinations that are required by the system at each keying level. In essence, it defines system functionality in terms of the number of locks and key combinations. A comprehensive premises survey must be accomplished prior to planning any master key system and developing such a specification.

Consideration must also be given to any access control system that is to be implemented or that is already in use, because even the most sophisticated systems can provide a false sense of security. Electronic access control using a variety of technologies has become common in any installation that has secure areas. Unfortunately, most electronic systems have a mechanical lock that can be used as an emergency bypass in the event of failure of the main system. Therein lies the problem, because in almost every keying system that employs any form of access control, there is also a master key system. As detailed in subsequent sections, virtually every master key system is vulnerable to attack and compromise. In a successful attack, the access control system can be completely bypassed through the use of a top level master key.

The following primary issues must be resolved in planning any

master key system:

- **Different levels of access;**
- **Kind of installation;**
- **Floor plans;**
- **Information for every opening;**
- **Risks associated with master keying for a specific facility;**
- **A functional diagram of the entire system. This will dictate the structure of the system;**
- **Have spaces been grouped to reduce functions in terms of keying requirements;**
- **Have high security locks been integrated into the system? Is there a mixture of high security, old locks, new locks, or interchangeable core locks;**
- **Are access control devices presently in use or desired to be implemented into the system;**
- **How is the system to be administered and maintained;**
- **What key control measures will be implemented;**
- **Are there any mechanical issues involving the locks that have been selected for use in the system;**
- **What are the potential number of combinations that are presently and projected to be required for the system;**
- **What is the best approach to keying;**
- **Lock technology desired and needed for the specific installation;**
- **Number of locks;**
- **Number of change keys that are required under each master key;**
- **Number of group access levels or levels of keying;**
- **Identification of individual access requirements;**
- **Necessity to use sectional keyways;**
- **Desirability of restricted keyways;**
- **Security enhancements for the lock technology that has been chosen: sidebar, magnetic, electronic, master ring, other system;**
- **Total potential number of locks within each system;**
- **Potential for uncontrolled cross-keys or incidental**

master keys;

- **Nature and size of the business or entity in terms of personnel, potential turnover, and operational requirements;**
- **Typical requirements for certain types of installations. For example, hospitals will generally have different needs than primary and secondary schools in terms of keying levels and change keys under each level;**
- **Will the design of the system encourage key picking (the use of change keys to open an unintended lock by manipulation);**
- **Has the expansion specification been thoroughly defined.**

For systems integrating monitoring of door opening and closing and alarm functions using computerized-control, additional considerations may include:

- **Area access restrictions;**
- **Time of day and day of week restrictions;**
- **Delay on entry;**
- **Lockout capability;**
- **One-way entry: lock or unlock only;**
- **Audit functions.**
- **The type of master key system, and how mechanical locks are integrated into access control. Can the sophistication of the access control system be compromised with a key? If locks are not utilized in coincidence with access control protection, then the entire system can be compromised if the TMK is obtained.**

It is mandatory, to create an organizational flowchart and expansion specification for the following reasons:

- **Show the relationship between keys and locks and how they control access for each security level;**
- **Provide a uniform and effective method of graphically depicting the entire system;**

- **Offer better control of keys in the system;**
- **Explain the function as well as the use of each key;**
- **Identify potential key interchange and cross-keying problems that can be easily overlooked.**

From the flowchart, the building owner, management, or security staff can readily understand what the system will and will not do. In the context of a criminal investigation, it may be advisable to request a system flow chart to pinpoint access. It is standard practice to submit the master key system requirements to the factory for pinning of cylinders through keying specifications and a system matrix or listing of all assigned locks and keys. In the unlikely event that the system is developed on site, extra attention must be paid to cross-keying potential and key design.

The expansion specification provides an arithmetic definition of the combinations required for all of the locks in the system and can be considered as the logical extension of the Standard Key Coding System. Like the SKCS, the actual specification is noted by keying levels, and denotes the level, number of master keys and the number of associated change keys. The notation is written to define how many levels there are from highest to lowest order and the number of combinations required for each level. The method of notation is always the same. Expansion specification must take into account both **symmetrical** and **asymmetrical** systems. That is, some systems may have an unequal number of change keys under certain master keys.

Expansion specifications for symmetrical notation

- **Three or more levels of keying;**
- **The specification does not indicate that all of the possible master keys and change keys will in fact be required or used. It simply projects the maximum possible needs of the system;**
- **The expansion specification is often based upon a division of the key in the key bitting array to provide for the maximum number of keying levels and change keys that may be required. Note: such a "division" may be altered by the use of incidental master keys;**
- **The specification must reflect any change keys that are under a level not directly above them. Thus, change keys may be directly under a grand master key, but not under the master key directly below that grand master key. It should be noted that there will**

in fact be a theoretical master key combination above such change keys, but it may never be cut;

- **The number of theoretical combinations is the same for any level of master key. A system that is noted as 1-5-50 specifies one grand master key, five master keys, and fifty change keys under each master key. The system is said to be symmetrical because for each grand master key, there are five master keys, and for each of those five master keys, there are fifty change keys. In certain systems, however, this specification would be different for specific master key levels. In such case, the notation would be asymmetrical to denote the differences;**
- **The specification should anticipate the maximum number of change keys that will be required for any master key, now and in the future. An example would provide for a three level system (one grand master key, three master keys, and forty change keys). Remember, the specification is symmetrical, so if presently there is only a requirement for thirty change keys under two of the master keys, and forty change keys under the remaining master key level, then the specification would require that forty change keys be provisioned for each master key. The notation would be written 1-3-40.**

The table shows the relationship between the expansion specification for a symmetrical system and the standard key coding system. In our example, Roman numerals (I, II, III, IV, V, VI) are used to denote keying levels, and the arithmetic notation system.

SYMMETRICAL EXPANSION SPECIFICATION*	Level of Keying	Key Name	Level ID	Abbreviation	Key Symb
	1	Change key	Level I	CK or k	
	2	Change key Master key	Level I Level II	CK MK	1AA, 2AA AA
III-II-I	3	Change key Master key Grand master key	Level I Level II Level III	CK MK GMK	AA1, AA2 AA, AB, A
IV-III-II-I	4	Change key Master key Grand master key Great grand master key	Level I Level II Level III Level IV	CK MK GMK GGMK	AA1, AB1 AA, AB, A, B GGM
V-IV-III-II-I	5	Change key Master key Grand master key Great grand master key Great great grand master key	Level I Level II Level III Level IV Level V	CK MK GMK GGMK GGGMK	AAA1, AA AAA, AAB AA, AB A, B GGGM

VI-V-IV-III-II-I	6	Change key Sub-master key Master key Grand master key Great grand master key Great great grand master key	Level I Level II Level III Level IV Level V Level VI	CK SMK MK GMK GGMK GGGMK	AAAA1, A AAAA, AA AAA, AAB AA, AB A, B GGGM

***Note that the expansion specification is written from top level to lowest level, Our example utilizes Roman numerals to define each level. The actual notation format is in single integers.**

Examples of expansion specifications for symmetrical systems:

1-3-50: three level system, one grand master key, with three master keys under the top level, and fifty change keys under each master key;

1-3-5-35: four level system, one great grand master key, three grand master keys, five master keys, and 35 change keys under each master key;

Certain systems may require change keys to appear directly under higher keying levels, such as grand master (GMK), or great grand master key (GGMK), rather than master key level. The method of notation is different to reflect this change. Remember, in symmetrical notation, integers are separated by dashes; the dashes denote keying levels. The numbers show the actual quantity of combinations for each level. For notation of change keys directly under higher keying levels, parenthesis are utilized. In order to indicate the association of change keys with a specific master key level, they are indicated by parenthesis immediately to the right of the keying level.

In the example above for our three level system with three master keys and fifty change keys under each master key, the notation was 1-3-50. Let us say, however, that we require ten change keys under the grand master key, as well as fifty change keys under each master key. This would be written as 1(10)-3-50. In this instance, the dash is utilized to distinguish keying levels. As with standard symmetrical notation, levels run from top level to bottom, left to right. The (10) is associated with the top level master key because **both** are to the left of the dash separating levels.

Examples of expansion specifications for symmetrical systems with change keys directly under higher levels:

1-100: Two level system, one master key, one hundred change keys;

1(10)-3-50: Three level system, one grand master with three master keys, each having fifty change keys, and one with ten change keys under the grand only;

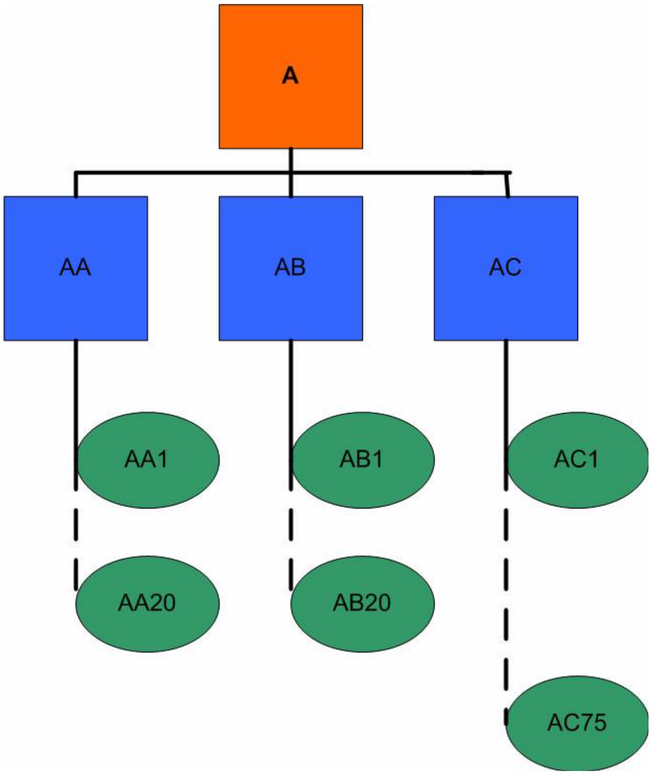
1(35)-5-10-50: Four level system with one great grand, with five grands, ten masters under each grand, fifty changes under each master, thirty-five change under the great grand only;

1(10)-4(20)-5-55: Four level system, GGMK with four grand masters, five masters under each grand, fifty-five changes under each master, ten changes under each great grand only, and twenty changes under each grand only.

1-15(28)-3-50: Four level system with one great grand, fifteen grands, three masters under each grand, and fifty change keys under each master, and twenty-eight changes under each grand only;

Expansion specifications for asymmetrical systems

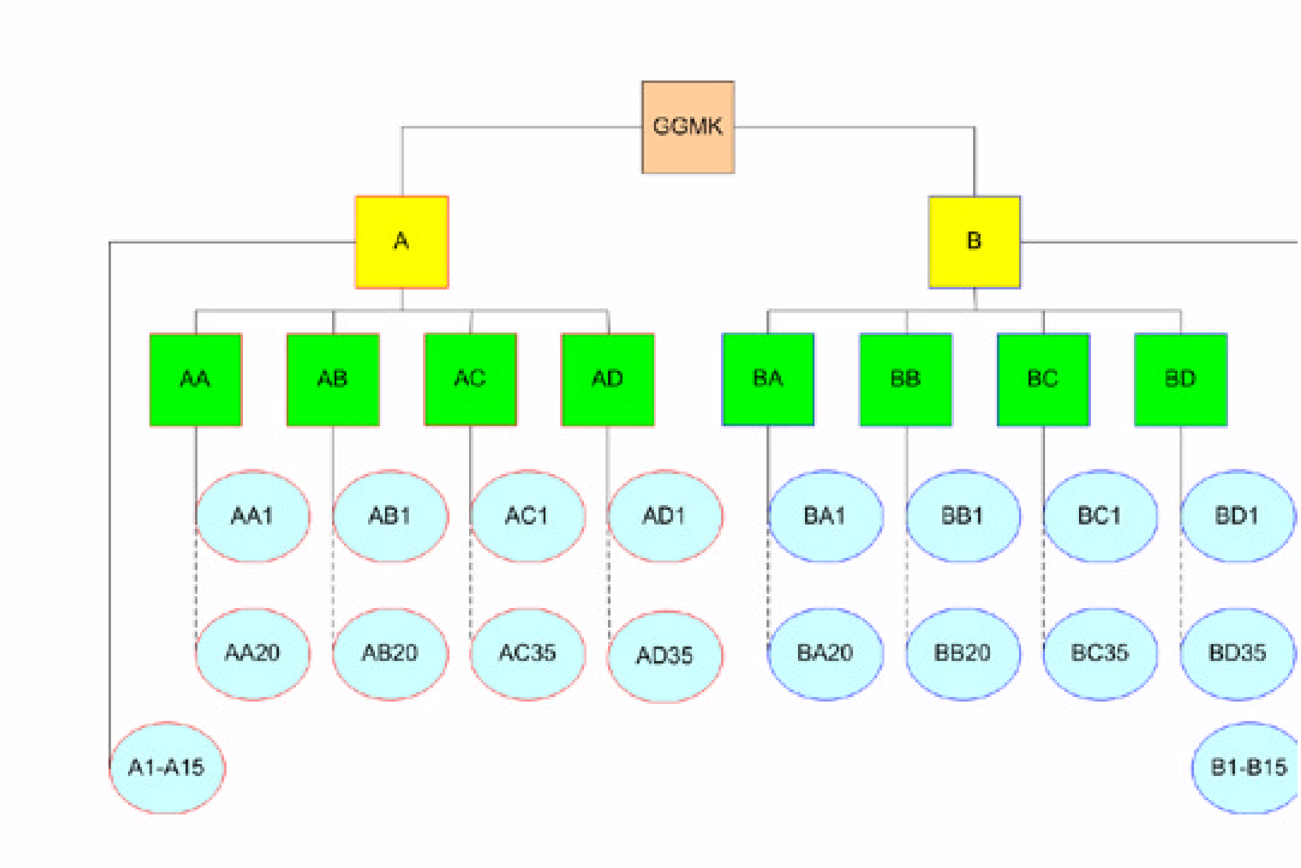
An asymmetrical system is one in which there is an unequal number of change keys under each master keying level. Note the distinction in this scenario and the one above where there are change keys associated directly under a grand master or higher level, but not with the master key level directly above the change key level. Thus, for example, in a three level system with a total of three master keys, there may be two master keys each with twenty change keys, and one master key with seventy-five change keys. Again, parenthesis are utilized to associate master key levels with their change keys. Thus, the above cited example would be written as **1-(2-20)(1-75)**, where red indicates the grand master key, blue is the master key level, and green, the change key level.



Compound asymmetrical expansion specifications may also be written. These reflect systems that have different numbers of master keys and associated change keys, as well as change keys that are directly under higher levels of masters. The notation follows the same format with respect to the use of parenthesis and groupings.

Example of expansion specifications for compound asymmetrical system with change keys directly under higher levels

1-2(15)-(2-20)(2-35): Four level system with one great grand master, two grand masters each with four master keys, (two master keys with twenty change keys under each grand, and two master keys with thirty-five change keys under each grand), two grand masters with fifteen changes under the grands only. Each keying level is color coded (orange, yellow, green, blue) for ease in understanding, and line colors (red and blue) denote the association between keying levels



11_5.3.3.4 Master Keying Records and Documentation

Security, maintenance, and liability issues make it imperative that proper and comprehensive records be maintained for every master key system. The process begins with the first site survey and keying conference and continues to include the ordering and installation of hardware throughout the life of the system. The following documentation and processes are essential.

- **Site survey and keying conference. Compile complete and accurate data about the facility. This includes:**

- **list of all openings (doors, padlocks, overhead doors) and their function. Openings (not the doors) should be individually marked;**
    - **keyways;**
    - **number of chambers within each lock;**

- **verify that all hardware is operational;**

- **Hardware schedules(134). All hardware should be listed;**

- **Keying schedules. You can combine keying and hardware schedules, if desired, organized by lock. These must be kept updated and accurate to be of value;**

- **TMK Register and end-user register. The TMK and end-user registers provide critical information regarding all keys within a system. Registers should never be provided to the customer. The TMK register allows the locksmith to organize the bitting lists for all clients in order to prevent duplication of the TMK and the isolation of client systems geographically. These registers must be kept secure. Liability issues are detailed in chapter 37. The TMK register reflects the design of the top level master key and is based upon specific design criteria defined in this chapter.**

- **Progression and bitting lists. For security, there should be no customer identification associated with this information, but rather an indirect code that is only available to employees of the locksmith with a need to know. The lists must be secure and accurate. Remember, the failure to develop comprehensive records can cause the reuse of combinations by error, possibly incurring liability.**

- **Authorizations and key inventory records. In high security systems, there must be strict procedures for the distribution of restricted blanks and duplicate keys.**

11_5.3.4 General System Design Rules

Every manufacturer establishes different standards for bitting depth and spacing, as well as pin lengths. These guidelines must be followed and will define:

- **How many depth cuts are available, and how they are numbered;**
- **The maximum allowable vertical increment between adjoining cuts (MACS);**
- **How the tumbler cuts are spaced on the blade of the**

key;
- **The minimum depth increment;**
- **Whether a one or two-step progression system is utilized in a master key system.**

Failure to adhere to rules relating to master keying can result in loss of security, mechanical problems that can lead to operating failures, cross-keying difficulties, and broken keys.

11_5.3.4.1 Change Keys and Master Keys

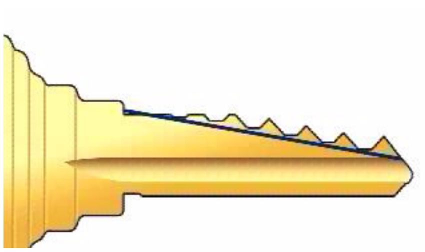
Within any master key scheme, all keys must have the same keyway or sectional keyway system, acceptable bitting patterns must be developed, and standard depth cuts must be utilized. Note that master key systems can be expanded through the use of different sectional keyways.

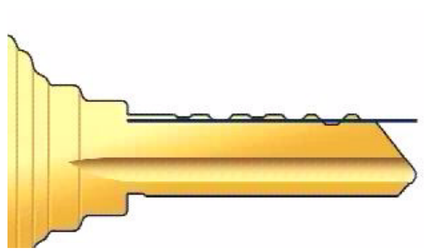
All keys in a master key system should be designed to incorporate certain characteristics to maintain security. The basis, in large measure, is reliant upon the mechanical parameters of the lock and its capability to offer a significant number of **real** rather than theoretical differs or different keying combinations. Jiggling of a key should not result in opening the lock. Although any key combination can be utilized as a master key or TMK, there are certain accepted guidelines that are based upon the keying scheme that generally include the following requirements:

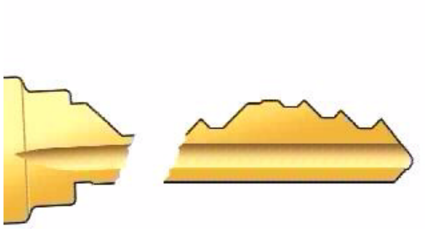
- **With respect to the design and layout of individual combinations, at least one very deep cut may be desirable, so long as it is not placed near the bow of the key, thereby causing structural weakness. Within the TMK, at least one cut that is deeper than any within the change key will prevent jiggling. It is also advisable to use one very shallow cut to avoid change keys being altered to a master key combination;**
- **There should be a mix of depths so that not all cuts are shallow or deep. A stair-step pattern of cuts should not be made because they can allow a key to be improperly withdrawn from the lock during rotation of the plug and will also make the lock easier to pick;**
- **No more than three adjacent cuts in any key should be of the same depth, nor should there be more than four cuts of the same depth in any one key. This requirement will not be an issue with even-odd parity;**

- **Strict adherence to Maximum Adjacent Cut and depth-cut specifications is imperative to prevent overlapping of V cuts;**
- **The accepted standard minimum depth-cut difference or increment is between .023" and .028" for master pins. Any increment less than .023" will require a two-step progression;**
- **Nickel silver blanks should be used whenever possible due to their strength. They are usually supplied with high security cylinders;**
- **Refer to cuts as shallow or deep, not high or low;**
- **Use factory OEM pins. Do not utilize old or filed pins, and be certain that all pins are chamfered for smooth operation;**
- **Never file pins or plugs;**
- **In master key systems that were implemented more than forty years ago, manufacturers typically established the master key cuts lower than or equal to the change key depths to facilitate manual pinning of the lock. Within Corbin locks, for example, a master key code of 80008 would be common, with all change keys having bitting higher than those values. This practice should be avoided.**

LSS204: Brian Chan discussing old style master keying and pinning.







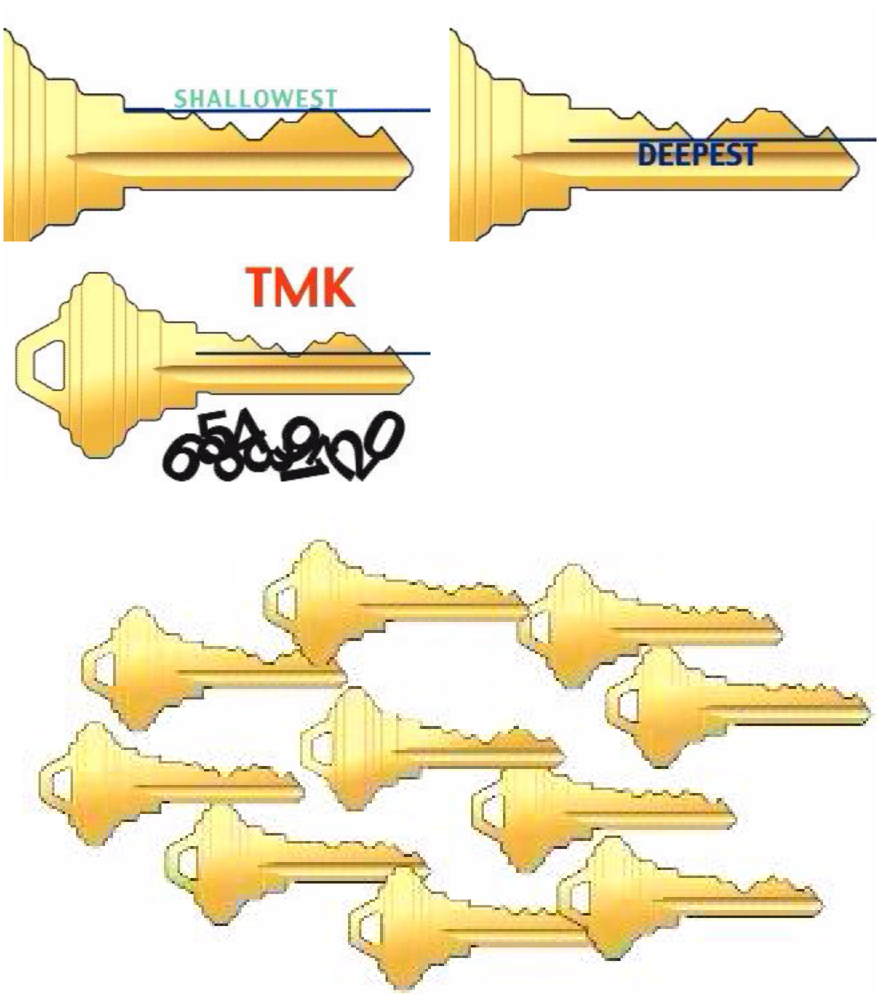


Figure LSS+1112 Keys must be designed to avoid stair-step or sequence patterns, all cuts close to the same depth, and very deep cuts close to the bow of the key. In addition, the system should be calculated so that the master key has at least one deeper and shallower cut than the change keys, if possible. This will avoid the potential for filing or modifying change keys to work as master keys. Master keys should also be normal in appearance, and have no special attributes that would identify them as a special or master key. Master keys should be carefully planned and not have random patterns. Courtesy of HPC Interactive Learning Series.

There are very specific rules with regard to depth and spacing in complex master key systems. These relate to adjacent cut depths, the thickness of master pins, and the design of the master keying levels. If MACS and other rules are not followed, the result will be a decrease in security and potential mechanical malfunction.

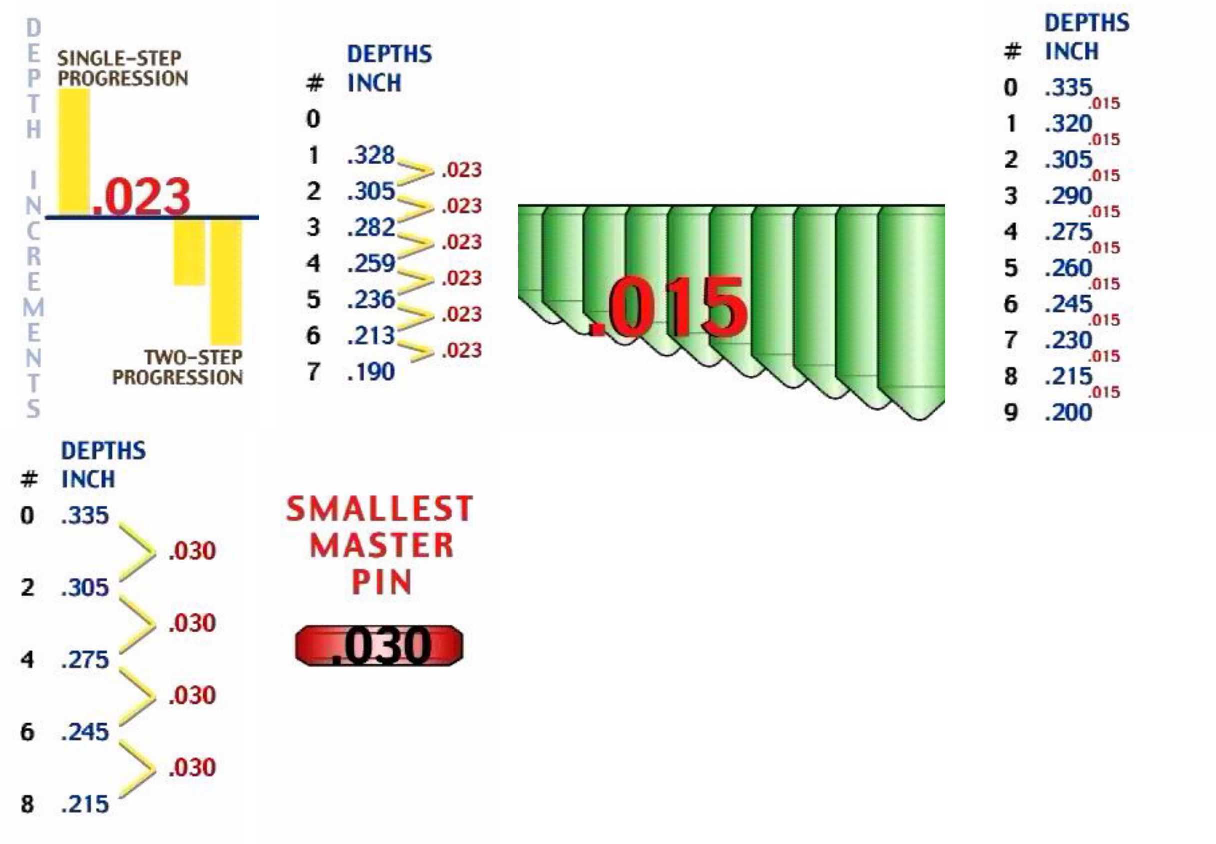


Figure LSS+1108 This series of diagrams represents the different approaches to depth levels by manufacturers. Some manufacturers, such as Schlage, utilize a constant difference of .015" between cuts, while others utilize .023" or greater. Depending upon how many bitting depths are created, the master key system will utilize single-step or two-step progression to set the depth coding for master key levels. A master pin must be at least .023" thick. If the manufacturer utilizes .023" as the difference between pin lengths, then there will be a greater number of different depths available for use in the KBA and generation of combinations. In contrast, if there is only 0.015" difference between cuts, then in a ten depth system (0-9 in the example), there will only be five positions that are available for insertion into the KBA. Courtesy of HPC Interactive Learning Series.

0	0	**0**	0	**0**	0
1	**1**	1	**1**	1	**1**
2	2	**2**	2	**2**	2
3	**3**	3	**3**	3	**3**
4	4	**4**	4	**4**	4
5	**5**	5	**5**	5	**5**
6	6	**6**	6	**6**	6
7	**7**	7	**7**	7	**7**
8	8	**8**	8	**8**	8
9	**9**	9	**9**	9	**9**

Figure LSS+1109 This chart represents the reduced number of available depths for a master key system. Only half of the total available depths can be used in this progression. This chart refers to Figure LSS+1108 (above) wherein Schlage utilizes .015" steps between each depth. A two-step progression (every other depth) is required. Thus, only five of the ten available depths can be used to define master and change keys. In this example, there are 5^6 or 15,625 differs available. This number would be further reduced by other rules. Courtesy of HPC Interactive Learning Series.

11_5.3.4.2 Maximum Adjacent Cut Specification (MACS)(135)

As described elsewhere in this chapter, MACS is a concept that relates to the mechanical design of a specific cylinder and the interaction of the key, bitting design, depth, and tumblers within adjacent chambers. The violation of manufacturers specifications can lead to improper and erratic operation and lockouts. The following statements can be made regarding maximum adjacent cut specifications:

- **MACS relates to a physical limitation on how a key can be cut and shaped;**
- **Not all theoretical combinations are practical or useable. Although a combination may be available, it may also violate MACS and not be useable;**
- **Forbidden combinations will usually violate MACS;**
- **A MACS violation is generally undesirable because of its physical characteristics. Thus, a deep cut next to a shallow one is not allowed;**
- **Violation of MACS for some products will allow the adjacent**

depths to be utilized in extreme cases, but not desirable;

- **MACS can prevent a key from being cut. However, the bitting code can be used in the system;**
- **In designing a master key system, each progressed column must be examined for MACS violations;**
- **MACS is computed based upon each manufacturers specifications. Schlage, for example, provides for a MACS of greater than 7. Thus, adjacent cuts of 92 would be acceptable, but 91, 90, 80 would not be allowed;**
- **MACS is calculated by subtracting the value of adjacent cuts;**
- **The angle of cut is also factored into the MACS equation;**
- **The calculation of MACS can be affected when computed from bow to tip, or tip to bow, depending upon manufacturer.**

11_5.3.5 General Pin Tumbler Master Keying Theory

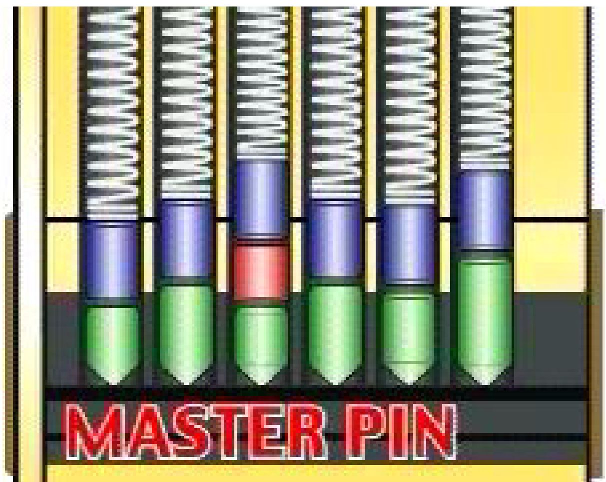
This section deals with traditional pin tumbler locks having one physical shear line between the plug and shell. A later section examines keying and decoding of interchangeable core locks and master ring locks that contain two physical shear lines.

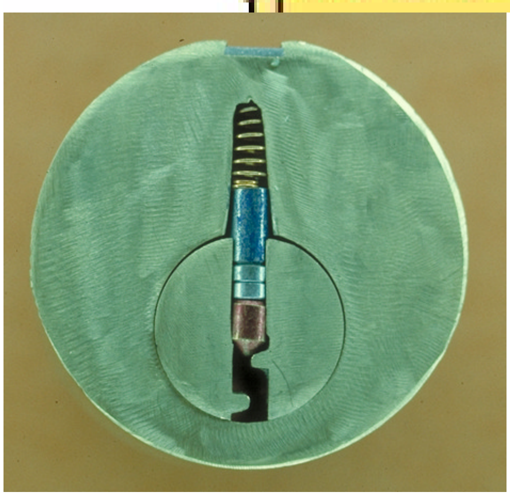
Master keying involves the segmenting of pin tumblers, thereby allowing keys with different individual combinations to create more than one virtual shear line. The pin tumbler lock is adaptable for simple to complex keying systems because of the use of pins with varying lengths. The ability to alter and create different lengths through the introduction of pin segments, using one or more master pins in all or some of the pin chambers, is the essence of master keying.

In a cylinder with only one change key, all of the pins are raised and split at the shear line upon insertion of the correct combination. Within the master keyed lock, in contrast, there is created another level or split. Usually one master pin is used for this splitting. The methodology of implementing a master key system can be quite complex and generally involves one of two accepted techniques: total position progression (TPP) or rotating constant (RC). Both of these algorithms have been designed to minimize cross-keying by limiting the number of virtual shear lines that are created and to increase security.

In the TPP scheme, every pin stack has only one defined bitting

position for the top master key, and that depth is never used in that position for the change key. In the RC method, the depth for one or more specific pin stack positions can be shared between the change key and master key, but the positions may rotate for a group of locks. Each of these schemes presents its own security issues, however, which are discussed in a subsequent section.





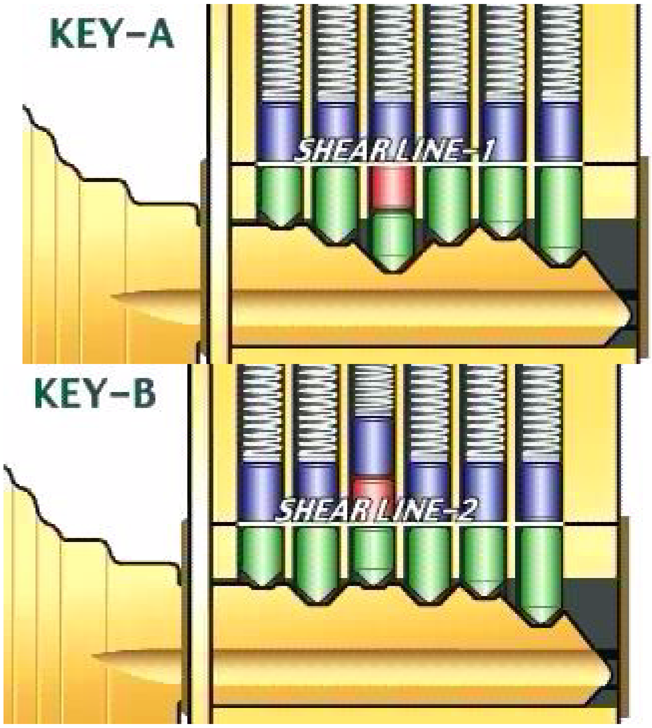


Figure LSS+1110 In this series of diagrams, the master pin is shown in the third chamber position. A different shear line is created for a top master key (A) and a change key (B). When one master pin is utilized in each chamber, a complex keying system can be created. Courtesy of HPC Interactive Learning Series.





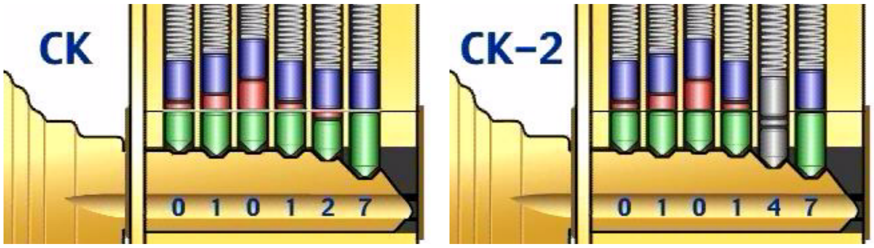


Figure LSS+1111 In this illustration, CK (change key) 010127 opens the lock by creating a combination shear line with both lower pins and master pins. CK-2, however, will not open the lock, as pin number 5 does not break at shear line. Courtesy of HPC Interactive Learning Series.

Four different theoretical keying examples will be presented to illustrate how master pins are utilized, followed by a discussion of master keying schemes. Note that in **example 4**, we do not take into account recognized master keying schemes or levels. These issues are considered subsequently. The cross-keying problems that are shown would largely be eliminated in any master key system that was defined through TPP or RC schemes. Rarely, if ever will there be more than two lower pins (bottom pin and master pin) in any chamber. The exceptions would involve master ring locks, the intentional cross-keying of cylinders, and maison keying, discussed elsewhere. Otherwise, the result of keying a cylinder in the manner shown in **example 4** would create a serious loss of security and is not considered as acceptable practice. The example is illustrative of the issues that occur in maison keying with regard to cross-keying and incidental master keys. These examples are presented merely as an introduction to the concept of split pin master keying, allowing the creation of virtual shear lines and the use of the combination of lower and master pins to derive combinations. This will become especially relevant when we examine complex multilevel master key systems that utilize incidental master keys. Other issues, such as one and two-step progression, parity, MACS, and key design have not been considered for this discussion.

Keying Example 1

In our first example, the plug for a Corbin five-pin tumbler lock, having a change key with the code 75126 and a master key with a code of 80008, must be set up. These are direct reading codes: a "1" cut being a very shallow depth, a "0" the deepest possible cut. If just the lower pins for the change key were present, they would allow the plug to rotate only when

combination 75126 is introduced. If the master key is inserted, all of the change key tumblers are going to be **beneath** the shear line for the combination of 80008.

To allow the master key to work, more pin segments are added to increase the length of each pin. This creates another shear line (virtual shear line) for combination 80008. In order to **make up the difference in length** between 75126 (our imaginary change key) and 80008 (the master key), added pin segments must be placed in each chamber. The composite combination of these added segments would be 15982.

In our example, the combination of the change key plus the master pins must equal the master key pin lengths. Thus,

7 5 1 2 6 Change Key
+ + + + +
1 5 9 8 2 Master Pins
----
8 0 0 0 8 Master Key

Keying Example 2

In a slightly different example, the master key is coded 21135 and the change key 50347. In this case, the master key has cuts that are shorter than the change key. Thus, the following mix of tumblers would be used:

2 1 1 3 5 Master Key
+ + + + +
3 9 2 1 2 Master Pins
----
5 0 3 4 7 Change Key

Keying Example 3

In this example, some of the change key cuts are lower, and some are higher than the master key cuts. Thus, our change key has a combination of 26335, and the master key has a combination of 80114. Note, however, that some of the pin lengths are added and some are subtracted.

2 6 3 3 5 Change Key

+ + - - -
6 4 2 2 1 Master Pins
----
8 0 1 1 4 Master Key

The **actual order** of pin stacking for each chamber in this example would be:

1 2 3 4 5   Pin Position within Plug

6 4 2 2 1   Master Pins
2 6 1 1 4   Lower Pin set

In the above example, the first two bottom pins and the last three **lower and master pins** combine to form the individual change key combination. Likewise, the master key combination is formed by using the combination of both lower tumblers in the first two chambers, and the last three bottom tumblers only.

Keying Example 4

In the **grand master** system, we have **three** separate keys that will open one lock: the change key, the master, and the grand master key. In TPP or RC systems, such complex keying may be accomplished with only two bottom pins; there is no necessity to add more master pins to create additional virtual shear lines. In locks with master rings, however, pin segments are added at the ring shear line for each required combination. However, to demonstrate the disastrous result that would occur from the addition of more master pins within a conventional lock, the following example is offered. This also illustrate how complex the job of keying would be in comparison to utilizing accepted industry practice with TPP or RC. It is important to note that the same bad result will occur in maison system where multiple pin segments are employed to allow the operation of many keys in one lock. This is a prime example of intended cross-keying.

In our example (that does not rely upon TPP or RC methodology), more master pins are added to create the **grand master** key. Let us assume that our change key is 13308, our master is 75126, and our grand master is 80008. A total of **108 keys** would be created for this lock if it was pinned as shown below (3 x 3 x 3 x 2 x 2).

1 3 3 0 8 Change Key
+ + - - -

```
6 2 2 8 2  Master Pins
---------
7 5 1 2 6  Master Key
+ + +
1 5 7 - -  Master Pins
---------
8 0 0 0 8  Grand Master Key
```

11_5.3.6 Incidental Master Keys, Cross-Keying, and Key Interchange

The concepts of incidental master keys, cross-keys, and key interchange relate to the creation or use of keys that are intended to open one lock, but are able to actually open more than one cylinder. These three concepts are interrelated and are discussed throughout this chapter. Each can have a serious impact upon the security of the keying system and therefore must be thoroughly understood.

11_5.3.6.1 Incidental Master Keys

Incidental master keys are the intended consequence of keying a system that is defined by the total position progression or rotating constant method. They are inherent in split pin master keying systems. TPP or RC schemes rely upon the creation of incidental master keys in order to provide for complex keying levels and access. The charts in sections **11_5.8.2** standard progression format, and **11_5.8.3** matrix format provide an amplification of why incidental master keys are vital to any complex system and how they are utilized.

In a six-pin lock with a total of ten depths per position, and using two-step progression, there are theoretically 10^6 or 1,000,000 combinations. There are actually only 15,625 (5^6) permutations. When one depth is removed for the TMK, there remains **4^6** or 4,096 combinations. **This leaves 11,529 theoretical incidental master keys per system in this example.** The number of incidentals is reduced in a rotating constant system because the number of master pins that are required is less than in a TPP system.

As can be seen in the chart in **11_5.8.2,** incidental master keys are a composite of the change key and TMK bittings. In the true total position progression format, there are always two lower

pins in each chamber: a bottom pin and a master pin. In a lock with six chambers, we therefore must create a total of 64 (2^6) permutations. Other than the change key and master key, all others (total of 62) are incidental master keys. Depending upon the complexity of the system, these incidentals comprise the row, block, horizontal group, vertical group, and page master keys. Remember, split pin master keying allows different keys to work in the same cylinder; this is the basis for the TPP and RC systems.

In the standard progression format listing in **11_5.8.2**, we choose combinations of lower pin segments to create these incidental master keys. Thus, the first VGM 030107 in the chart is actually a composite of the first three positions that define the master key AA, the fourth position (1) which is common to all of the change keys in the vertical group, and the fifth and sixth positions (07) which is common to the TMK. This (incidental) **v**ertical **g**roup **m**aster key is a composite of the lower pin segments that make up the bittings of the master key, change key, and TMK, and will open sixteen locks. As can be seen, any combination of bottom pins and master pins can be utilized to create incidentals. That is how complex keying systems can be created with just two lower pin segments, rather than several master pins in each chamber.

In another example to further illustrate the point, the ninth block master 030167 will open four locks associated with it: 030161, 030163, 010165, and 010169. This is accomplished by using the first three positions for AA master key (030), the fourth and fifth positions of the change key (16), and the sixth position (7) of the TMK. A close examination of these codes reveal that where the bitting values remain constant in every lock (030 in the first three positions and 16 in fourth and fifth positions), those constants are utilized as part of the incidental master key. However, it can be seen that the sixth position in this example utilizes all four available depths (1,3,5,9), and thus the TMK value of 7 is chosen as the constant. Another way of stating this is that the TMK value is always utilized to replace a progressed value for the change key or master key.

Incidental master keys can be defined as those combinations that result from the selection of a composite of pin segments to create keys that will open one or more locks in one or more keying levels. The following master keys are incidental and created by virtue of the use of master pins:

Row master key: A row master key represents the "C" column (fourth position or first change key progressive) that is substituted with the fourth position of the TMK. It is also a one-pin master key, and will open the four locks associated with its row. There are sixteen row master keys per page.

Block master key: The common depth for all combinations within a Block of four locks. This is the first five positions and the TMK sixth position (A). A BM wil operate any cylinder that is on the TMK and is within the block. It is referred to as a one-pin master key because there is one pin different from the change key in that block. One TMK position is utilized as a substitute for the progressed position of the change key. There are sixteen block master keys per page.

Vertical group master key: This is a two-pin master key because two progressed pins are substituted with the TMK values. In this case, the fifth and sixth positions (B,A) are substituted with the TMK values. There are four vertical group master keys per page.

Horizontal group master key: This is a two-pin master key that will open sixteen locks in four blocks by substituting the fourth and sixth positions (C,A). There are four horizontal group masters per page.

Page master key: This is a three-pin master key because the fourth, fifth, and sixth positions (C,B,A) are substituted with the TMK values. There is one page master key for 64 locks where the division is three chambers for the master key and three chambers for the change key (six pin lock), with a two-step progression. The first three positions (F,E,D) are always constant for each page. The last three positions (C,B,A) repeat 64 patterns for each page. There are therefore 64 change keys per page (4 x 4 x 4).

Groups of pages: There are also incidental master keys for groups of pages. Thus, there are sixteen four-pin master keys that will operate sixteen groups of pages. There are four five-pin master keys for four consecutive groups of sixteen pages. And, of course, there is one TMK that will operate all sixty four pages.

11_5.3.6.1.1 Selective Master Keys

Selective master keys are employed in large systems where high

level access is required across different keying levels. The SMK will be programmed to open most, but not all of the locks within the system, thereby distinguishing it from a true TMK. Engineers and housekeeping supervisors are often issued selective master keys because they have a need to access most, but not all areas. From the standpoint of functionality, the design of a SMK can be compared to a master key for keyed alike groups of cylinders. Generally, the selective master key will open locks under different master keys in a system having three or more levels of keying.

A selective master key (SMK) may be considered as a subset to an incidental master key and as a modified alternative to the TMK. They can, in effect, be turned on and off for any lock, and they do not create key interchange. In order to implement selective master keying, one progressive is sacrificed: its code will differ by one depth (in one position) from the top level master key (through double pinning). There is usually only one SMK in a system because of the requirement to sacrifice one progressive. In the **diagram**, the engineers key is identified as AA1 and can open most of the locks under both AA and AB levels.

There is a difference between **selective key systems** and a **selective master key**. Selective key systems are utilized in Europe and provide that every key can be a master key. This would occur in a system wherein there are a limited number of keys and extensive cross-keying requirements. Extra master pins are utilized, making the locks extremely vulnerable. This security issue is in part offset through the use of sidebars and large numbers of pins.

11_5.3.6.2 Cross-Keying: Intended and Unintended

Cross-keying, whether intended or not, can occur in all split-pin master keying systems. Physically, it results from the use of more than one master pin within a chamber. Each time another pin segment is introduced, more virtual shear lines are created, resulting in additional combinations that will open the lock. In certain systems, it is desirable to have change keys open more than one lock. Certain cylinders would be intentionally pinned to accomplish this result. In other instances, unintended cross-keys or key interchange can be created through pinning or system design errors. Cross-keying issues may be largely eliminated in recognized keying schemes that prevent the TMK combination from

being used in any change keys.

In the controlled cross-keying scenario, two or more keys under the same master key level and same higher level will operate one cylinder by design. In such event, security and system expansion is limited. If more than a few cross-keyed cylinders are utilized within a keying system, then many keys may operate such cylinders. The diagrams represent two typical scenarios that employ cross-keyed cylinders. In the first example, four private offices (2AA-5AA) are accessed and shared by a common reception area (1AA). The individual change key to each private office must also access the common area but the key for the common area cannot open any of the private offices. In this instance, **X1AA is operated by 2AA-5AA and AA.**

In the second example, a dormitory lounge serves three individual rooms. There is no change key (X1X) for the lounge, but each of the individual room keys must be able to enter the common access door. The lounge **X1X can be opened by AA1-AA3, AA, and A.**

If uncontrolled cross-keying is implemented by design, then two or more keys under different higher levels of master keying will open one cylinder. Thus, **XAA1 also operated by AB, AB1.**

The following issues and design rules must be considered with regard to cross-keying in any system:

- **Cylinders are cross-keyed, not the keys that fit them;**
- **It is not normal for two or more keys to operate one cylinder. Thus, careful planning of the system is mandatory;**
- **All cross-keyed cylinders must be documented, together with an explanation of what is controlled by each key. Show ALL keys that operate each cylinder; A cross-keyed cylinder with no dedicated change key is denoted by X1X;**
- **X indicates a cross-keyed cylinder;**
- **Cross-keying requires the use of added master pins, resulting in a loss of security;**
- **Cross-keying issues must be analyzed and planned from the inception of a system;**
- **Cross-keying will result in a loss of combinations. Therefore, the number of locks that are intentionally cross-keyed must be minimized;**
- **All locks that are cross-keyed should have combinations that are close to each other or consecutive within the progression**

list: the more identical cuts, the better. Conversely, the greater the number of different cut values that are selected will result in greater loss of available combinations;

- **System expansion will be limited if more than a few keys operate one cylinder and more than a few cylinders are cross-keyed within a system;**
- **Cross-keying is undesirable and should be avoided;**
- **A loss of security will result from cross-keying;**
- **If poorly executed, key interchange will result;**

Although cross-keying is not a recognized system, it must be defined because the condition can create a subsystem of keys to open unintended locks. Cross-keying, if unintended, is an error inherent in master key system design. It results in the creation of extra and unintended key combinations outside of the system. Such permutations are generally unknown and may allow an unauthorized key to open a lock for which it was not designed.

Cross-keying is perhaps the greatest threat to security in conventional master key systems. The problem occurs because of the increased number of tumbler splits that are created in order to allow keys to open locks where such action would not normally occur. A cross-key condition is simply the addition or subtraction of tumbler lengths that occur between the change and master key levels. For example, in a five-tumbler lock with one change key and one master key, there are thirty-two possible cross-combinations (2^5) or different keys **that will all open the lock.** They can also be referred to as incidental master keys. Let us say that the code for the change key is **33308,** the master key is **80096.** The incidental master keys would be as follows:

33308 30308 83308 80308
33306 30306 83096 80306
33398 30398 83306 80398
33396 30396 83398 80396
33008 30008 83396 80008
33006 30006 83008 80006
33098 30098 83006 80098
33096 30096 83098 80096

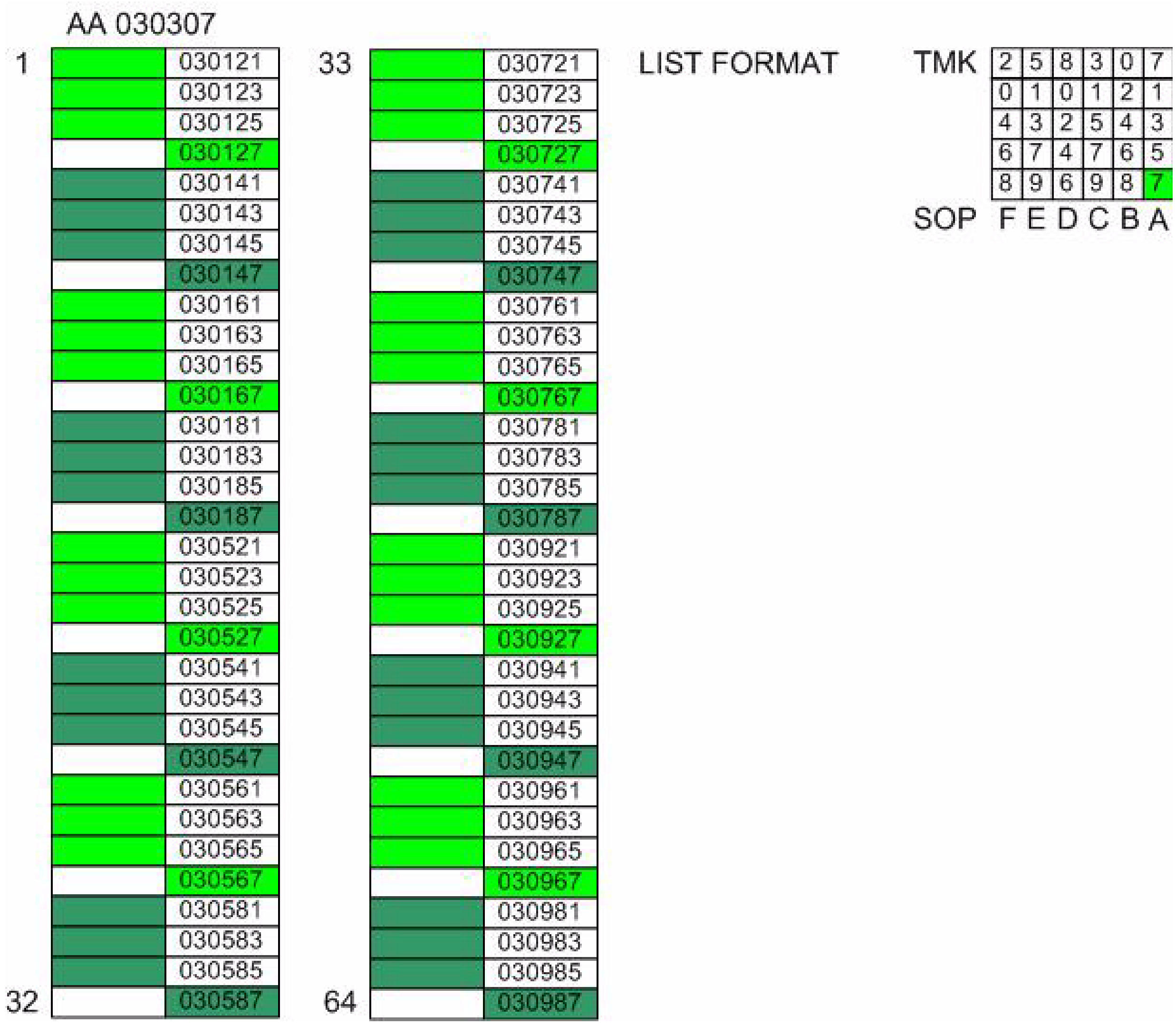
Every one of the above listed keys will open our hypothetical lock. If this system required added master pins in one or more chambers to intentionally cross-key a cylinder, then the number of combinations would dramatically increase. It can be seen that

the addition of extra master pins can substantially reduce the security of both the lock and system in terms of its resistance to picking, impressioning, key interchange and use of unauthorized keys.

11_5.3.6.3 Key Interchange

Key interchange means that a specific key will open one or more locks for which it is not intended. The error can subject the locksmith to liability in the event of a loss resulting from unauthorized access. Key interchange will occur when an error is made in defining the KBA, thereby creating one or more incidental master keys from a progression that repeats values incorrectly. An example is shown below where common depths have been used in the TMK and change key. Remember: never is the same depth shared between the TMK and CK in the total position progression system.

In the progression list in the example, an error has been made in the sixth position of the KBA. The available depths should have been 1,3,5,9. However, a 7 was substituted for 9, with the consequence that sixteen incidental master keys have been created which would open a total of 48 unintended locks under master key 030307. Note that each incidental master key is shown in green, with the three associated locks that can be opened by that key in the same color.



Key interchange between systems in different facilities or locations can also occur when single-step progression is utilized because the available pool of differs (combinations) are the same for all systems that share a common keyway, even though there are more theoretical combinations in the single-step system than in a two-step progression (and parity is not utilized). It is imperative that the locksmith maintain an accurate TMK register to insure that key interchange between client-systems does not occur.

Poor tolerances and cumulative tolerance error within a lock can also contribute to key interchange by allowing the creation of a greater window or gap for the shear line. This could occur from

the filing of the plug, filing of pins, or use of worn components. The ability for key jiggling in such a case is also increased, allowing unintended keys to open a lock.

11_5.3.6.4 Design of the Top Level Master Key (TMK)

Stringent rules govern the design of the top level master key (and control key for an interchangeable core system) if proper system security is to be maintained. As a result, there are few acceptable combinations that are actually useable for the TMK for any manufacturer. As noted elsewhere in this text, it is imperative that accurate and timely records, in the form of a **TMK register(136)**, be maintained by any locksmith who defines the TMK for any system. This is vital in order to avoid conflicts between client systems which could lead to a breach in security and subsequent liability. The maintenance of proper records will:

- **Eliminate the potential for reuse of TMK combinations in different systems that are serviced by the locksmith, especially within the same geographic area;**
- **Reduce the likelihood of key interchange between systems, especially those that utilize the same keyways;**
- **Provide a method to geographically isolate systems;**

The following design rules apply when defining the top level master key.

- **The combination is not chosen at random;**
- **Reasonable criteria must be applied to the TMK definition;**
- **No declining stair step patterns. For example, 02468 can be removed in an unlocked position. The combination 020402 can not be removed in the rotated position;**
- **Do not use uniformly deep or shallow cuts. Uniform patterns are easy to pick and manipulate and are subject to key jiggling;**
- **Keys should not be designed where the depths run in a straight line and have little cut-to-cut variation, thereby reducing pick resistance and pull-out capability of the key;**
- **There should not be extreme cut-to-cut variation that can cause excessive wear on locks and keys;**
- **There should be no deep cuts near the shoulder or bow of the key that can result in metal fatigue and breakage;**
- **Combinations must be chosen that eliminate the potential that**

change keys can be altered to the TMK. For example, the combination of 67876 would not be acceptable. This particular combination also exemplifies the problem of pull-out, low pick resistance. The TMK must contain one cut that is shallower than all others to prevent this practice;

- **Be certain to verify the relationship between key sections between systems to avoid a conflict;**
- **Never use published or pre-written master key systems;**
- **Do not replicate keying systems for different customers;**
- **Do not design the system based upon uniformity or predictability;**
- **Do not use off-the-shelf keys as the TMK;**
- **Alter the parity for added security. A lower level master key in one system may be the same as the TMK in another system. This can also be true of a change key. Changes in parity can prevent this problem. Thus, OOEEOE 512894, EOOOEE 817326, and EEOEOE 627415;**
- **Certain manufacturers may utilize different key sections for master keyed systems as opposed to stock products;**
- **Employ moderate deep-to-shallow cut-to-cut design so as to appear as a normal key and reduce the potential for MACS violations;**
- **Utilize the shallowest cut in one position so that all of the depth cuts utilized in the change key will be deeper, thereby preventing physical alteration. Note that the change key may be modified to replicate an incidental master key, but not the TMK;**
- **Make one of the cuts the shallowest possible to minimize the capability to modify the change key. This will provide added pick resistance in a rotating constant system and will also prevent key jiggling or manipulation;**
- **Manufacturers such as Schlage may not utilize the most shallow cuts (0,1,2) for stock products. In such a case, it would be far easier to decode the master key and top level master key by visual inspection;**
- **Be aware that some manufacturers may write uniformly deep or shallow cuts for the TMK, making them far easier to compromise.**

11_5.3.7 Improving Master Key Security

In all conventional systems, master keying generally reduces security. Depending upon the system, the higher the level of

keying, the lower the security. Although master keying will offer simplified organization and greater convenience, there are many considerations affecting security that are involved in planning, implementing, and monitoring any specialized keying system. The master key scheme that is chosen can also have a significant impact upon security. The basic rule: **master keying systems are not recommended if there is an alternative.**

Unless the proper procedures and guidelines promulgated by the manufacturer are adhered to, serious degradation of system security will result. Issues involving tolerances, differs, adjacent cut specifications, keyway design and control, and generation of bitting combinations will all affect the potential for the system to be compromised by cross-keying issues, key interchange, change key modification, extrapolation of the TMK, and picking.

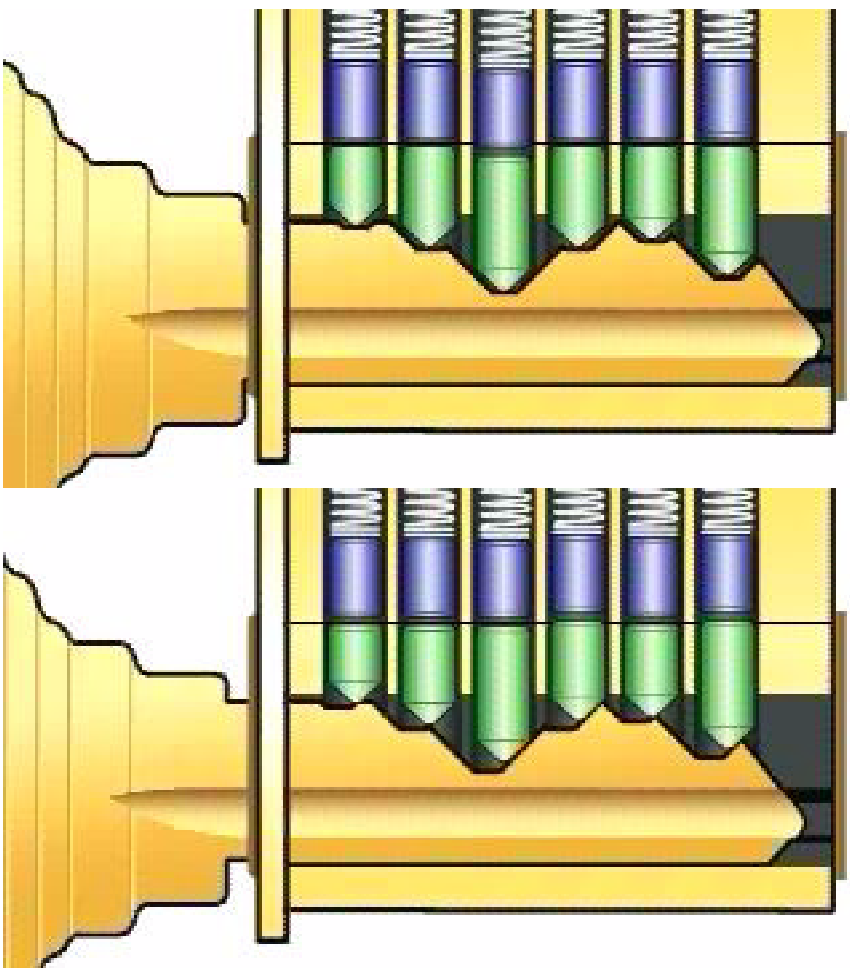


Figure LSS+1101 If master keys are not properly designed and differs calculated, then there is the potential that a change key can be jiggled to raise pins to shear line in a lock that was not intended to be opened by that specific change key. The practice is called "key-picking." Courtesy of HPC Interactive Learning Series.

For any system that is to be master keyed, careful planning is a necessity. Most master key systems have a life of between five and fifteen years, although many are in place for a much longer period. Unless proper control procedures are implemented, it is a sure bet that the system will be compromised long before the end of its projected life.

11_5.3.7.1 Security Considerations

Any conventional master key system is subject to compromise or bypass through a variety of techniques that are in large measure dependent upon the design of the system, the scheme employed to define master and change key levels and combinations, and mechanical enhancements that increase resistance to picking and similar forms of covert attack.

Although the master key for these types of systems cannot be derived from the inspection or decoding of one single change key, the code for master keys may be determined through the analysis of several change keys, depending upon the algorithm that was utilized to define the system. If a significant sample of change keys is obtained and either a total position progression or rotating constant scheme was used to define the key bitting progression, then it is possible to extrapolate the TMK bittings through a process of elimination and reverse engineering. This assumes that significant data is available about the lock so that a hypothetical KBA can be constructed that provides all possible bitting values based upon a one or two-step progression. Each change key is evaluated for each chamber and depth code. In a true TPP system, the TMK values will never be used in a change key. Thus, the value of the TMK bitting for each position can be deduced, based upon a computation of all of the values that are present in the change key samples. Whatever depths remain are possible TMK values.

In addition, as explained in **chapter 31**, a very simple method exists to extrapolate and decode all master key levels within a system. This technique presents a serious threat to the security of any installation where one or more master keys will open all of the locks. It is important that the reader thoroughly

understand the fundamentals of master keying theory contained in this chapter in order to properly analyze, define, and protect any system for which he is responsible. Remember that the unauthorized compromise of the top level master key can eliminate the security of an entire facility.

The security of any master key system is based upon the following factors:

- **Design of the TMK;**
- **Type of master key scheme (TPP, RC);**
- **Numbering sequence that is established in the KBA. It may be ascending order (shallow to deep), descending order (deep to shallow), sequential incrementing (up or down) from each TMK bitting (odometer), or pseudo-random value selection and progression;**
- **Limited number of people with access to master keys;**
- **Security of physical keys and key codes;**
- **Security policies with regard to all individuals that have access to any key that opens a lock that is master keyed. This issue relates to rights amplification, and the ability to compromise the system by modifying or altering a change key to work as a master key;**
- **Design of change keys to prevent their modification to allow them to act as master keys through filing of bitting positions, or of building up certain positions;**
- **Secondary locking system for enhanced security against cross-keying, key interchange, picking, key jiggling, decoding, and other methods of entry. Means include the use of master rings, security tumblers, sidebars, magnetics, integration of microprocessors, sectional keyways, and the addition of extra master pins to make decoding and extrapolation more difficult. Note that the addition of master pins will severely reduce the security of the lock, however, and thus should be carefully considered because the problems that are created far outweigh any security advantage. An analysis was completed by Matt Blaze at AT&T Labs regarding the insertion of extra master pins to make decoding more difficult, and the increased likelihood of key interchange in doing so;**
- **Proprietary keyways. See the discussion regarding the Easy Entrie key machine;**
- **Effective key control;**
- **Control of locks within the system, and monitoring for**

tampering or removal. People often talk about key control, but rarely discuss lock control. This concept is very important;

- **Control of extra cylinders in inventory;**
- **Background investigation on all individuals who work on, handle, duplicate, re-key, or maintain locks within the system;**
- **Adherence to master keying rules in design and determination of the bitting progression;**
- **Design of bitting pattern of change keys and master keys;**
- **Number of differs that are available;**
- **Key jiggling may be an issue in locks that employ sidebars;**
- **Sidebars will generally not affect the decoding of locks for the TMK.**

In an ideal master key system, the following rules would virtually prevent the compromise and bypass of any conventional system:

- **Nobody has access to a top level master key except one person;**
- **The TMK is difficult to replicate;**
- **The TMK cannot be extrapolated from the change key by physical inspection and decoding of one or more keys or locks;**
- **Nobody can gain unauthorized access to a cylinder for the purpose of disassembly, removal, or decoding;**
- **The TMK is difficult to derive and decode through any bypass process, including:**
    - **Decoding as defined herein;**
    - **Use of the Falle pin-lock pin-and-cam decoder system;**
    - **Use of the Falle original pin lock decoder system that employed shim wires;**
    - **Shimming of a cylinder with depth keys;**
    - **Use of a change key to extrapolate the TMK;**
- **Blanks are not available;**
- **Bittings are extremely difficult to replicate or cut. Unique sidebar codes, keyways, or other techniques that are only active for master keys or change keys, and for which no information can be derived from the individual change keys (regarding master keys). The Medeco M3 can provide this level of security.**

Several techniques and mechanical designs have been employed within conventional locks to increase the security of master keyed cylinders. These include use of a **master ring**, double keyways, sectional keyways, and double-throw bolts that can only be actuated by the master key. High-security locks will offer higher tolerances in concert with security enhancements, thus providing a greater number of useable combinations. The Medeco Biaxial and M3 locks, for example, can offer a very high number of key combinations in complex keying environments due to the ability to both lift and rotate tumblers in several positions. See the discussion of the Medeco M3 system in **chapter 17.** Mechanical security enhancements may provide added protection against certain forms of surreptitious entry, but may be of limited value with regard to the security of the master key system.

11_5.3.7.2 Security Procedures

The major threat to the security of any system is the compromise of master keys. When this occurs, every lock is vulnerable. For this reason, it is essential that procedures be implemented to insure the continued integrity of a master key system. The procedure to extrapolate the TMK from virtually any conventional master key system is discussed in **chapter 31.** It is important to understand accepted master keying schemes and to properly implement them in order to reduce the risks from this procedure.

The following checklist details the security issues that must be considered in the planning, as well as the investigation of potential compromise of a master key system.

- **Record the location and code of all locks that are master keyed;**
- **Record each key that is issued;**
- **Issue master keys only to those with a valid need;**
- **Restrict access, view, ability to copy, or possession of master keys to authorized personnel only;**
- **Maintain all spare master keys in a locked, controlled access cabinet;**
- **Conduct routine key and lock audits;**
- **Know your locksmith or person/organization responsible for changing, repairing, or rekeying locks. Instruct staff as to individuals who are**

authorized to work on locks;

- **Establish a procedure for providing clearance for outside workers to do maintenance and perform other duties that will require access to secure areas. Do not loan keys to such individuals without a proper policy of identification and background checks;**
- **Removable plug or construction locks should be employed in new facilities so that keys may be changed prior to acceptance of the building;**
- **Restrict access to blank keys;**
- **Do not stamp direct codes on keys or designations such as M, MK, GM, GGM;**
- **Any lock that is accessed by non-employees should not be master keyed. Restrooms, garages, storage areas, HVAC, vending, pharmacies, communications facilities, fire control equipment, elevator control areas, mail and package delivery areas, telephone and utility closets, pools, waste systems, and other areas should have only one change key (not master keyed) to minimize the ability of unauthorized individuals to extrapolate and decode the TMK;**
- **In some installations, locks in primary entrance areas should not be master keyed;**
- **Key codes should not be stored on a computer that is connected to a network or accessible to the internet;**
- **The design of the TMK should follow accepted guidelines, not be easily distinguishable, not permit easy alteration of a change key and should allow a high yield of master keys and change keys;**
- **Critical areas that contain weapons, explosives, nuclear materials or sensitive information should not be master keyed.**

11_5.3.7.3 Hardware and Security of Master Key Systems

The use of quality high-security locks can increase security in the master key environment. This results from the use of recognized keying schemes, maintenance of high-tolerance (creating more useable combinations), sidebar technology, restricted sectional keyways, protected profiles, and other

enhancements. It must be noted, however, that high security locks may be subject to compromise with regard to the TMK, and that merely using such locks does not guarantee added security **for the master key system.** Such systems may make the generation of test keys more difficult, but the addition of a sidebar will not frustrate the process. Sidebar codes will remain constant for virtually every system and can be easily replicated in the decoding process. Virtually **any** lock that relies upon multiple virtual shear lines for master keying can be compromised through extrapolation and decoding.

Unless the manufacturer restricts availability of its key profiles through patent and copyright protection, distribution safeguards and stringent key control, high security locks offer no advantage. Recent controversy regarding the decoding of master key systems has alerted security managers to the ease with which such systems can be compromised. That subject is treated in depth in this chapter, and in **chapter 31**.

The only way to protect a master key system from compromise through the extrapolation and decoding process is to insure that the key profile is secure. Sidebars, security pins, and other security enhancements are relevant to a discussion of picking, decoding, and impressioning, but have little significance when considering the ability to extrapolate the TMK code of the lock through sampling techniques discussed in this text. In the author's view, only those high security locks that make key generation extremely difficult would be capable of frustrating the compromise of the TMK in a conventional master key system. Locks in that category would include the Medeco M3, the Evva 3KS and MCS, and to a limited extent, the Abloy Disklock, Schlage Primus, Assa, and Medeco Biaxial. The ability to silicone impression and copy a key containing a sidebar code may make such compromise even easier. The replication of certain restricted blanks using specialized key machines such as the Easy entrie can also be a simple process.

Protected profiles and other enhancements can reduce the likelihood that a master key system can be compromised through the decoding and extrapolation process in many ways. The task can be made more difficult to:

- **Duplicate a key;**
- **Generate a key by code;**
- **Obtain or produce blank keys;**

- **Decode different depths on a sample key to determine:**
    - **depth coding and available depths;**
    - **master key schemes and sequences;**
- **Simulate different depths in order to sample each chamber;**
- **Obtain information regarding special bitting codes for master and change keys.**

11_5.3.7.4 Misconceptions Regarding Master Key Systems and Security

LSS204: Brian Chan on assumptions regarding master keying

There are many misconceptions regarding master key systems and their security. The discussion that follows is preliminary to the material presented in **chapter 31** regarding the compromise of conventional master key systems through extrapolation, and provides a foundation for understanding methods of bypass.

ASSUMPTION: A master key can be visually decoded from one key.

FACT: A master key cannot be deciphered or extrapolated from the inspection and measurement of one change key. Depending upon the keying scheme, a system can be evaluated and potentially compromised from the inspection of a significant sample of change keys, in order to provide information regarding depths that are common to several keys for one or more specific chambers, and to allow reverse engineering of the system. Depending upon the grouping and progression of change keys, the level of master keying, and the implementation of security enhancements to the system, the ability to extrapolate a master key may be problematical at best.

ASSUMPTION: A master key can be derived from the analysis of one change key.

FACT: A top level master key can be extrapolated from the analysis of one cylinder associated with that TMK, and the use of one change key for that lock.

ASSUMPTION: There are master keys that will globally open all locks.

FACT: Only in the movies. There is no universal master key, except perhaps a brick that is utilized to smash a window! The closest thing to a universal key would be for a warded lock, but even that would depend upon keyway and bullets or wards.

ASSUMPTION: Master key cuts are not repeated on all keys within a group, section, or progression on change keys, and thus, no relevant information can be obtained from the analysis of change keys.

FACT: If enough samples are available, certain patterns will emerge that may provide information as to one or more bitting positions that are utilized within the master key algorithm. This is particularly true within a rotating constant system where one or more values of the TMK will be shared with the master key and change key

ASSUMPTION: A change key cannot easily be converted to a master key.

FACT: This is a process known as "rights amplification" and will allow the alteration of a change key so it can be used as a master key. If the system is engineered properly, at least one cut of the master key will be both shallower and deeper than any change key cut, thus preventing the practice, although the deeper cut has several functions.

ASSUMPTION: In order to decode a master key, it is required to analyze more than one cylinder through disassembly.

FACT: As detailed in chapter 31, this is not necessarily true. If a change key is available, a system can be decoded without the need to disassemble a cylinder, either through sampling or shimming. In the alternative, the possession of a change key can make the disassembly and decoding of a master keyed lock quite simple and can insure the correct derivation of the master key or TMK.

ASSUMPTION: In complex multilevel master key systems, there will often be more than two master pins in several chambers, thus creating many cross-keys and a corresponding difficulty in deriving the correct code for the top level master key.

FACT: In the properly designed master key system, there will never be more than one master pin in each chamber. In the

rotating constant system, there may only be master pins in a few chambers, depending upon the number of differs required in the system, and rotation patterns applied to the KBA. In master ring and IC systems, there can be more than one master pin in each chamber to accomplish keying for more than three levels, or where control keys are master keyed.

ASSUMPTION: It is required to disassemble a lock in order to derive the master key.

FACT: Disassembly is not required in conventional master key systems in order to derive the top level master key. See chapter 31 for a detailed discussion of extrapolation through the use of the change key. A cylinder can also be shimmed with depth keys to determine its coding without the necessity of disassembly.

11_5.3.7.5 Sidebars and Security

Manufacturers throughout the world produce a variety of sidebar locking systems. Although Medeco was the original inventor of this technology as applied to pin tumbler locks, it is now prevalent in pin tumbler, disk, and lasertrack locks. The use of a sidebar does not mean that the lock is rated for a high security installation; it simply indicates that either the primary or secondary locking mechanism utilizes an indirect locking method described elsewhere in this text. Indeed, some sidebar locks are suitable and rated for high-security applications; others are not. Some locks utilize one sidebar in conjunction with a traditional shear line; others utilize it in conjunction with rotating magnetic disks. Some locks employ two sidebars for increased resistance to picking and other forms of covert attack.

In the context of master key systems, sidebars may increase the number of theoretical combinations that are available and reduce or eliminate the problem of cross-keying and key interchange. However, the presence of a sidebar in most cases does not increase the security of the system in terms of extrapolation and decoding of the top level master key. The design of the key and how it interacts with the active locking components will determine whether it actually increases the security of the lock against surreptitious entry.

There are many different sidebar schemes described in this text. Each is slightly different in design, mainly to circumvent prior

art that is already protected by patent claims. All sidebars, regardless of mechanical configuration, accomplishes the same result: to provide a means to prevent rotation of the plug through an independent means that cannot be directly affected by the application of tension applied to the plug. Assa, Abloy, Medeco, Schlage, Bilock, Ikon, Evva, and other manufacturers utilize sidebars in conjunction with pins, discs, sliders or wafers that must be moved to the correct position in order that the sidebar can retract into the plug.

Other systems employ a modified technology that provides a direct link between the key and sidebar. Although technically these manufacturers are utilizing a mechanical design that acts like a sidebar, in fact the same level of security is not attained. An excellent example is shown below.

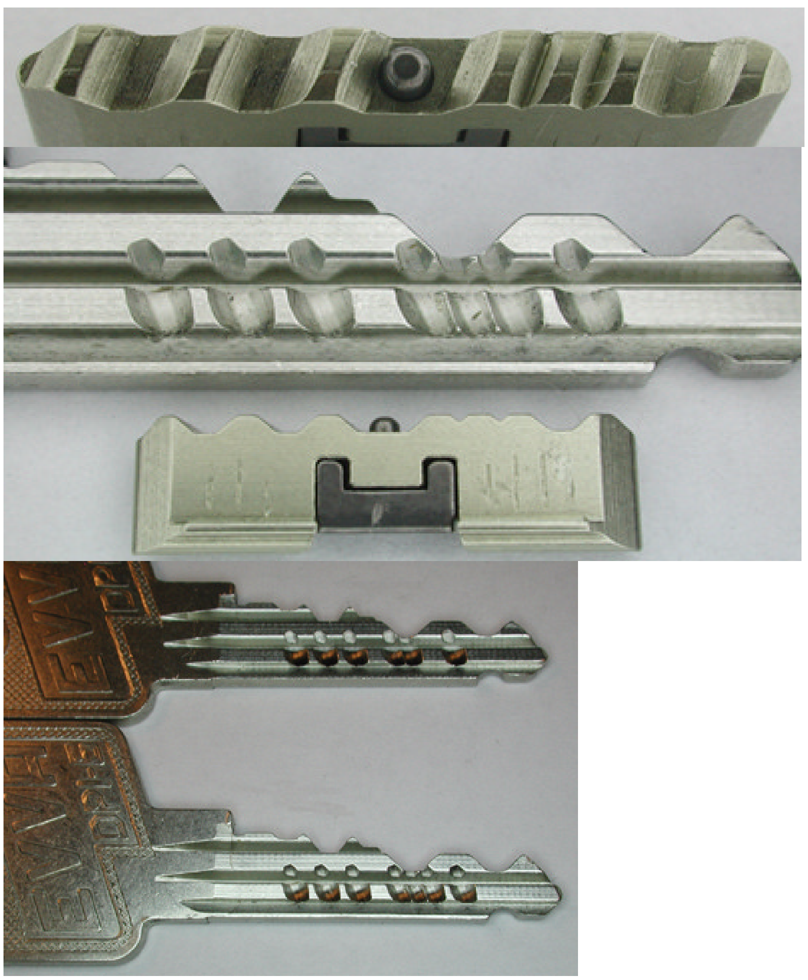


Figure LSS+1128 Evva DPI series dual sidebar lock, showing two different

milling codes.

This series of photographs shows a recent introduction by Evva (Austria) of their DPI series dual-sidebar lock, utilizing the same technology as their 3KS lasertrack system described elsewhere in this text. One sidebar is controlled by the traditional bittings on the key; the other by the side millings. Shown is the mating sidebar that is the reverse image of the side cuts on the key. Note the two different sidebar patterns in the photograph (right). This system resembles that which is utilized by Assa with one significant difference: the Assa design relies upon secondary pins that must be raised to the correct height to match the predefined sidebar code. In the Evva DPI series, there is a direct link between the key and sidebar insert. Thus, if all of the side bittings are milled out, the sidebar can be retracted into the plug. Only one point must be raised to correspond with the movable piece in the center of the sidebar insert. A spring-biased pin that protrudes from the shell will catch if this piece is not equal to the dimensions of the outer edge of the sidebar insert. The relevance of this is clear: an examination must be conducted to determine the action of all sidebars in **any** lock that is installed in a high-security system to insure that its function is consistent with the desired level of security.

11_5.4 Master Key System Algorithms

11_5.4.1 Introduction

There are two recognized schemes for planning, defining, and generating secure bitting combinations for a master key system: **total position progression** and **rotating constant.** A variation of the TPP is the **partial position progression** system. Each of these has advantages and drawbacks and are explored in the following text. This treatment is not intended as a treatise on master keying, but rather a required primer to allow the reader to fully understand the security implications of each technique. This will provide the necessary foundation of keying theory to allow for a competent analysis of bypass potential, countermeasures to system compromise, and the requisite knowledge to allow the bypass of master key systems.

11_5.4.2 Planning the Master Key System

Regardless of which progression scheme is selected for generating individual bitting combinations, it is imperative that complete data is gathered and evaluated in order to asses the user access requirements for the system while maintaining security. The following issues must be analyzed and factored into the design of the system in order to choose the master key scheme that will yield the greatest number of secure combinations:

- **Number of locks;**
- **Levels of master keying;**
- **Complete analysis of access levels through the development of an expansion specification;**
- **Physical design of the TMK;**
- **Number of change keys under each master key;**
- **Consideration of the optimum approach to layout of the master key system;**
- **Available lock technology, required integration with current systems, and desires of the user;**
- **Size of the system in terms of the number of locks, access points, and interaction of master keying levels;**
- **Available security enhancements;**
- **Number of available differs, determined after generating a Key Bitting Array;**
- **Which master keying scheme will be selected;**
- **What rules apply for the generation of master and change keys;**
- **Manufacturers specifications with regard to depth and spacing, as well as the following issues:**
    - **Tolerance;**
    - **Number of chambers within the lock;**
    - **MACS;**
    - **Rules and limitations;**
    - **Differs;**
    - **Keyways available;**
    - **Sectional keyways;**
    - **Keyway protection;**
    - **Ability to duplicate;**
    - **Integration of high security locks with conventional profiles;**
    - **Access levels;**
    - **Conventional or positional master key system;**

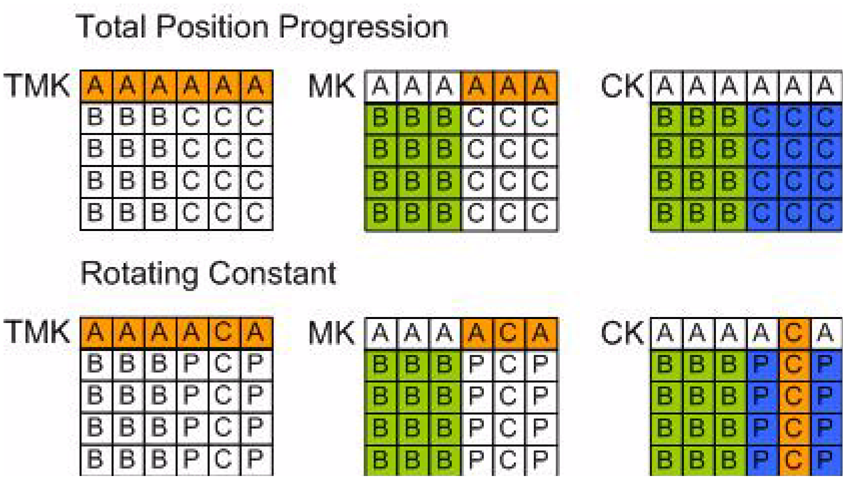
- **Required security;**
- **Cross-keying issues;**
- **Standard or non-standard bitting depths;**

• Use of single or two-step progression in the generation of bitting codes. This will be dependent upon the actual difference between each bitting depth. The accepted rule requires that any difference between individual depths of less than .023" requires a two-step progression system. This means that every other depth can be factored into the key bitting array. If there is more than .023" between cuts, then every depth can be utilized in the KBA. There are exceptions to this rule, such as the Best A4 system;

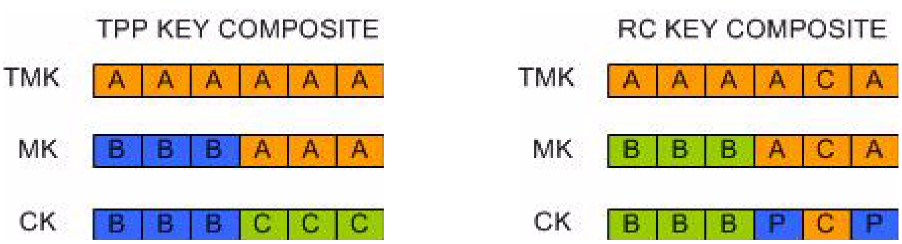
11_5.4.2.1 Levels of Keying and Method Selection

Decisions with regard to whether total position progression or rotating constant is utilized will in part be based upon the required levels of keying, the number of master keys and associated change keys. A summary comparison of the two systems with a view toward analyzing the math involved in computing theoretical and practical combinations for each method should prove helpful for the discussion that follows with regard to specific master keying techniques.

A graphic comparison of total position progression and rotating constant is shown to highlight the differences inherent in the progression schemes. The diagrams are amplified in subsequent sections for greater understanding. A six pin cylinder is shown, with a 3:3 key division. The coding for the diagrams is: **A** = TMK, **B** = master key, **C** = change key, **P** = progressed, and **C** = constant.



Keys within a master key system, whether total position progression or rotating constant, are formed by a composite of progressives from the KBA, as shown below. In fact, it can be seen that rotating constant can be looked at as a subset of total position progression. Rotating constant **is** a total position progression system but always has at least one change key value that is shared with the TMK.



In the diagram of the TPP composite, the top level master key is formed by positions assigned in the KBA that cannot be utilized by the change key. Although in some instances one of the chambers may be held constant in a total position progression system (referred to as partial position progression), this is not the rule. In such a rare event, the values of A would be shared by the MK and CK. The master key is a composite of BBBAAA. In the example, the first three positions are progressed to derive a total of 64 possible master keys. All master keys will utilize the remaining three chambers AAA of the TMK. The change key is a composite of BBBCCC. BBB and CCC are progressed separately and then combined.

In the TPP diagram above, the relationship between the TMK, MK, and CK is clearly defined by color:

- **The TMK can never have any of the same elements as the change key;**
- **The MK always shares cuts with the TMK;**
- **The MK shares cuts with the CK, complementary to those shared with the TMK;**
- **A+B is always a constant, based upon the key division;**
- **B+C is always a constant, also based upon the key division;**
- **A is never a part of C and C is never a part of A;**
- **B is always a part of A and C;**
- **The number of chambers and positions value for A, B, C is constant;**
- **Each chamber is dedicated for a specific progression (master key or change key) based upon the division of the key;**

The rotating constant scheme also defines the TMK, but slightly differently than with the total position progression system. In the RC method, one or more positions are held constant between the TMK, MK, and CK, and other positions are progressed. Patterns, as shown in subsequent sections, define the matrix of all constant and progressed positions for locks in which one to seven chambers are to be rotated. In other words, the pattern matrix defines how many chambers are to be rotated, and within each pattern, which are to be progressed and which are to be held constant.

There are two distinct concepts that distinguish RC from TPP. In TPP, we divide the key and fix the number of positions that will be available for progression for the master key and change key portion of the key. In the RC approach, as with the TPP, we also define how many chambers will be available in the division of the key for the MK and the CK. However, based upon a matrix of all of these possibilities, we choose different patterns of constant and progressed positions. The term "rotate" actually indicates that the relationship between constant and progressed positions, as well as the number of positions to be so affected is based upon a pattern matrix. Simply stated, within the total position progression scheme, the sequence of progression is fixed; in the rotating constant method, the sequence of progression can be said to change. Unlike the TPP system, positions within the SOP may or may not be progressed, depending upon whether they are held constant or not. Generated combinations are based upon **which** positions are progressed. In the TPP, this relationship **never** changes, once established.

In the RC system, the constant positions will appear in the TMK, MK, and CK, as shown. In the example, utilizing two chambers that are progressed and one that is held constant, the top level master key is comprised of AAAACA; the master key is BBBACA. The change key is made up of BBBPCP. The key division is 3:3, meaning that three chambers are progressed for the master key and three chambers are utilized for the change key. However, the difference (and similarity) between the TPP and RC method is clear. Rotating constant will utilize different rotational patterns for the change key and master key, if required. Although the first pattern in our example is PCP (indicating **P**rogress or **C**onstant), it could just as well have been PPC, CPP, CPC, PCP, or expanded to include one or more of the master key positions. This is one critical difference between total position progression and rotating constant: the positions that can be progressed will rotate, whereas in the TPP, once the key is divided, they are fixed. Note, however that the **number of positions** that are progressed and held constant cannot be varied. A series of key bitting arrays shows actual progressions for different patterns.

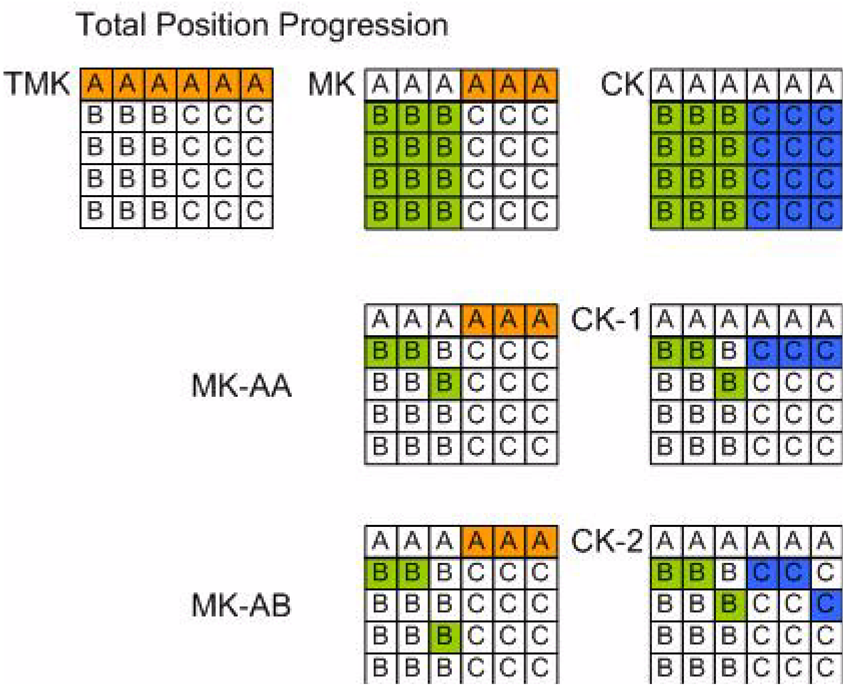
In the diagram of the RC key composite, one or more values of the TMK (A) will always be part of the MK (B) and the CK (C). However, the **position** of the constant and progressed chambers for B and C will not be constant.

Total Position Progression:

- **TPP defines how many progressives, most commonly in powers of 4 or 5, are computed from the depths available in the key bitting array;**
- **The number of levels of key -1 defines the key division;**
- **The number of positions within the KBA must match the requirements of the expansion specification in terms of key division;**
- **In the TPP system, the chambers are progressed in a sequence, based upon the Sequence of Progression (SOP);**
- **In TPP, the key is divided between the master key and change key to derive a sufficient number of combinations for each, based upon the expansion specification;**
- **The division of the key, once set, never changes;**
- **The key division is a composite of two progression subsets: MK and CK:**
    - **which positions are progressed for the MK and CK are**

predefined;

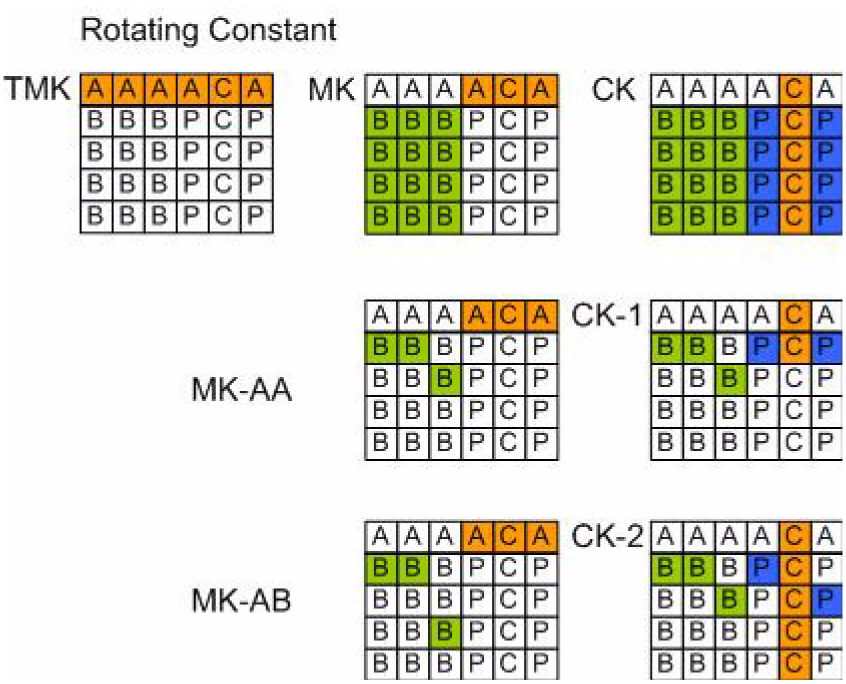
- **the only constant is the TMK: these values are never progressed;**
- **key combinations are derived by the addition of the products of the individual master key and change key progressions. In other words, progress each subset separately, then the two subsets are combined to make up the key;**

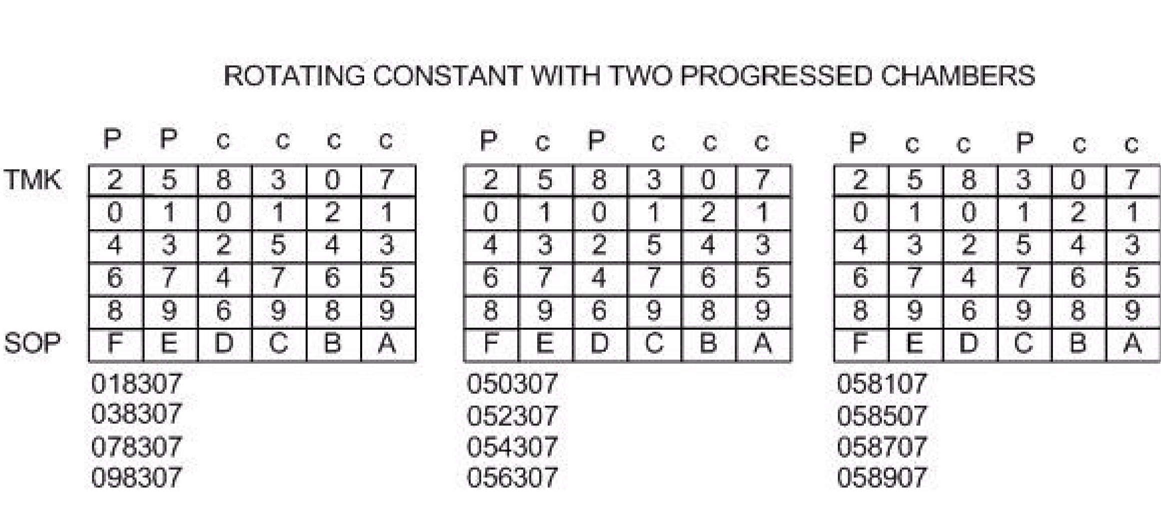


Rotating Constant:

- **Rotating constant is almost never employed in a system that has more than three keying levels;**
- **The makeup of the key in a rotating constant system can be defined by the key division and the pattern of constants and progressed positions;**
- **Within a selected pattern, progressed chambers can never be constant and vice versa. This is the essence of pattern progression;**
- **At least one of the TMK values (depending upon selected pattern) will be shared between all three keys (TMK, MK, CK);**

- **Rotating constant, for two levels of keying, will produce more changes than a TPP system;**
- **Division of the key may not be altered once established, or key interchange will result;**
- **Rotating constant system has fewer master pins than a TPP system and is more secure;**
- **Less key interchange possibilities;**
- **More difficulty in picking;**
- **A rotating constant system is more applicable for two levels of keying or a small three level system;**
- **Rotating constant is based upon the number of progressives. The key division is established -1; Patterns are utilized to determine how many positions must be progressed and held;**
- **Within a rotating constant system, which chambers are constant cannot be easily derived from the analysis of a few keys unless in the same group;**
- **In the RC scheme, the position of the constant will change, based upon the selected pattern;**
- **The number of chambers that are constant and which are rotated are set;**
- **Define the chambers to be rotated and which of those chambers will be held, pursuant to the pattern selected;**
- **In both the RC and TPP systems, the design of the change key and master key have common elements. In the TPP scheme, the TMK is a composite of the TMK and MK bittings. The chambers that are progressed for the change key are different that those for the master key, based upon the division of the key. Only in RC, the change key and master key may share common values with the TMK;**
- **More depth increments are available in the RC system.**





11_5.4.2.2 Dividing the Key and System Paradigms

A key division is simply a logical method to derive master key and change key permutations. It is necessary to define the key bitting array in terms of the number of required combinations that will be available for master keys and for change keys and

the number of keying levels. The requirement to generate a specific number of master keys and change keys is dictated by the expansion specification that is provided for the proposed system. The KBA must be "divided" because the columns (progressives) for the MK and CK are acted upon separately, then combined to make a composite key as shown in preceding sections.

The principle for the division of the key is the same for both the total position progression and rotating constant systems. In the diagram below, two separate divisions are shown: 2:4 and 3:3. In the 2:4 example, two columns are allocated for the master key and four are designated for the change keys. This means that a total of 16 combinations for master keys and 256 combinations for change keys could theoretically be created. In the 3:3 example, the KBA is divided equally, so that there would be 64 theoretical master key combinations and 64 change key combinations available for each master key. Note that in both examples, there is a total of 4,096 theoretical combinations for all keys. In a second example for a five pin lock, the KBA is divided 2:3, with one position not progressed. This may be referred to as a **partial position progression** and is a hybrid between TPP and RC.

A key can be divided in any desired manner so as to produce the required number of combinations. However, there are only so many ways to accomplish such division, and there are only so many theoretical combinations available for a given lock and KBA. The derivation of combinations is based solely upon the number of chambers within the lock and the minimum depth increment established by each manufacturer, which in turn controls whether a single or two-step progression is utilized. If a manufacturer, for example, establishes a minimum depth increment of .015" and has ten available depths, there will be five depths for each progressive that are actually available (one for the TMK and four for progression). A key can be divided so that a specific number of chambers are dedicated to each keying level.

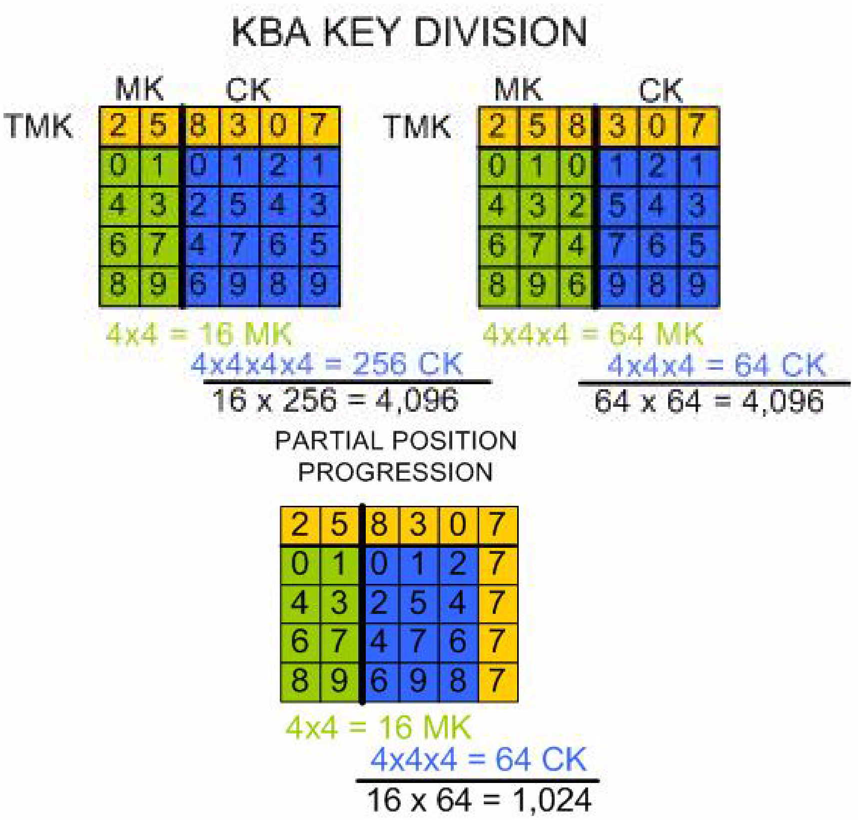


Figure LSS+1129 KBA division for TPP and partial position progression.

11_5.4.2.2.1 System Paradigms

The tables provide a matrix of theoretical combinations that can be generated within a total position progression system utilizing cylinders containing five, six, and seven pins for one and two-step progression. In the KBA key division table, the number of progressives assigned to each keying level is shown for a two, three, and four level system. In the lower portion of the table, the total number of theoretical combinations are calculated for single and two-step progression.

KBA DIVISION OF KEY

MATRIX OF CHAMBERS DEDICATED TO EACH KEYING LEVEL
TOTAL THEORETICAL COMBINATIONS

LEVELS	5 PIN DIVISION	6 PIN DIVISION	7 PIN DIVISION
	DEDICATED CHAMBERS	DEDICATED CHAMBERS	DEDICATED CHAMBERS
GGMK-GMK-MK-CK	1-1-3 1-2-2 1-3-1 2-1-2 2-2-1 3-1-1	1-1-4 1-2-3 1-3-2 1-4-1 2-1-3 2-2-2 2-3-1 3-1-2 3-2-1 4-1-1	1-1-5 1-2-4 1-3-3 1-4-2 1-5-1 2-1-4 2-2-3 2-3-2 2-4-1 3-1-3 3-2-2 3-3-1 4-1-2 4-2-1 5-1-1
GMK-MK-CK	1-4 2-3 3-2 4-1	1-5 2-4 3-3 4-2 5-1	1-6 2-5 3-4 4-3 5-2 6-1
MK-CK	5	6	7

TOTAL THEORETICALS	5 PIN	6 PIN	7 PIN
ONE STEP	3,125 5^5	15,625 5^6	78,125 5^7
TWO STEP	1,024 4^5	4,096 4^6	16,384 4^7

Figure LSS+1130 Key bitting array division of key for two, three, and four level system. The top level is never shown in the number of chambers.

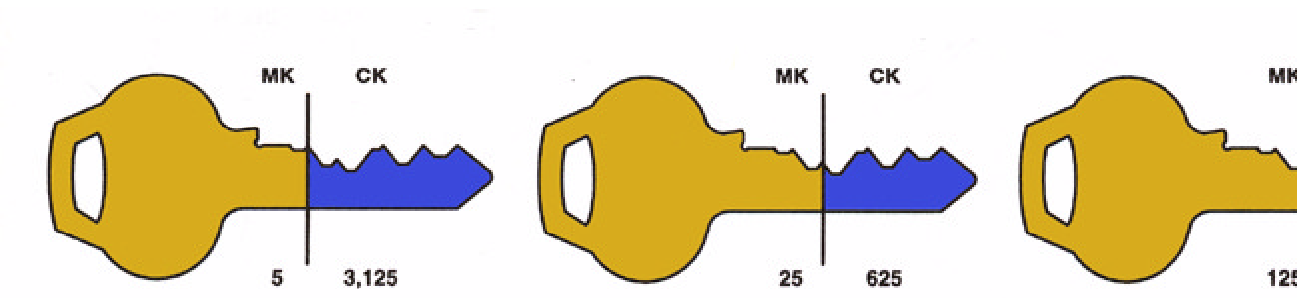
The table of system paradigms contains the expansion specifications for keying systems of two, three, and four levels using one and two-step progression. These correlate to the key division tables above.

TOTAL POSITION PROGRESSION SYSTEM PARADIGMS

EXPANSION SPECIFICATIONS: TWO, THREE, AND FOUR KEYING LEVE
FOR FIVE, SIX, AND SEVEN PIN CYLINDERS
ONE AND TWO-STEP PROGRESSION

	5 PINS		6 PINS		7 PINS
LEVELS	ONE STEP	TWO STEP	ONE STEP	TWO STEP	ONE STEF
GGMK GMK MK CK	1-1-625-5 1-5-5-125 1-5-25-25 1-5-125-5 1-25-5-25 1-25-25-5 1-125-5-5	1-4-4-64 1-4-16-16 1-4-64-4 1-16-4-16 1-16-16-4 1-64-4-4	1-5-5-625 1-5-25-125 1-5-125-25 1-5-625-5 1-25-5-125 1-25-25-25 1-25-125-5 1-125-5-25 1-125-25-5 1-625-5-5	1-4-4-256 1-4-16-64 1-4-64-16 1-4-256-4 1-16-4-64 1-16-16-16 1-16-64-4 1-64-4-16 1-64-16-4 1-256-4-4	1-5-5-3,12 1-5-25-62 1-5-125-12 1-5-625-2 1-5-3,125- 1-25-5-62 1-25-25-12 1-25-125-2 1-25-625- 1-125-5-12 1-125-25-2 1-125-125 1-625-5-2 1-625-25- 1-3,125-5-
GMK MK CK	1-5-625 1-25-125 1-125-25	1-4-256 1-16-64 1-64-16 1-256-4	1-5-3,125 1-25-625 1-125-125 1-625-25 1-3,125-5	1-4-1,024 1-16-256 1-64-64 1-256-16 1-1,024-4	1-5-15,62 1-25-3,12 1-125-625 1-625-125 1-3,125-2 1-15,625-
MK CK	1-3,125	1-1,024	1-15,625	1-4,096	1-78,125

Figure LSS+1131 Total position progression system paradigms table.



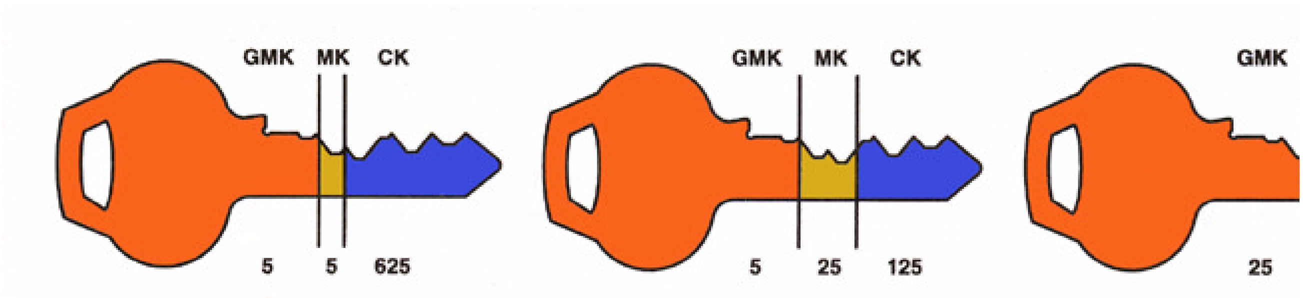


Figure LSS+1132 Diagrams representing the division of a key for a three and four level system are shown for a cylinder providing five progressives within a six pin lock. From top left, the expansion specification correlation to the table would be 1-5-3,125, 1-25,625, 1-125-125; 1-5-5-625, 1-5-25-125, 1-25-25-25. Courtesy of Corbin Russwin.

11_5.4.2.3 Key Bitting Array: Computing and Defining Useable Combinations and the Concept of Progression

The progression of available depths as defined in the key bitting array is the basis for deriving theoretical combinations that can be used in a master key system. The concept of progression simply relates to an orderly process for sequencing a set of numbers in a specified order to obtain the greatest number of available combinations without repeating any of them. It is designed to prevent key interchange. Progression, as will be further explained, utilizes the KBA as a grid to organize the available numbers (depths) for progression. There are two **methods** of progression: total position progression and rotating constant. There are two **types** of progression: one-step and two-step. The method is in part determined by the number of specified keying levels and the number of combinations that are required for each level.

The type of progression is controlled by the hardware manufacturer and is a function of the number of available bitting depths and increment between each depth. This will in turn determine whether a one or two-step progression may be utilized. The industry standard is a minimum depth increment of .023" to allow for the use of every available depth (for single-step progression). Thus, a lock wherein the manufacturer determines that the incremental difference between each depth is .015" would require a two-step progression in order to exceed the .023" rule.

The number of theoretical and actually available differs for a

master key system must be determined in order to assure a sufficient number of change keys and master keys are available for each level. The computation is achieved through the creation of a key bitting array (KBA). As shown, this is a table that defines all of the available bitting positions for each chamber, and is dependent upon the keying scheme that is utilized. Described elsewhere in this text, the theoretical number of differs is computed by taking the number of available depths, raised to a power that is equal to the number of chambers. Thus, in a six pin Schlage lock where the manufacturer has defined ten individual depths per chamber, there would be 10^6 or 1,000,000 theoretical combinations. As will be shown, however, there are far fewer actual differs for this lock, due to factors described below.

Factors that will reduce the number of available combinations include:

- **Cross-keying;**
- **Too many levels of keying;**
- **Construction master keying;**
- **Selective master keying;**
- **Use of interchangeable core cylinders;**
- **Mixing high-security, master ring, and conventional cylinders within one system;**
- **Use of Brink or block out function cylinders.**

The relevant criteria that will determine the actual number of available differs include:

- **Master key scheme that is selected;**
- **Number of depths and chambers that are available for the specified lock;**
- **Spacing between depths, as defined by the manufacturer;**
- **Whether a one or two-step progression must be utilized in defining the available depths that can be used to formulate the master key system;**
- **Maximum adjacent cut specifications, as defined by the manufacturer;**
- **Rules regarding the use of the same depth for adjacent cuts;**
- **Rules regarding unusable bitting patterns.**

There are different parameters to define the KBA which are

examined for both TPP and RC schemes in the text that follows. The attributes of a key bitting array are summarized in the table below.

- **The KBA is a graphic display of all possible or theoretical bittings;**
- **Theoretical bittings are available but may not be useable;**
- **The KBA controls the progression of the available depths;**
- **The KBA, if properly devised, will eliminate the potential for key interchange within the system but not from keys of a different system;**
- **The KBA allows an orderly progression of numbers;**
- **How the individual available depths are entered into the KBA will determine their output as combinations and specifically how the sequence of numbers appear. Ths is based upon whether the digits are entered in odometer, shallow to deep, or random style;**
- **The KBA is defined by three critical factors: the TMK combination, method of progression, and type of progression;**
- **The KBA is "divided" based upon the number of required master keys and change keys. That division corresponds to the division of the key;**
- **The KBA has four major components: the TMK line, the master key and change key division portions, and the sequence of progression (SOP) line at the bottom of the array;**
- **In a total position progression system, there will be no TMK bittings in any column that is progressed. This is not the case in a rotating constant system;**
- **Columns are progressed in the same way that an odometer advances its wheels: from right to left (depending upon the sequence of progression);**
- **If the KBA utilizes depths in a two-step progression, the concept of parity is also introduced to further prevent key interchange between systems;**
- **Parity within a column is maintained between the TMK bitting value and the remaining values to be progressed;**
- **The progression order of bitting values as they are applied to the key (left to right or right to left) must match those provided by the manufacturer for cutting the key (bow to tip or tip to bow);**
- **The KBA format is the same for TPP and RC systems, however in the rotating constant system, only progressives from selected positions are utilized.**

Regardless of which keying scheme is employed, every lock has a theoretical number of differs or different key combinations that are available. In the example shown below, a Schlage lock has ten depths available in six chambers. Thus, there are 10^6 or 1,000,000 theoretical differs for this lock.

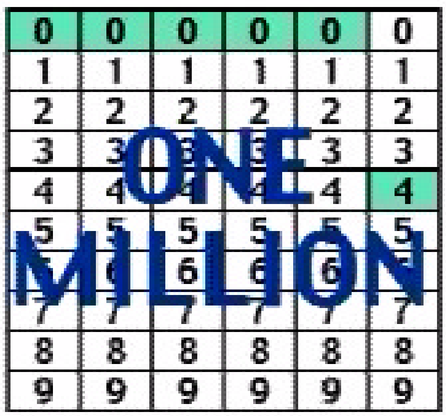
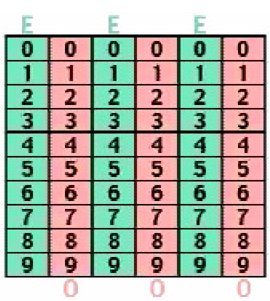
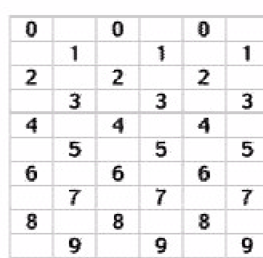


Figure LSS+1113 shows a key bitting array of the total number of theoretical differs for a six pin lock with ten depths. Minimum depth increment is not considered. Courtesy of HPC Interactive Learning Series.

In most keying schemes, odd and even depths are alternated between chambers in set parity patterns. When parity is implemented, the actual number of differs is reduced because all depths cannot be utilized in every chamber; only odd or even. The number is further diminished if the manufacturer utilizes incremental spacing between depths that is less than .023". In such case, every other depth will be utilized in a two-step progression system, as depicted below. In a two-step system, there is no loss of combinations with the implementation of parity, because it is inherent in the system.





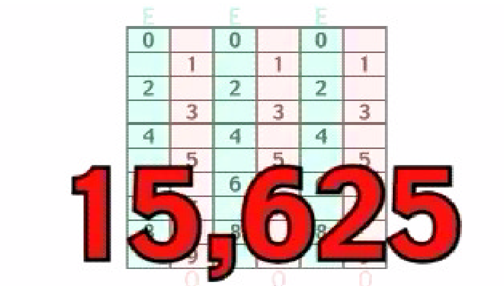


Figure LSS+1114 is a representation of the KBA for a two-step progression, with even-odd numbering in adjacent chambers. Courtesy of HPC Interactive Learning Series.

From 1,000,000 differs, our useable number of combinations for a master key system in a six pin lock has been reduced to a total of 5^6, or 15,625. This number results because there are now only five depths that are available for each chamber. However, the actual number will be far less than that, as will be seen when we examine the way in which combinations are produced.

- **The use of different keyways can expand the number of theoretical combinations within a multi-sectional system. There are certain general rules regarding the use of keyways:**
  - **Each individual keyway can be divided differently with respect to master and change keys;**
  - **If all keyways are divided in the same manner, the number of combinations for any one level can be expanded by multiplying by the number of keyways utilized.**

11_5.4.2.3.1 Sequence of Progression

LSS204: Brian Chan on the Sequence of Progression

The concept of sequence of progression (SOP) relates to the order that individual columns (chambers) are progressed within the key bitting array to derive combinations. The SOP is generally indicated as a series of letters that are positioned at the bottom of the KBA: they are read and progressed in ascending order from the least significant letter on the right. When the SOP is altered from a standard configuration such as **FEDCBA** as shown below, confusion can result if the concept is not fully understood. If the SOP of **FEDCBA** were changed to **FEDCAB**, for

example, that code would indicate that B, then A, then C would be progressed for the change key if the division was 3:3. It does not mean that columns B and A are transposed, for if that were the case, then either the combination of the TMK would be altered, or the bitting values under each TMK position would be wrong.

Depending upon whether total position progression or rotating constant is selected, the SOP will have a unique meaning relating to each method. If TPP is chosen, then the values within each column within the KBA are acted upon in a specified order. In the diagram below, the order is defined as **FEDCBA.** This code is read from right to left and indicates that column A is progressed first, then B, and C for the change key if the KBA was divided 3:3. Whether TPP or RC, the columns are always progressed **below** the first horizontal row that indicates the TMK bittings. Of course, the TMK values are never progressed. The **order of progression** or how the depths within a column are arranged, must also be defined for each KBA.

TMK	2	5	8	3	0	7
	0	1	0	1	2	1
	4	3	2	5	4	3
	6	7	4	7	6	5
	8	9	6	9	8	9
SOP	F	E	D	C	B	A

In our example, the progression for FEDCBA and FEDCAB for the first five change keys would read:

SEQUENCE OF PROGRESSION EXAMPLE	
FEDCBA	**FEDCAB**
010121	010121
010123	010141
010125	010161
010129	010181
010141	010132

In the rotating constant method, the sequence of progression becomes somewhat more complicated because the order is in part determined from a pattern matrix that defines the columns that

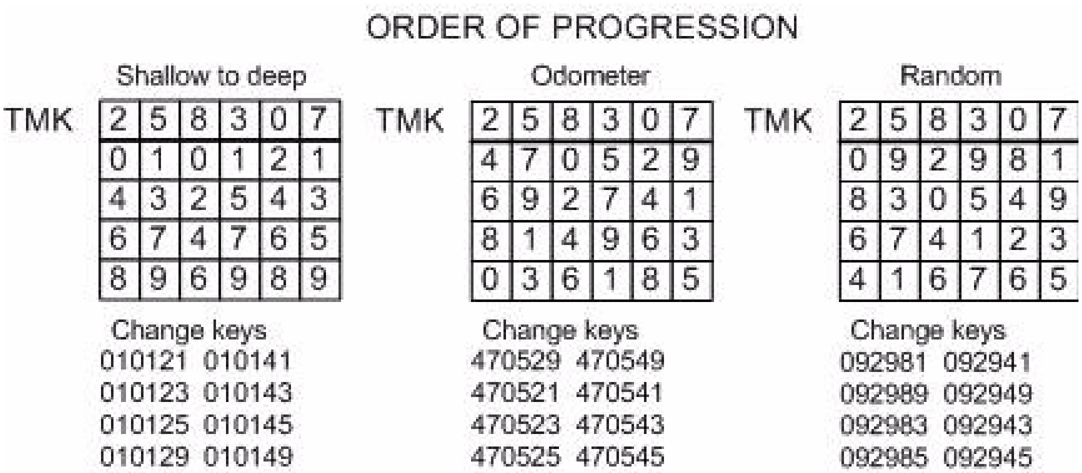
are to be progressed. Once the pattern is selected, the sequence of progression can be chosen.

11_5.4.2.3.2 Order of Progression

The bitting values within each column of the KBA can be initially entered in one of three recognized ways: **shallow to deep**, **odometer style**, or **scrambled**. The latter two modes are recommended. Why is this important? The arrangement of bitting values in the KBA will define their output as they are progressed. Once the TMK values are established, the remaining available depths are entered into each column (excluding the TMK value). From these, all available combinations will be derived. In our example KBA (using Schlage two-step), the TMK is defined as 258307. For the first column, the available values for progression would be 0,4,6,8. So, how do we actually enter those values in the KBA under the TMK? Logically, they would be entered so as to minimize the potential for error, in ascending order, as they are shown in the above example. As a result, the derived combinations would progress from shallow (0 cut) to deep. The problem with this method is one of predictability, key manipulation, reduced resistance to picking, and possible derivation of master key sequences by examining change keys. Values for the TMK may also be extrapolated.

Our bitting values of 0,4,6,8 for the first column could also have been written as a logical sequence from the TMK value of 2, in what is referred to as odometer format. As shown in the example below, this sequence would progress as the wheels in an odometer. The values would appear as 4,6,8,0 in the KBA. The values may also be scrambled or entered randomly. Thus, for example, they could be inserted into the table as 6,0,8,4.

The way in which the KBA is originally defined will affect the resulting combinations as they are progressed. Examples of the three methods of writing the KBA are shown below, together with output combinations for the first eight change keys.



11_5.4.2.3.3 Parity

Parity is another variable that can be utilized to reduce key interchange on the same keyway and between master key systems. It alters the relationship between the available depths for adjacent chambers, and provides an orderly way to define the KBA. Parity provides added security with regard to the use of keys from another master key system. In a lock with six chambers, there are a total of 64 different parity combinations, shown in the table below. Any of these can be selected for the KBA. Comparable to a virtual keyway, the use of different parity for each system that a locksmith defines in his geographic area (where such system has the same keyway) will minimize the potential that keys from one system can be used to access another. In other words, parity can minimize the key interchange between master key systems that utilize the same keyway. Parity patterns are chosen that do not have four adjacent chambers with the same odd or even value. Rather, patterns are preferred with no more than two adjacent values.

PARITY TABLE FOR SIX PIN LOCK (2^6 COMBINATIONS)						
EEEEEE	EEOEEE	EOEEEE	EOOEEE	OEEEEE	OEOEEE	OOEEEE
EEEEEO	EEOEEO	EOEEEO	EOOEEO	OEEEEO	OEOEEO	OOEEEO
EEEEOE	EEOEOE	EOEEOE	EOOEOE	OEEEOE	OEOEOE	OOEEOE
EEEEOO	EEOEOO	EOEEOO	EOOEOO	OEEEOO	OEOEOO	OOEEOO
EEEOEE	EEOOEE	EOEOEE	EOOOEE	OEEOEE	OEOOEE	OOEOEE
EEEOEO	EEOOEO	EOEOEO	EOOOEO	OEEOEO	OEOOEO	OOEOEO
EEEOOE	EEOOOE	EOEOOE	EOOOOE	OEEOOE	OEOOOE	OOEOOE

EEEOOO	EEOOOO	EOEOOO	EOOOOO	OEEOOO	OEOOOO	OOEOOO

Note: E=Even O=Odd

11_5.5 Total Position Progression (TPP)

Total position progression is the most popular method for deriving master and change key combinations. It provides an orderly means to generate sequential bitting patterns to insure that incidental master keys and cross-keying issues are minimized, and that the system provides sufficient change keys under each master key level. Perhaps the most critical feature of the TPP is its ability to protect the TMK bitting positions and depths from reuse. In the ideal system, **none** of the TMK values are ever utilized within a change key, although in some systems, one chamber may in fact share a common pin length for the TMK, MK, and CK (may be referred to as **partial position progression**). TPP systems are favored for three or more levels of keying because of their ability to generate sufficient combinations. Other attributes of the total position progression system include:

- **A master pin is placed in every chamber;**
- **The change key and TMK values are different in every position, unlike the rotating constant system;**
- **The key can be divided so as to make available any number of positions for master key levels and reciprocal positions for the change key combinations;**
- **Every column is progressed in the TPP format;**
- **The change key and master keys are derived solely from progressed columns;**
- **The master key and TMK share one or more common values;**

The KBA in a TPP system provides several functions that are required to assure a successful implementation:

- **The KBA defines combinations and numeric progressions for all combinations;**
- **Prevents rule violations;**
- **Insures system security;**
- **Defines master key cuts and positions, and prevents their use in change keys;**

- **Provides an organized method for calculating and generating required combinations for master and change keys;**
- **Defines the number of master key and change key progressives;**
- **Defines all possible depths for all chambers, which equals the global number of differs based upon manufacturers data. This is based upon a one-step or two-step progression;**
- **Allows for system diagramming of all bitting positions and eliminates the potential for duplicate bitting assignments;**
- **Reduces MACS violations by defining the KBA with MACS violation at the bottom of the sequence. This process is referred to as casting.**

The following example will provide an overview as to the steps required in order to generate a master key system utilizing the TPP system. Our hypothetical system utilizes Schlage locks having six chambers and ten available depths, as shown in the diagrams above. We shall require one top level master key (TMK), with ten individual master keys under the TMK, and 40 change keys under each master key. TPP allows us to generate each keying level in an orderly fashion. In our example, the required procedure is as follows:

- **Define a grid that shows all useable differs;**
- **Define the KBA for a three level system (1 TMK, 10 MK, 40 CK), taking into account the manufacturers specifications;**
- **Determine the division of the key, based upon the expansion specification;**
- **Determine the code for the TMK;**
- **Calculate the number of positions that must be progressed at the MK and CK levels in order to provide the required number of combinations;**
- **Progress each column for the desired number of permutations.**

Using a grid for graphic representation, we first define all possible depth increments for each chamber as shown above. We then remove those depths and positions that cannot be used. Recall that if the manufacturer defines a minimum depth increment less than .023", then we must utilize every other depth in our KBA. Because Schlage employs a .015" change, we use 0,2,4,6,8 for even depths, and 1,3,5,7,9 for odd depths, based upon a two-step progression. In such cases, even and odd are alternated between chambers, based upon the selection of a parity code. In this instance, we have chosen EOEOEO.

Next, we choose the code for the TMK. In this case, we selected **258307**. In our KBA, we originally determined that our Schlage lock allowed for five depth positions in six chambers. In the TPP system, we can never allow any depth or position of the TMK to be utilized in a change key. Thus, we must eliminate those positions from our key bitting array. In the charts below, all possible depths are shown on the left, while the useable depths are shown on the right. Note that the TMK depths have been removed on a chamber-by-chamber basis. Thus, 2 may never be used in the first chamber, 5 in the second chamber, 8 in the third chamber, 3 in the fourth chamber, 0 in the fifth chamber, and 7 in the sixth chamber. We are now left with 4^6, or 4,096 useable differs.

2	5	8	3	0	7	TMK
0		0		0		
	1		1		1	
2		2		2		
	3		3		3	
4		4		4		
	5		5		5	
6		6		6		
	7		7		7	
8		8		8		
	9		9		9	

2	5	8	3	0	7	TMK
0		0				
	1		1		1	
		2		2		
	3				3	
4		4		4		
			5		5	
6		6		6		
	7		7			
8				8		
	9		9		9	

2	5	8	3	0	7	TMK
0	1	0	1	2	1	Key Bitting Array
4	3	2	5	4	3	
6	7	4	7	6	5	
8	9	6	9	8	9	

4,096

We next define a progression sequence by setting up a grid having three rows: one for each level of keying.

	CHAMBERS					
GMK						
MK						
CK						

	CHAMBERS					
GMK	H	H	H	H	H	H

Figure LSS+1115 illustrates a key bitting array for a three level master key

system. Courtesy of HPC Interactive Learning Series.

For the TMK, we must never use any of those depths in our progression for other keying levels. Thus, we place an "H" (Hold) in each grid position corresponding to the chambers of the top master key. We then must determine how many MK positions are required to progress the required number of master keys. In our example, we need a total of ten separate bitting combinations. It can be seen that there are four available depths for each chamber. We therefore must use two of the chambers to obtain the needed permutations for our progression. This would provide a total of 16, or 2^4 combinations. So, we must **P**rogress two of the chambers. We show this by placing a P in two of the chamber positions, as shown in the grid.

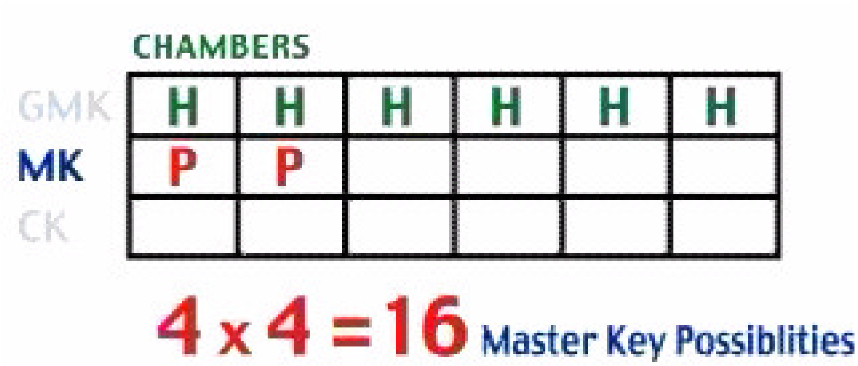


Figure LSS+1116 is a key bitting array for the master key level, with two chambers progressed in a TPP system. Courtesy of HPC Interactive Learning Series.

Next, we determine how many chamber positions we must progress in order to meet our requirement for 40 change keys. We need three chambers, or 4^3, which will yield a total of 64 permutations. Because this is a true TPP system, we actually show four columns that can be progressed. In the following section, we will construct this table in a **partial position progression** format with only three of the columns progressed for the change key and one that is held.

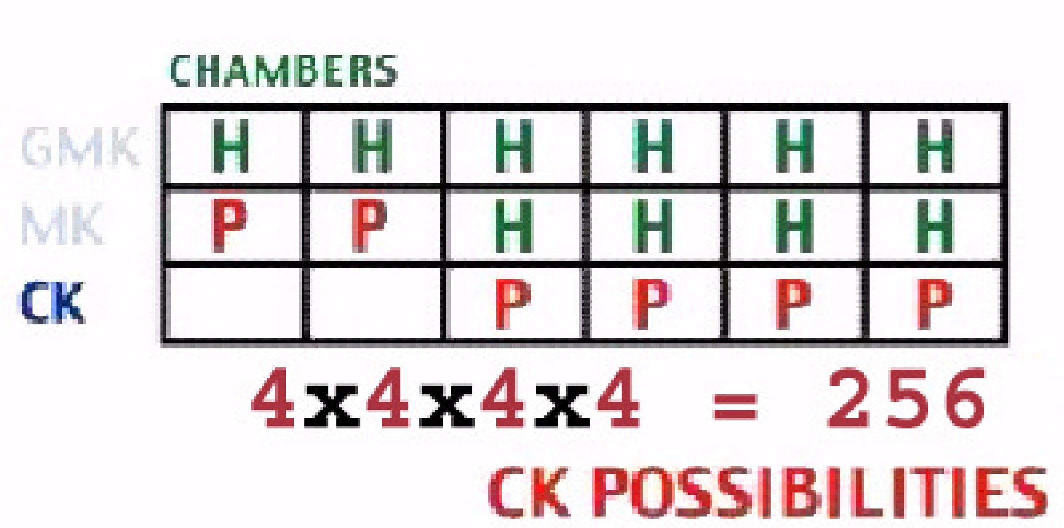
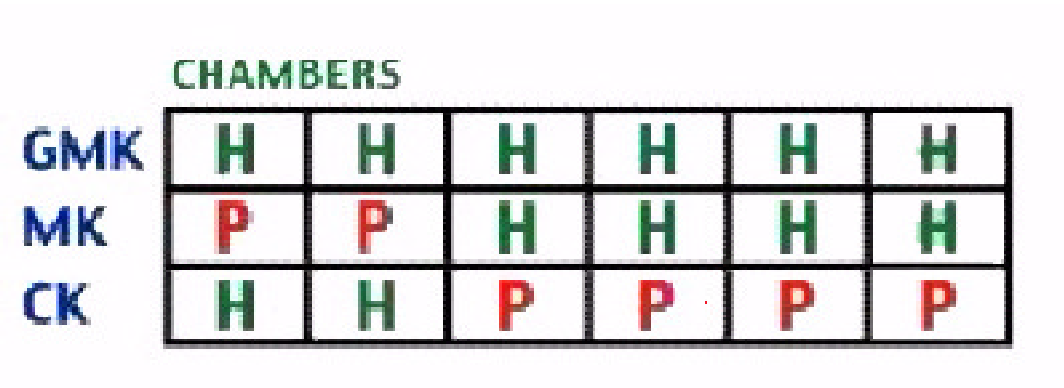


Figure LSS+1117 shows a key bitting array for a change key with four chambers progressed in a TPP system. Courtesy of HPC Interactive Learning Series.

This matrix allows us to progress each of the MK positions to create the required number of master keys (P1, P2). The change key chambers for a TPP system would utilize (P3, P4, P5, P6) and are likewise progressed under each of the master key levels. Each bitting code for the change key is a composite of all chambers, in sequence, as shown in earlier diagrams.



	CHAMBERS					
GMK	H 1	H 2	H 3	H 4	H 5	H 6
MK	P 1	P 2	H	H	H	H
CK	H	H	P 3	P 4	P 5	P 6

Figure LSS+1118 is a key bitting array showing the progression of master key and change key chambers. Courtesy of HPC Interactive Learning Series.

We can deduce the following information and rules from these grids with regard to the derivation of combinations for each keying level:

- **The TMK has a code of H1 H2 H3 H4 H5 H6. The TMK can have no other combination of depths;**

- **The MK has a code of P1 P2 H3 H4 H5 H6. Each master key is a composite of the progressed chambers and "held" positions of the TMK;**

- **The CK has a code of P1 P2 P3 P4 P5 P6. It is a composite of the progressed positions of the MK (P1, P2) and CK (P3, P4, P5, P6). Note: as will be shown, the CK would have a combination of P1 P2 P3 P4 P5 H6 in a partial position progression system if the last chamber were held constant;**

- **We can only progress one progressive at a time, within each division;**

- **We never progress the TMK chambers;**

- **The MK and CK levels, as defined by those chambers that are progressed, create the progression sequence. The chambers at the CK level are progressed against the chambers at the MK level, as will be shown in a later table;**

- **Each master key has a specific number of change keys that can be associated with it as a result of the division of the key. In**

the above example, there are a total of 16 possible master keys (4 x 4), and 256 (4 x 4 x 4 x 4) change keys that can be created under each master key. Remember, each change key has its associated master key code as part of its combination. This prevents a master key or associated change key from opening a lock under a different master key or group of locks;

- **The top level master key bitting code can never appear as part of any change key bitting in the total position progression system;**

- **There are a maximum of two lower pins in any chamber for any system, unless intentional cross-keys or selective master keys have been created (in which case the chamber is double pinned). This means that there can only be two depth positions that can be at shear line for each chamber: the change key depth, and the TMK depth;**

- **It can be seen that there are a maximum of two virtual shear lines in chambers 1-6.**

Derivation of master key codes can be easily understood from the charts below. Two of the chambers, P1 and P2 are progressed in order to meet the requirements of our hypothetical system (10 master keys). P1 and P2 are progressed in sequence and in ascending order, and replace the bitting codes H1 and H2 from the TMK. The progression, as shown, utilizes the first available depth in each chamber. For chamber 1, a 0 cut is utilized, while in chamber 2, the first cut is a 1. Thus, the first MK progression is 01. The least significant chamber in the sequence is always progressed first. This follows the same rule as with a base ten numbering system that we are all utilizing for counting. That is, we assign the value of a digit in a number sequence based upon its position. Thus, the number 25 actually is a code for 2 times 10 and 5 times one (one being the least significant digit). We add to the least significant digit to increment the value. The same rule applies when we progress the pin depths for each chamber.

In our example, P2 is the least significant chamber in sequencing the MK bitting. So, we take the least significant digit (P2) and increment it against P1, until there are no more possibilities (depths) available. We then begin the sequence again, only this time, we increment P1 to the next available depth, which happens to be 4. We repeat the progression with P2. When we have

exhausted the depths available for P2, we increment P1 to the next available depth, which is 6. We repeat the process by incrementing P1 to the last available depth which is 8, and then we repeat the sequence, using each of the available depths, in P2. In this manner, we are able to generate a total of 16 different master keys, all with unique codes.

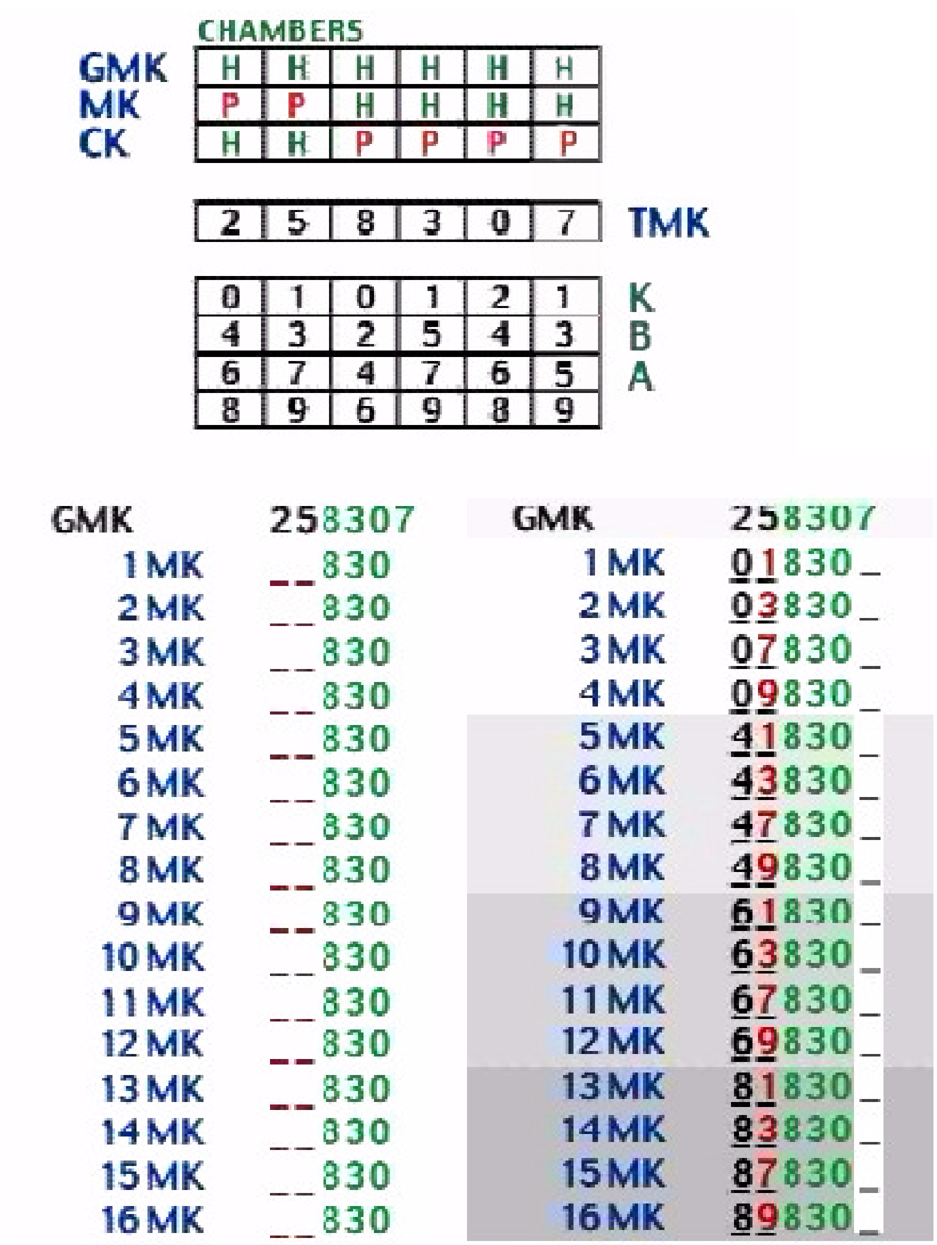


Figure LSS+1119 shows the progression in a TPP system for sixteen master keys.

Random assignment of symbols is not considered in the diagram. Courtesy of HPC Interactive Learning Series.

Next, we must define our change keys. Recalling our requirements in the example, a total of 40 change keys must be created for each master key. In the charts below, there are a total of 4^3, or 64 individual change keys that are progressed from chambers P3, P4, and P5. Although we only required 40 change keys for our example, there would be 24 available for system expansion. The change keys for each individual master key will contain the first two positions (P1 and P2) of its associated master key.

In the tables, the progression for 1MK is shown. Note that the sequence is identical with that shown for the MK level: the least significant digit is first sequenced (P5) through all possible depths that appear in the KBA (shown in red). Then, P4, then P3 is sequenced to generate a total of 64 combinations, each of which will only be controlled by 1MK. No other master key can access this group of locks, because no other master key has 01 (chambers P1 and P2) as its first two depths. Remember, the code for 1MK is only associated with the 40 change keys under its control. A new progression will be generated for 2MK, 3MK through 10MK. In our example, ascending progression values are selected for the bitting of each key. This progression can be modified to increase the security of the system and to make it more difficult to predict or extrapolate either change key or master key sequences or individual values. Also note that we have not entered a value for P6 at this time. We shall do so in the next section, dealing with partial position progression.

Key	Code
GMK	258307
1 MK	018307
1 CK	01___
2 CK	01___
3 CK	01___
4 CK	01___
5 CK	01___
6 CK	01___
7 CK	01___
8 CK	01___
9 CK	01___
10 CK	01___
11 CK	01___
12 CK	01___
13 CK	01___
14 CK	01___
15 CK	01___
16 CK	01___

Key	Code
GMK	258307
1 MK	018307
1 CK	01012
2 CK	01014
3 CK	01016
4 CK	01018
5 CK	01052
6 CK	01054
7 CK	01056
8 CK	01058
9 CK	01072
10 CK	01074
11 CK	01076
12 CK	01078
13 CK	01092
14 CK	01094
15 CK	01096
16 CK	01098

Key	Code	Key	Code
GMK	258307	GMK	258307
1 MK	018307	1 MK	018307
17 CK	01212	33 CK	01412
18 CK	01214	34 CK	01414
19 CK	01216	35 CK	01416
20 CK	01218	36 CK	01418
21 CK	01252	37 CK	01452
22 CK	01254	38 CK	01454
23 CK	01256	39 CK	01456
24 CK	01258	40 CK	01458
25 CK	01272	41 CK	01472
26 CK	01274	42 CK	01474
27 CK	01276	43 CK	01476
28 CK	01278	44 CK	01478
29 CK	01292	45 CK	01492
30 CK	01294	46 CK	01494
31 CK	01296	47 CK	01496
32 CK	01298	48 CK	01498

GMK	258307
1 MK	018307
49 CK	01612
50 CK	01614
51 CK	01616
52 CK	01618
53 CK	01652
54 CK	01654
55 CK	01656
56 CK	01658
57 CK	01672
58 CK	01674
59 CK	01676
60 CK	01678
61 CK	01692
62 CK	01694
63 CK	01696
64 CK	01698

Figure LSS+1120 shows the progression in a TPP system for 64 change keys under one master key. Courtesy of HPC Interactive Learning Series.

We can define a logical construct with regard to the change key and master key bitting position, and their relationship to the TMK bitting. This becomes extremely important to the discussion in **chapter 31**, with regard to the extrapolation of the top level master key bitting. Using the definition of each chamber at the MK and CK level that is marked for progression:

The TMK bitting for chamber 1 must be P1 or H1;
The TMK bitting for chamber 2 must be P2 or H2;
The TMK bitting for chamber 3 must be P3 or H3;
The TMK bitting for chamber 4 must be P4 or H4;
The TMK bitting for chamber 5 must be P5 or H5;
The TMK bitting for chamber 6 must be P6 or H6.

Any chamber that is progressed, regardless of whether it is at the MK or CK level:

Can only have two depths;
P1 can never equal H1

```
P2 can never equal H2
P3 can never equal H3
P4 can never equal H4
P5 can never equal H5
P6 can never equal H6
```

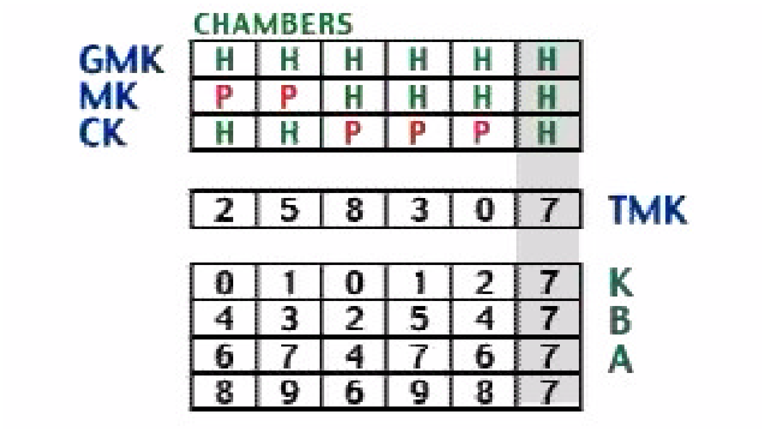
11_5.6 Partial Position Progression

Although not often discussed in master keying texts, a partial position progression system shares some of the attributes of both the total position progression and rotating constant schemes. It is employed in some systems where one chamber if held constant and its position never rotated. Often, a locksmith may create a PPP system, believing that it is in fact a rotating constant. Practically speaking, it is a theoretical difference, but deserves mention because it is sometimes employed.

Partial position progression can be considered as a subset of total position progression and a hybrid between TPP and RC. In the PPP scheme, not all of the columns in the KBA are progressed as with total position progression. The PPP shares a characteristic of rotating constant, in that one or more chambers is held constant. However, unlike RC, those progressives that are constant are **not rotated**; they are fixed at the time of the division of the key.

The distinction between PPP and RC can be understood by analyzing the difference in change key combinations between total position progression and partial position progression formats. It will be noted in the KBA (below) that the sixth column is held rather than progressed, and the value of the TMK (7) is shared between the TMK, MK, and CK, as with the rotating constant method.

	CHAMBERS					
GMK	H1	H2	H3	H4	H5	H6
MK	P1	P2	H	H	H	H
CK	H	H	P3	P4	P5	H6



We can now deduce the following information and rules from these grids with regard to the derivation of combinations for each keying level in partial position progression:

- **The TMK has a code of H1 H2 H3 H4 H5 H6. The TMK can have no other combination of depths;**

- **The MK has a code of P1 P2 H3 H4 H5 H6. Each master key is a composite of the progressed chambers and "held" positions of the TMK;**

- **The CK has a code of P1 P2 P3 P4 P5 H6. It is a composite of the progressed positions of the MK and CK;**

- **We can only progress one progressive at a time within each division;**

- **We never progress the TMK chambers;**

- **The MK and CK levels, as defined by those chambers that are progressed, create the progression sequence. The chambers at the CK level are progressed against the chambers at the MK level, and added to the held positions;**

- **Each master key has a specific number of change keys associated to it, by virtue of the fact that the MK and CK codes are interrelated. Thus, there is no possibility that a change key code can inadvertently be used in a lock located in an area for which it is not authorized;**

- **The top level master key code can appear as part of either the master key or change key;**

- **There are a maximum of two lower pins in any chamber for any system, unless intentional cross-keys or selective master keys have been created (in which case the chamber is double pinned). In those chambers that share a TMK value, there will only be one lower pin. This means that there can only be one or two depth positions that can be at shear line for each chamber: the change key (or master key) depth, and the TMK depth;**

- **It can be seen that there are a maximum of two virtual shear lines in chambers 1-5, and one shear line in column 6.**

- **Any chamber that is not progressed can only have one depth. That chamber will always be constant. The change key bitting will always equal the TMK bitting. Thus, H6 (or other chamber) will always equal the TMK bitting.**

- **It can be seen that there are a maximum of two virtual shear lines in chambers 1-5, and one shear line for chamber 6 (because this chamber is not progressed, so the bitting in this position is the same for all three levels of keying.**

- **In our example, the sixth chamber is not progressed at any level because it is not needed. That is, there are sufficient permutations available by using two chambers at the MK level, and three chambers at the CK level. If we had needed more than 64 different change keys, then we would have used the sixth chamber and made available a total of 256 or 4^4;**

In our example, the sixteen master keys under 1MK are derived as shown. Note that the sixth column is a constant 7, which is the same value as the TMK. The 64 change keys are sequenced as shown and they also contain a constant value in the sixth column with the TMK.

GMK	258307
1 MK	018307
2 MK	038307
3 MK	078307
4 MK	098307
5 MK	418307
6 MK	438307
7 MK	478307
8 MK	498307
9 MK	618307
10 MK	638307
11 MK	678307
12 MK	698307
13 MK	818307
14 MK	838307
15 MK	878307
16 MK	898307

GMK	258307
1 MK	__8307
2 MK	__8307
3 MK	__8307
4 MK	__8307
5 MK	__8307
6 MK	__8307
7 MK	__8307
8 MK	__8307
9 MK	__8307
10 MK	__8307
11 MK	__8307
12 MK	__8307
13 MK	__8307
14 MK	__8307
15 MK	__8307
16 MK	__8307

CALCULATING THE CHANGE KEYS

0	1	0	1	2	7
4	3	2	5	4	7
6	7	4	7	6	7
8	9	6	9	8	7

GMK	258307
1 MK	018307
1 CK	01___7
2 CK	01___7
3 CK	01___7
4 CK	01___7
5 CK	01___7
6 CK	01___7
7 CK	01___7
8 CK	01___7
9 CK	01___7
10 CK	01___7
11 CK	01___7
12 CK	01___7
13 CK	01___7
14 CK	01___7
15 CK	01___7
16 CK	01___7

GMK	258307
1 MK	018307
1 CK	010127
2 CK	010147
3 CK	010167
4 CK	010187
5 CK	010527
6 CK	010547
7 CK	010567
8 CK	010587
9 CK	010727
10 CK	010747
11 CK	010767
12 CK	010787
13 CK	010927
14 CK	010947
15 CK	010967
16 CK	010987

GMK	258307
1 MK	018307
17 CK	012127
18 CK	012147
19 CK	012167
20 CK	012187
21 CK	012527
22 CK	012547
23 CK	012567
24 CK	012587
25 CK	012727
26 CK	012747
27 CK	012767
28 CK	012787
29 CK	012927
30 CK	012947
31 CK	012967
32 CK	012987

GMK	258307
1 MK	018307
33 CK	014127
34 CK	014147
35 CK	014167
36 CK	014187
37 CK	014527
38 CK	014547
39 CK	014567
40 CK	014587
41 CK	014727
42 CK	014747
43 CK	014767
44 CK	014787
45 CK	014927
46 CK	014947
47 CK	014967
48 CK	014987

Key	Bitting
GMK	258307
1 MK	018307
49 CK	016127
50 CK	016147
51 CK	016167
52 CK	016187
53 CK	016527
54 CK	016547
55 CK	016567
56 CK	016587
57 CK	016727
58 CK	016747
59 CK	016767
60 CK	016787
61 CK	016927
62 CK	016947
63 CK	016967
64 CK	016987

11_5.6.1 MACS Violations and Useable Combinations

This section will provide an example of theoretical and practical combinations that are derived through the progression method and the affect that maximum adjacent cut specifications can have with regard to the generation of useable combinations. The subject of MACS is also examined in section 11_5.3.4.2.

In our example, we have defined a system with 1 TMK, 10 MK, and 40 CK for each master key level. However, certain of the combinations at the MK and CK level may not be utilized due to **MACS(137)** violations. Schlage establishes a MACS of 7 and is shown in our example. Therefore, any two adjacent cuts that exceed a difference of 7 cannot be used. Even-odd depths between chambers will prevent the occurrence of a combination of 1 and 9, but will not prevent 0 and 9. It can be seen that **4MK** begins with 09, and thus, all of this master key level and associated change keys must be removed from the system. Likewise, the values of the

second chamber (P2) of MK levels 8, 12, and 16 is **9**, so all change keys with a third chamber (P3) value of **0** must be eliminated. MACS is a physical cutting limitation for keys. Although a lock can be keyed to a MACS violation, the physical key will not functional properly in that lock. MACS does not affect security, just the physical operation of the key. MACS losses will depend upon the design of the TMK and parity.

GMK	258307
1 MK	018307
2 MK	038307
3 MK	078307
098307	
5 MK	418307
6 MK	438307
7 MK	478307
8 MK	498307
9 MK	618307
10 MK	638307
11 MK	678307
12 MK	698307
13 MK	818307
14 MK	838307
15 MK	878307
16 MK	898307

GMK	258307
1 MK	018307
2 MK	038307
3 MK	078307
5 MK	418307
6 MK	438307
7 MK	478307
8 MK	498307
9 MK	618307
10 MK	638307
11 MK	678307
12 MK	698307
13 MK	818307
14 MK	838307
15 MK	878307
16 MK	898307

8 MK	498307
12 MK	698307
16 MK	898307
1 CK	890127
2 CK	890147
3 CK	890167
4 CK	890187
5 CK	890527
6 CK	890547
7 CK	890567
8 CK	890587
9 CK	890727
10 CK	890747
11 CK	890767
12 CK	890787
13 CK	890927
14 CK	890947
15 CK	890967
16 CK	890987

13 CK	890927
14 CK	890947
15 CK	890967
16 CK	890987

Figure LSS+1121 shows a progression of sixteen master keys in a partial position progression system, and the removal of four of the MK levels because of MACS violations. Courtesy of HPC Interactive Learning Series.

11_5.6.2 Pinning the Cylinder

Each cylinder must be populated with bottom pins, master pins, and top pins. This is done in a specific order (for each chamber) so that all combinations work as intended. Many manufacturers also utilize balanced drivers to insure that the overall pin stack height (top pin, master pins, bottom pin) is of a constant length. This practice will insure that a comb pick cannot be employed, that springs are not crushed, and that there is sufficient vertical movement of the pins. See the discussion regarding balanced drivers elsewhere in this text.

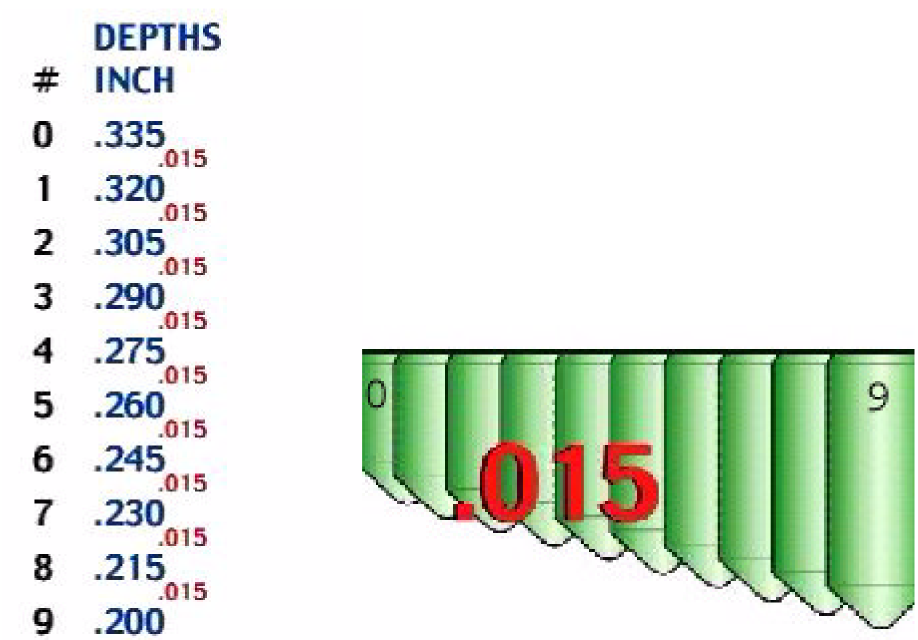
We shall use a change key with a combination of 010127 and the TMK with 258307. A chart of all Schlage depths is shown below, together with a graphic representation of pin depths, showing that a "0" cut has the most bitting and thus requires the shortest pin. Remember, bitting is measured from the base of the key blade to the root of the cut, and is inversely proportional to the length of the corresponding pin.

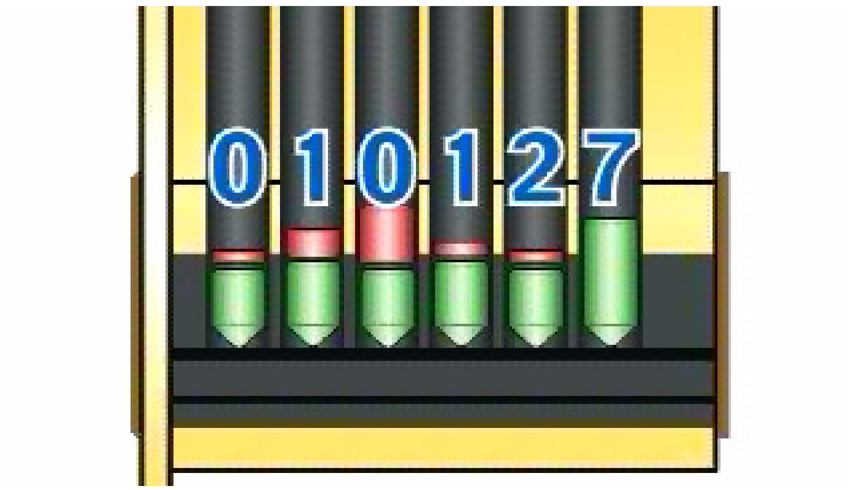
In order to properly place bottom pins and master pins into each chamber so that change key, master keys and top level master key will break at shear line, we compute the total length of the pin stack exclusive of the top pins. This means that the shallowest cut for each chamber plus a master pin must equal the deeper cut for each position. In our example, the change key has a code of 010127, and the TMK has a code of 258307. It can be seen that the first cut of the change key, "0" is the shorter of the two depths (2 is .030" longer than a 0 cut) and therefore "0" must be the bottom pin in chamber one. An additional length of two bitting depths (.030") is required to make up the difference for the TMK depth of 2 in the first chamber, so we add a number two master pin with this value to the pin stack. Now both a 0 and 2 will break at shear line. We repeat this procedure for each chamber so that both the change key depth and master key depth will split at the shear line.

The following procedure is followed to determine pinning for each chamber:

- **The shorter bitting value must always be loaded first and appear as the bottom tumbler;**

- **Notate the TMK bitting directly above the CK bitting on the chart;**
- **Transpose the smaller of the two numbers on the top in a second sequence;**
- **Eliminate duplicate numbers for each chamber. That means, for example, that if depth 7 is utilized in chamber 6, write it only once;**
- **Create a pinning chart, placing the shorter row of numbers on the bottom;**
- **Calculate the difference for each chamber between the shorter and longer pins. This value will be the master pin for each position and should appear above the first row of numbers in the pinning chart;**





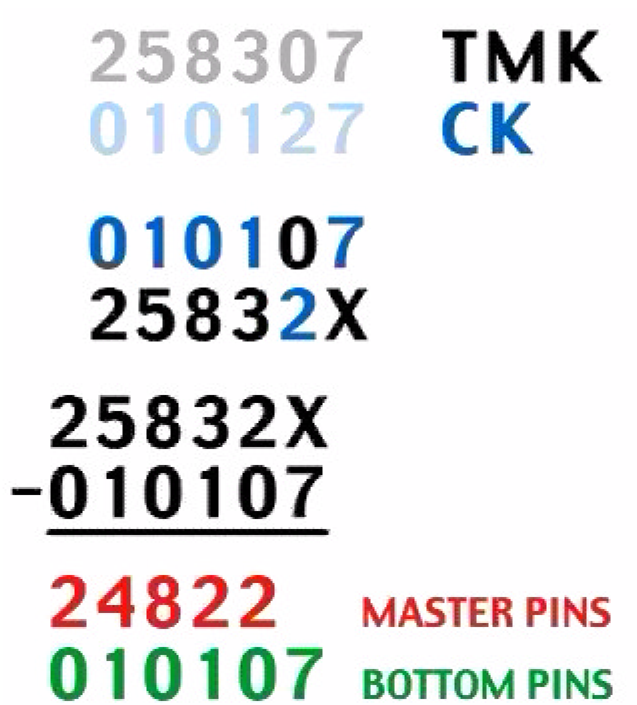
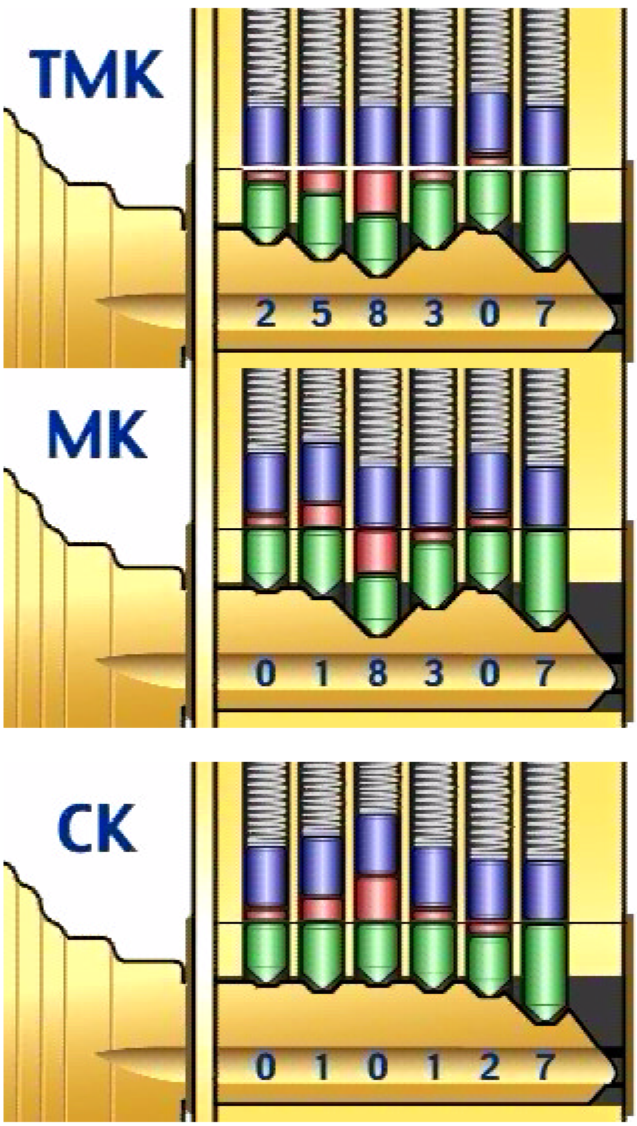


Figure LSS+1122 graphically illustrates the pinning of a master keyed cylinder, and the resultant cross-keys. Courtesy of HPC Interactive Learning Series.

When the cylinder is pinned properly, the TMK, master key, and corresponding change key will break at shear line. Note that a master key for another group will not open the cylinder. In our example, the following codes are all active for the cylinder

shown below: 258307 (TMK), 018307 (1MK), 010127 (CK associated with 1MK). Change key code 010147, however, will not open this lock because the pinning is incorrect for this combination, even though the combination is associated with the 1MK group. It can be seen that various composite pin combinations (incidental master keys) allow master keying schemes to operate one lock. In each of the examples, a combination of lower pins and master pins are raised to shear line and allow the plug to turn with three different keys. It can also be understood that there are a total **32 different combinations(138)** that will open this lock. Adherence to the keying scheme prevents any other keys in the system from matching these unintended cross-key combinations.



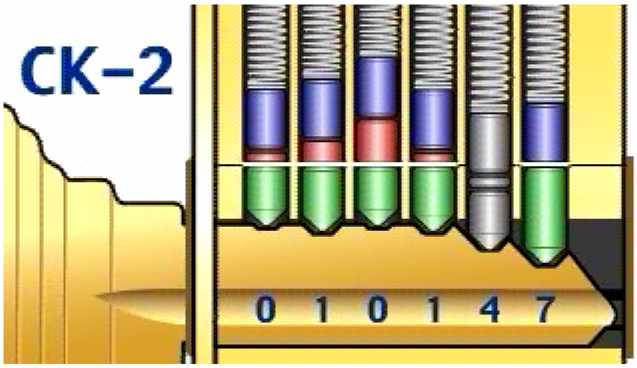


Figure LSS+1123 shows the different shear lines that are created when pinning a master key system. Courtesy of HPC Interactive Learning Series.

11_5.6.2.1 Verifying Cylinder Pinning

LSS204: Brian Chan on the use of system keys.

Brian Chan (UC Berkeley) has developed a method to rapidly pin and verify multiple cylinders for Best IC and other systems. The technique can minimize pinning errors and the time that is required for each lock. It will also eliminate the need to cut change keys to test each cylinder. Accelerated pinning can be likened to mass production techniques introduced by Eli Whitney (cotton gin manufacturing) more than 150 years ago during the Industrial Revolution. In a TPP or RC system, locks are grouped and identified by chambers having the same bitting values. Thus, all locks are loaded for each chamber having the same pins, rather than populating each lock for all chambers, as is the customary practice. For the second part of the process, verifying correct pinning, Chan eliminates the normal requirement to test each cylinder with its change key, master key, and TMK.

There are two types of common pinning errors: use of the wrong length pin and reversal of pins within a pin stack. If an error has been made with respect to placement of the correct bottom pin or master pin for a specific chamber, then most likely neither the master key nor TMK will function. If, for example, a pin with a depth of "3" rather than a "2" was inserted into the first chamber, then neither the CK, MK, or TMK would work.

The second type of pinning error is more difficult to identify and occurs when one or more pins are reversed within a pin stack. An example will demonstrate the problem. If the 1 and 3 pins are reversed in the fourth chamber, it can be seen that the change

key will not operate the lock, but the master key and TMK will. If the insertion order for a pin stack is reversed in chambers three or four, both the master key and top level master key would work. Only the change would fail to operate the lock. If such errors occur, the usual practice would be to dump all pins and start over.

In our hypothetical master key system, the TMK has a value of 258307, the 1MK of 018307, and CK1 of 010127. Correct pinning of the cylinder would be as follows:

258307	**Top level master key**
018307	**#1 Master key**
010127	**#1 Change key**
24822-	**Master pin**
010107	**Bottom pins**

In order to determine which chamber(s) have been pinned in error, a method must be devised to individually test each pin stack. "System keys" are cut by Chan to exploit the composite combinations (incidental master keys) that are created by the multiple shear lines required for the different keying levels. This technique allows the isolation of each chamber to easily find pinning errors. The system keys for testing all locks within our hypothetical system would be coded to correspond with the available values that have been defined in he KBA for each chamber. In our example, we must test for all chambers. Because there are four available values for each chamber, we require a total of twenty system keys to test every lock.

The values for the system keys to test all progressives are shown in the chart below.

SYSTEM KEYS FOR TMK 258307		
T1-0	**058307**	**P1 bitting 0**
T1-2	**258307**	**TMK BITTING NOT USED**
T1-4	**458307**	**P1 bitting 4**
T1-6	**658307**	**P1 bitting 6**
T1-8	**858307**	**P1 bitting 8**

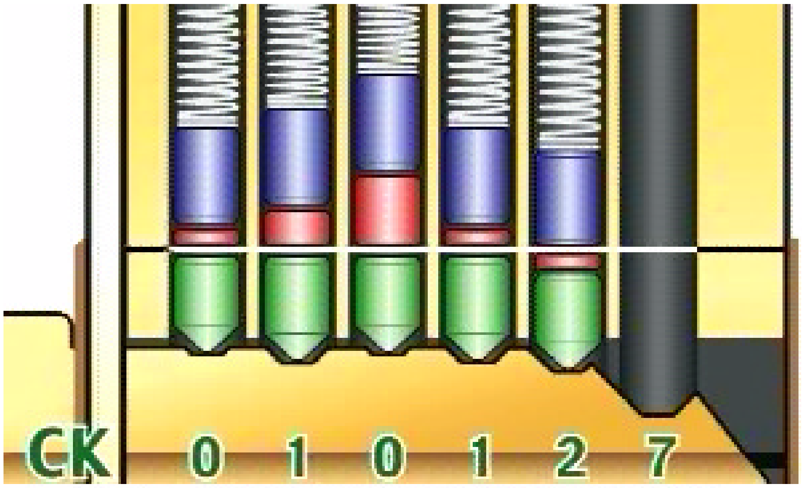
T2-1	**218307**	**P2 bitting 1**
T2-3	**238307**	**P2 bitting 3**
T2-5	**258307**	**TMK BITTING NOT USED**
T2-7	**278307**	**P2 bitting 7**
T2-9	**298307**	**P2 bitting 9**
T3-0	**250307**	**P3 bitting 0**
T3-2	**252307**	**P3 bitting 2**
T3-4	**254307**	**P3 bitting 4**
T3-6	**256307**	**P3 bitting 6**
T3-8	**258307**	**TMK BITTING NOT USED**
T4-1	**258107**	**P4 bitting 1**
T4-3	**258307**	**TMK BITTING NOT USED**
T4-5	**258507**	**P4 bitting 5**
T4-7	**258707**	**P4 bitting 7**
T4-9	**258907**	**P4 bitting 9**
T5-0	**258307**	**TMK BITTING NOT USED**
T5-2	**258327**	**P5 bitting 2**
T5-4	**258347**	**P5 bitting 4**
T5-6	**258367**	**P5 bitting 6**
T5-8	**258387**	**P5 bitting 8**

If an error is detected in the operation of a specific lock, the pinning chart is consulted to determine the bitting values for P3, P4, and P5. The test key for that chamber (T3, T4, or T5) and bitting would be used to test the operation of the lock. Based upon our previous discussion, we know that the change key bitting is a composite of the master key and change key progression. Thus, when the test key for a specific bitting value within a chamber is inserted, there are only two virtual shear lines: the change key and the TMK. If pinned correctly, the lock must open when the key is cut to the TMK or CK value. The master key division and associated depths for each individual master key portion can be tested in similar fashion with systems keys that are a composite of the master key and TMK depths.

This procedure provides further insight into the discussion in **chapter 31** with regard to the decoding and extrapolation of the TMK from the change key. In the verification of pinning described above, we know the bitting values of the change key and top level master key. We are seeking to determine whether the bitting depth that has been assigned to a specific lock and chamber for the change key matches the actual length of the pin. Conversely, when we are attempting to derive the TMK from a target lock, we know the correct value of the change key and that the lock has been pinned correctly. We do not know the bitting of the TMK, and will utilize the **change key** to determine the value of the TMK bitting. By using all system keys for each chamber, we are able to reverse the verification procedure and learn the specific value for the TMK for each position.

11_5.7 Rotating Constant Progression System (RC)

The application of rotating constant to master keying was first introduced by Yale in the 1800s. Much like the total position progression scheme, the rotating constant algorithm relies upon an orderly progression of available depths, derived from a key bitting array grid. The most critical difference is in the programmed use of one or more chambers having the same bitting depth in all keying levels, the use of constants, and in their rotation. It will be recalled in our hypothetical system for PPP that the sixth chamber was "held" and was therefore common to the TMK, MK, and CK. TPP systems will not allow this to occur, but in some situations, it can be the case that one chamber is common to all keying levels. The RC system is based upon a similar premise. In this system, at least one bitting value is held constant within a chamber, then its position is rotated in different progressions. The differences between TPP and RC can be graphically illustrated.



TOTAL POSITION PROGRESSION

2	5	8	3	0	7	TMK

0	1	0	1	2	1
4	3	2	5	4	3
6	7	4	7	6	5
8	9	6	9	8	9

Figure LSS+1124 shows the KBA for the total position progression system, but is equally applicable to a PPP system if the sixth progressive is held, as shown in the lock diagram. Note that the sequence of progression (SOP) is not shown in the key bitting arrays. Courtesy of HPC Interactive Learning Series.

In our PPP example, we held the sixth chamber constant between all keying levels. In TPP systems, however, this would not be the case, and all six chambers would be progressed as shown in the above KBA.

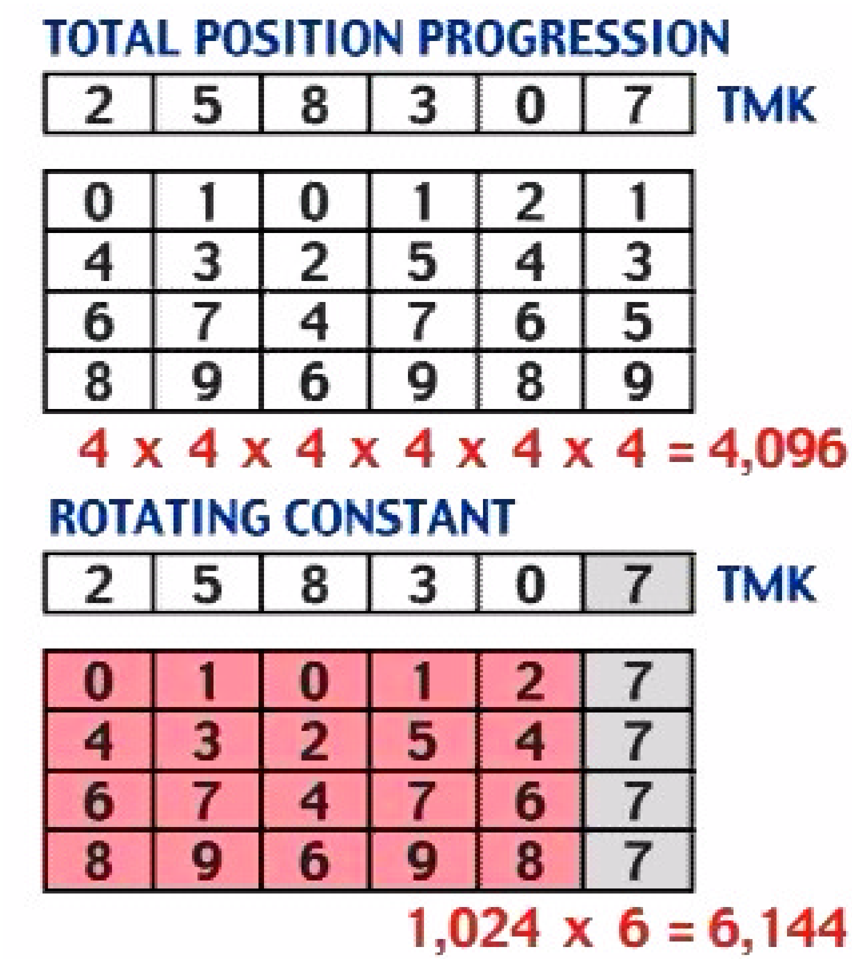


Figure LSS+1125 shows a comparison in KBA tables between a total position progression and rotating constant system. The RC table would also work for PPP, but the total number of theoreticals would be 1,024. Courtesy of HPC Interactive Learning Series.

In our hypothetical six pin lock when each chamber is held constant and the other five are progressed, a total of 6,144 combinations can be created, as shown in the charts below. Contrast this with a total number of possible differs of 4,096 in the TPP system.

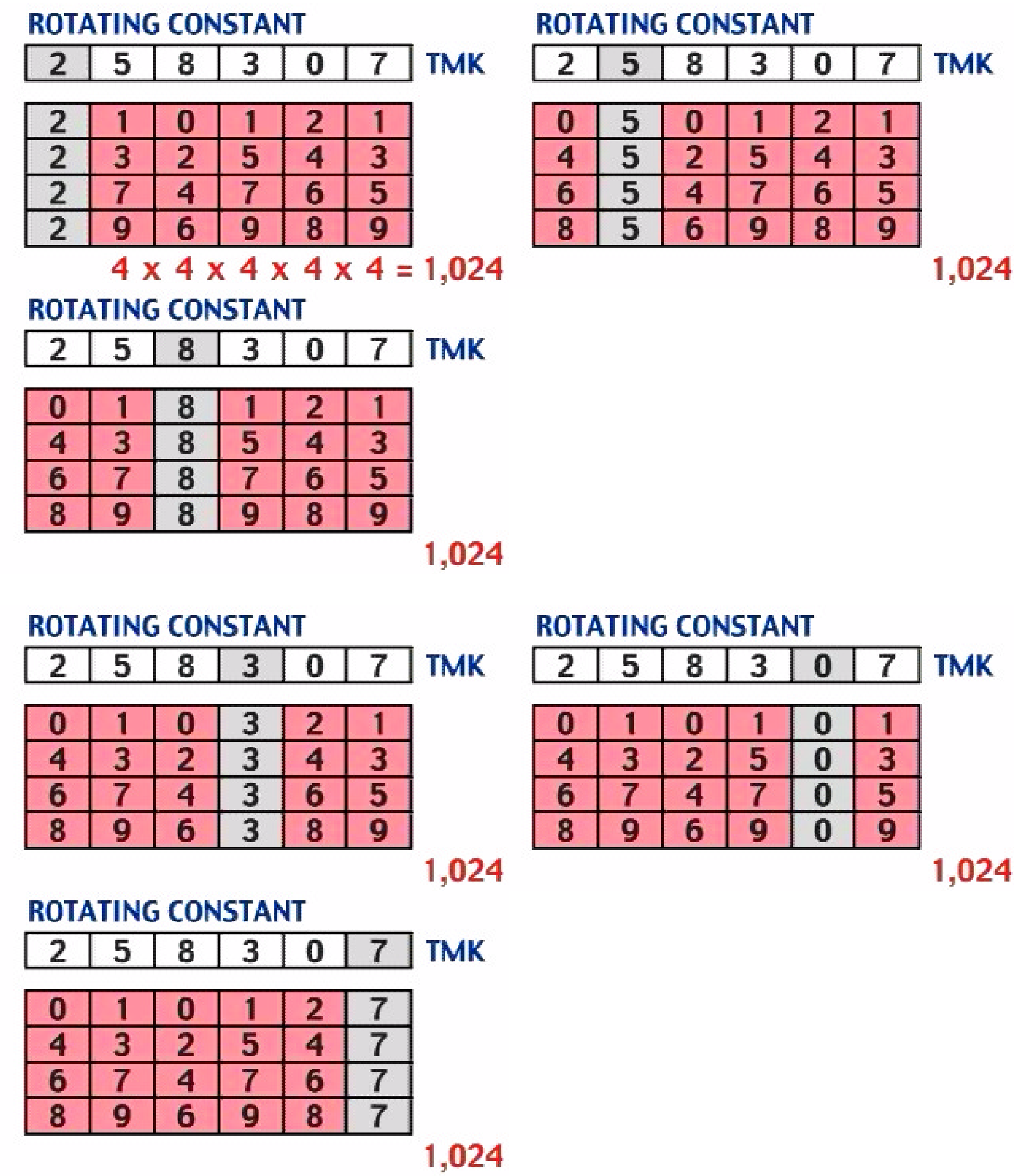


Figure LSS+1126 provides a graphic illustration of the rotating constant system, showing how one chamber is held constant while the others are progressed. A pattern matrix will define which columns are progressed and held. Courtesy of HPC Interactive Learning Series.

The rotating constant system has certain attributes and advantages over the total position progression method. These include:

- **RC should be used in two level systems because of the ability to add locks in the future. For systems of three levels or higher, the TPP is preferred;**
- **There are fewer incidental master keys in a rotating constant system because there are fewer master pins required;**
- **The system provides more inherent security;**
- **The expansion specification will dictate whether rotating constant or total position progression will provide better system options;**
- **Master pins are only utilized in certain positions;**
- **The change key, master key, and TMK share bitting values in certain positions;**
- **Cylinders are more pick resistant;**
- **There is less likelihood of key manipulation;**
- **There is less key interchange potential;**
- **There are a limited number of combinations available for systems of greater than two keying levels;**
- **The same number of chambers must be progressed (and held constant) for all keying levels, once established;**
- **Positions are subject to rotation based upon a pattern matrix;**
- **Both one and two-step progression may be employed, depending upon manufacturer specifications;**
- **The TMK is part of every change key and master key**

11_5.7.1 Division of the Key for RC

As with the total position progression system, the key must be divided when using rotating constant. In a system of more than two keying levels, the division is fixed and those columns that are to be progressed or held constant must be defined. Unlike TPP, the RC system requires that patterns of sequencing of constant and progressives be selected to write the KBA. These are detailed in section 11_5.7.1.1 below.

11_5.7.1.1 Progression Patterns for Rotating Constant

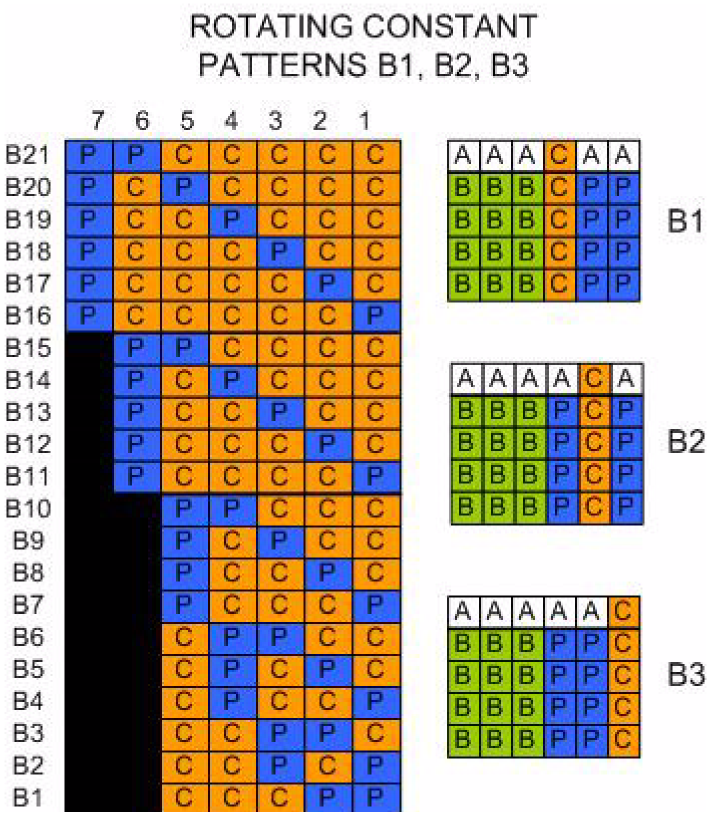
As described in the introduction to rotating constant theory, the system is based upon the selection of sequence patterns of all combinations of progressed and constant values. The key division

partition position progression table below shows the relationship between the number of chambers within a lock, the number of chambers that are progressed, and the number of patterns that will be produced and which can be utilized to build the KBA. Links from each table heading of progressed chambers provide the matrix for use in defining the KBA.

KEY DIVISION PARTITION POSITION PROGRESSION TABLE					
CHAMBERS	**1 PROGRESSED**	**2 PROGRESSED**	**3 PROGRESSED**	**4 PROGRESSED**	**5 PROGRES**
5	5	10	10	5	
6	6	15	20	15	6
7	7	21	35	35	21

11_5.7.1.1.1 Application of Progression Patterns

The use of patterns that have been generated from two progressed columns (**P**) in three different KBAs is shown below. In this example, patterns B1 (**cPP**), B2 (**PcP**), and B3 (**PPc**) have been applied to the KBA in order to generate combinations for different master keys. Note that two columns are progressed and one is held constant, and that the value of the constant is common to the change key, master key, and TMK. The master chart shows all possible patterns for a five, six, and seven pin lock. Patterns B1-B10 can be used for a five pin lock, B11-B15 for a six pin lock, and B16-B20 for a seven pin lock.



11_5.7.2 Procedure for Defining a Rotating Constant System

The procedure to define a rotating constant system requires the following steps:

- **Determine the expansion specification and the required number of master and change keys and keying levels;**
- **Define the TMK;**
- **Establish the division of the key. If there are only two keying levels, then the division will establish the number of positions for the master and change key. The pattern of progressed and constant chambers is selected, and the positions are progressed accordingly;**
- **For three or more levels, select the master keys that are going to be used;**
- **Select progression patterns to establish KBAs for each master key in order to generate change keys that are required to fulfill the requirements of the expansion specification;**

11_5.8 Documenting Master Key Systems

There are three principal formats for writing and displaying key bittings within a master key system: **list format**, **standard progression format**, and **matrix format**. Any of the three techniques may be utilized to document a system; each has its advantages in specific circumstances. Lock manufacturers typically provide system documentation in list format and will accept expansion specifications from the locksmith in any form that accurately reflects the system and provides precise direction as to how each cylinder is to be keyed. It is important to understand each method, especially if called upon to reconstruct or analyze a system after it has been implemented or for system expansion. The documentation will identify all keying levels, the association between each level of master key and change keys, cross-keys, key interchange, and all incidental master keys.

The format that is chosen to display all theoretical combinations (progressive list) within a system is different than the **bitting list**. The format, whether list, standard progression, or matrix, is able to display all possible combinations that can be used to define each lock within the system, whether they are in fact utilized or not. This would include both useable and unusable combinations.

The **bitting list** denotes the actual association between useable combinations and specific cylinders and documents all combinations used within the system, once key symbols are assigned. The printout that is generated from a specific format can also be used as the bitting list, if desired. It is important that anyone with the responsibility to generate, decode, maintain, or analyze a master key system be thoroughly conversant with each of the documentation techniques. An example and comparison of list, standard, and matrix format is discussed below.

11_5.8.1 List Format

List format is most often used in small systems, generally with two levels of keying, although the format may be utilized in larger systems as well. A **lead sheet** (shown below) will provide the necessary system information for bitting lists used in this format. It shows the expansion specification, identification

information for the specific system, as well as the key division, progression method, MACS, all master keys, and other system data.

MT SYSTEMS SECURITY SERVICE, INC.
Format: X List __Standard __Matrix
Progression: __One-Step X Two Step

SYSTEM #: USD-7
LEAD of _____

Expansion Spec: 1-12-40

Shallow/Deep: 0-9

MACS: 7
KEYWAY ID: SCHLAGE 923C
Key Division: MK | MK | MK | CK | CK | CK

TMK	2	5	8	3	0	7
	0	1	0	1	2	1
	4	3	2	5	4	3
	6	7	4	7	6	5
	8	9	6	9	8	9
SOP	F	E	D	C	B	A

File Ref: 0124 Written By: MWT Date: 1 / 12 / 04

HOOK BLANKS: X OEM __Other

Stamp Keys: NO Depth/Space: STD

NOTES:

MASTER KEYS

AA	010127
AB	010147
AC	010167
AD	010187
AE	010527
AF	010547
AG	010567

A system is written in list or other format after the following tasks have been performed:

- **Determine system expansion specifications;**
- **Method of progression: total position progression or rotating constant;**
- **Type of progression: one-step or two-step;**
- **Define the TMK and write the KBA;**
- **Write the progression list with the sequence of progression (SOP);**
- **Check for MACS violations and eliminate them;**
- **Assign key symbols and document the system.**

An example of a list format is shown in the table below. All of the combinations for a six pin system are presented. Note that

the key has been divided equally: three positions for the master key and three positions for the change key. The KBA is shown for the TMK of **258307.** The list indicates all of the bittings associated with one master key (AA) of 030307. These 64 combinations would be one "page" as described in standard progression format below. Note that key symbols have been assigned for thirteen change keys at random throughout the list of all possible combinations. All of the progressives were derived in odometer style, defined by the standard sequence of progression (SOP) CBA, shown at the bottom of the KBA. That indicates that columns A, then B, then C were progressed, in that order.

TMK	2	5	8	3	0	7
	0	1	0	1	2	1
	4	3	2	5	4	3
	6	7	4	7	6	5
	8	9	6	9	8	9
SOP	F	E	D	C	B	A

AA 030307 — LIST FORMAT

#	Key	Combination	#	Key	Combination
1	AA1	030121	33		030721
		030123			030723
		030125			030725
		030129		AA4	030729
		030141			030741
	AA3	030143			030743
		030145		AA10	030745
		030149			030749
		030161			030761
		030163			030763
	AA12	030165			030765
		030169		AA6	030769
		030181			030781
		030183			030783
		030185			030785
		030189		AA2	030789
	AA5	030521			030921
		030523			030923
		030525			030925
	AA9	030529			030929
		030541		AA7	030941
		030543			030943
		030545			030945
		030549			030949
		030561		AA8	030961
		030563			030963
		030565			030965
	AA11	030569			030969
		030581			030981
		030583		AA13	030983
		030585			030985
32		030589	64		030989

11_5.8.2 Standard Progression Format

This format (not utilized by most manufacturers), provides a clear graphical expression of all keying levels, and allows for the display of both symmetrical and asymmetrical systems. It represents a list format in **blocks**. There are 16 blocks per page, and 64 pages for a six pin system in a two-step progression. Each page has 64 combinations. Thus, there are 64 x 64, or 4,096 distinct theoretical combinations.

The chart below shows all 64 change key combinations for the AA master key, page 030307. In this example, AA would be one of 64

available master key combinations, because the KBA (shown in section **11_5.8.3**) provides for a division of the key wherein three positions are reserved for the master key and three for the change key.

In the example, note that the first three progressives **(**F,E,D if the sequence of progression (SOP) is F,E,D,C,B,A**)** are all **030.** That is because master key AA is 030 + the progressives C,B,A. A table can illustrate how F,E,D are progressed against C,B,A. Color coding is consistent with the chart in section **11_5.8.3.** Remember, C and B are always progressed against column A.

0	3	0	C 1	B 1	A 1
			C 2	B 2	A 2
			C 3	B 3	A 3
			C 4	B 4	A 4
F	**E**	**D**	**C**	**B**	**A**

C,B,A represent a total of 64 change keys for each master key (F,E,D). In the example above, the master key AA would be progressed in odometer format. Each group of four change keys represents one block, as shown in the standard progression format chart below. The first two blocks are illustrated and color coded below.

030 C1 B1 A1
030 C1 B1 A2
030 C1 B1 A3
030 C1 B1 A4

030 C1 B2 A1
030 C1 B2 A2
030 C1 B2 A3
030 C1 B2 A4

MT SYSTEMS SECURITY SERVICE, INC.
Format: __List X Standard __Matrix
Progression: __One-Step X Two Step

SYSTEM #: USD-7
LEAD of _____

Expansion Spec: 1-12-40

Shallow/Deep: 0-9

MACS: 7
KEYWAY ID: SCHLAGE 923C
Key Division: MK | MK | MK | CK | CK | CK

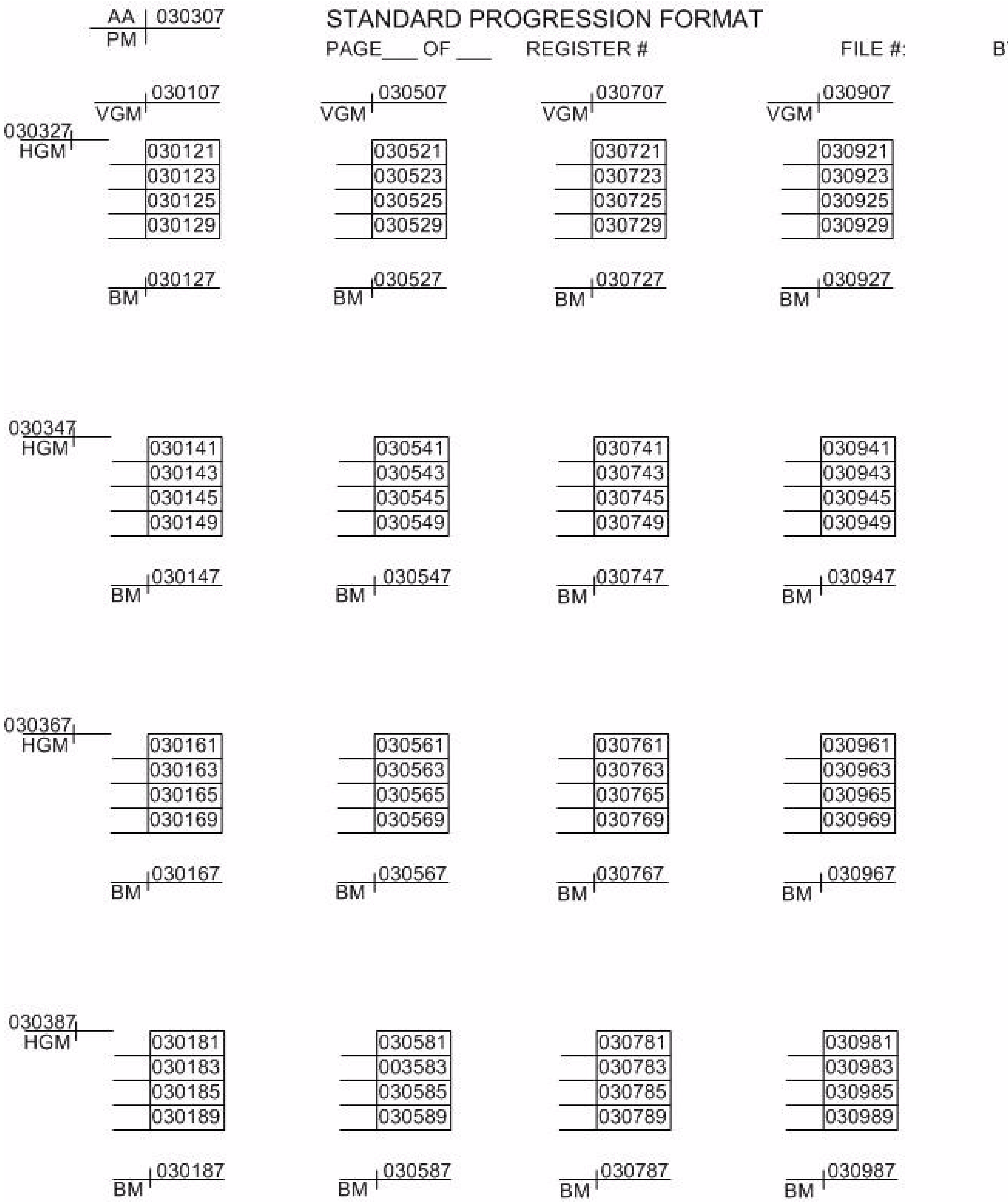
TMK	2	5	8	3	0	7
	0	1	0	1	2	1
	4	3	2	5	4	3
	6	7	4	7	6	5
	8	9	6	9	8	9
SOP	F	E	D	C	B	A

File Ref: 0124 Written By: MWT Date: 1 / 12 / 04

HOOK BLANKS: X OEM __Other

Stamp Keys: NO Depth/Space: STD

NOTES:


AA 030307
PM
STANDARD PROGRESSION FORMAT
PAGE___ OF ___ REGISTER # FILE #: B
VGM 030107
VGM 030507
VGM 030707
VGM 030907
030327 HGM
030121
030123
030125
030129
030521
030523
030525
030529
030721
030723
030725
030729
030921
030923
030925
030929
BM 030127
BM 030527
BM 030727
BM 030927
030347 HGM
030141
030143
030145
030149
030541
030543
030545
030549
030741
030743
030745
030749
030941
030943
030945
030949
BM 030147
BM 030547
BM 030747
BM 030947
030367 HGM
030161
030163
030165
030169
030561
030563
030565
030569
030761
030763
030765
030769
030961
030963
030965
030969
BM 030167
BM 030567
BM 030767
BM 030967
030387 HGM
030181
030183
030185
030189
030581
003583
030585
030589
030781
030783
030785
030789
030981
030983
030985
030989
BM 030187
BM 030587
BM 030787
BM 030987

Note that the horizontal and vertical group masters, row masters, block masters and page masters are all intermediate master keys (composites of TMK and MK values).

11_5.8.3 Matrix Format

The matrix format is the most sophisticated and efficient means for writing a progression list and can be used for both total position progression and rotating constant systems. It provides a means to cross reference and correlate information in an organized and abbreviated format and relies upon the fact that certain progression data in both rotating constant and total position progression is not repeated. As can be seen in the chart below, matrix can store and display the data for 64 pages (six-pin lock) on one printout page. The listing is ideal for symmetrical expansion specifications but requires a separate keying schedule. The technique was developed by Billy Edwards while employed by Medeco and has become the standard method for manufacturers to document information about a master key system.

In order to fully appreciate how to write a system in matrix format, the reader must understand the following concepts:

- **How theoretical combinations are derived;**
- **Split pin master key theory;**
- **Key division;**
- **Progression techniques;**
- **Relationship between the change key, master key, and top level master key;**
- **Constant values that exist in any master key system. In the progression method, there is certain data that remains the same for each portion of the divided key.**

Certain rules apply to the matrix system. A review of these prior to our discussion should prove helpful.

- **Progression of a KBA follows a predefined format based upon certain columns remaining constant in relation to other columns, in part resulting from the division of the key;**
- **The matrix has two components: the master key portion and the change key portion;**
- **The method of progression once set is constant and does not change;**
- **The key is divided into two segments: MK and CK in order to**

derive combinations for each;

- **Total theoretical combinations within any master key system are derived by adding the two key division segments together;**
- **Each master key is a composite of the MK portion of the KBA and the remaining values of the TMK;**
- **Each change key is a composite of the MK and CK portions of the KBA;**
- **Progression of columns for each portion of the key division is computed from right to left, or the least significant digit to the most significant digit;**
- **Every group of change key permutations is the same for each individual master key progression;**
- **The master key combinations are derived separately from those of the change key, based upon the division of the KBA;**
- **The data in columns I,II,III and in IV,V,VI represent the two divisions of the KBA in a six pin lock with a key division of 3:3;**
- **The data in columns I,II and IV,V represent all of the possible combinations for the progression of two columns of the KBA division;**
- **The data in columns III and VI represent the least significant digit of each division of the KBA, and are progressed against I,II and IV,V respectively;**

In the matrix system, each box correlates to a bitting combination. Think of a highway atlas that displays a list of cities and the mileage that can be calculated between each of these cities. A vertical and horizontal column of city names is provided with the mileages within all of the boxes that are intersected by the names. Mileage is displayed by drawing imaginary vertical and horizontal lines to an intersecting point. The matrix format for determining combinations works in essentially the same fashion.

As can be seen in the matrix below, there are three primary components: the KBA, the master key (MK) matrix, and the change key (CK) matrix. The KBA defines the top level master key, and identifies by Roman numeral each of the chambers. Roman numerals are utilized to avoid confusion with any other numbers. There are two matrix chart templates each providing 64 "addresses" or individual boxes in a 16 x 4 configuration. The matrix that is shown can display a total of 4,096 combinations for a six pin lock, two-step progression, four progressives per position. So, what does all of this mean?

Let us examine each individual component of our matrix to understand how each relates to the others. Note that the KBA reflects that the key is divided 3:3; positions **I, II, III** are for the master key in this example and **IV, V, VI** for the change key. This is the same procedure as for the list or standard progression format. We have simply identified each of the positions with Roman numerals. Now, look at each matrix. The vertical (X-axis) and horizontal (Y-axis) combine and converge to provide 64 separate positions or addresses. Recall that a two-step progression of four depths in three columns is equal to 4 x 4 x 4, or 64 combinations. Now recall that the table in section **11_5.8.2** in standard progression format shows how columns **C,B** are progressed against **A** for the change key. This would also hold true for **F,E** against **D** for the master key. This is further denoted by color coding for ease of understanding. In our matrix, each of the 64 boxes can be said to have a vertical (or X address) and a horizontal (or Y address). **X+Y will constitute each individual combination.**

Consider how the two matrix tables are displayed below. The legend to the upper left of each table identifies the vertical and horizontal column with Roman numerals. The MK matrix shows that the sixteen vertical rows represent **I,II** and the four horizontal columns represent **III**. The corresponding numbers that run vertical are "matrixed" or correlated against the numbers in the horizontal columns. The numbers for all columns have been color coded to show their origin.

In the MK matrix, columns **I,II** are combined with **III** to provide a total of 64 combinations. It can be easily seen that the first two columns of the KBA are progressed against the third column. In our example, MK combination **010** is the first to be generated. In the matrix, **"01"** is the first vertical number for the "X" portion of the address, and "0" is the first number for the "Y" portion of the address. In our example, the master key AA has been associated with X-Y address 010. In like fashion, the change key matrix plots **IV,V** against **VI** to represent the 64 possible change keys by progressing **IV,V,VI**. The table shows that the first change key from the KBA would be 121, or **IV,V** progressed against **VI** (which is exactly what is displayed in the CK matrix). In our example, we have assigned "1" to address 129. Remember that the 64 change key combinations are always repeated for **each** master key combination. So, when we combine the MK matrix with the CK matrix, we have 4,096 combinations ((4 x 4 x 4) x (4 x 4 x 4))that are available and can be easily identified. The

color-coded key diagram graphically displays the origin of each bitting position.

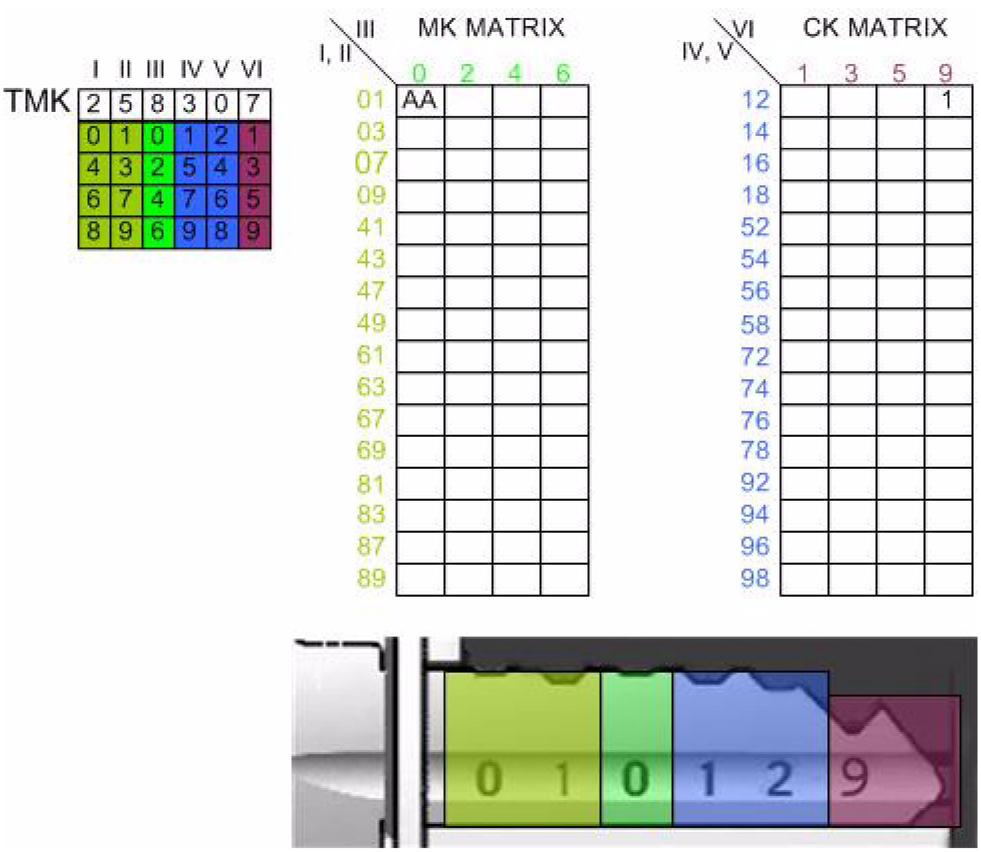


Figure LSS+1133 Division of the key shown in matrix format.

Individual master keys and change keys are selected in random fashion from each matrix, except for cross-keys, which are always chosen first. In the case of cross-keys, if they are not planned and identified initially it may be impossible to do so later. In the matrix format, not all bittings must be defined.

11_5.9 Reverse Engineering a Master Key System

A master key system can be reverse engineered to determine its structure, the relationship between keys, the levels of keying, and to reconstruct the bitting list. This can be done overtly or covertly, depending upon requirements. Reverse engineering may be

required to be accomplished by a locksmith to perform maintenance, especially on a system that has not been documented previously. Covert operations or a crime scene investigation may require the system to be analyzed for a variety of reasons. In either event, sample keys are examined with a decoding instrument such as a key gauge or micrometer. Further initial information may be available from symbol, number, or letter markings on keys to provide insight into how the system was defined.

The following steps should be followed to reverse engineer a master key system:

- **Measure as many keys as possible and list the bittings for each key:** This will allow us to deduce the following information:
    - division of the key
    - number of chamber or positions and how many have been progressed
    - one or two-step progression
    - potential for key interchange in a one-step system where two step should have been used

- **Scan the list for the method of progression, one position at a time:** Define the common cuts for each position. Determine parity, and whether it has been maintained between change keys;

- **Determine the method of progression**

- **Determine the levels of keying:** are all of the levels symmetrical. Are there the same number of change keys under each master key? Are the change keys actually incidental master keys?

- **Determine if each level of keying has the same number of master pins per cylinder.**
Do all change keys differ from the TMK in each position? Regardless of the number of levels of keying, there should never be a TMK depth utilized in any change key position in a TPP system. If, however, an incidental master key has been decoded, then depths will be shared or common to the TMK. Values may also be the same in an RC or PPP system;

- **Reconstruct the KBA:** What are the cut possibilities for each position? Make an educated guess whether the system is a rotating constant or total position progression. If a TPP system, then

cuts for the TMK can be eliminated.

- **Use the KBA to define a matrix.**

Based upon the theories of total position progression and rotating constant systems, it is possible to extrapolate and decode the TMK in these systems with little skill or previous training. A detailed examination of the process is presented in **chapter 31.** A white paper has also been written on this subject by **Matt Blaze**, (AT&T Labs Research). Appreciation is also expressed to Harry Sher, Billy Edwards, and Brian Chan for their assistance.

11_5.10 Master Ring and Interchangeable Core Systems

11_5.10.1 Interchangeable Core Systems and Master Keying

There are different configurations for IC locks, both large and small format, the discussion of which is outside the scope of this text. Differences relate to control lug design, control key interaction with operating shear line, pin stack dimensions and other specifications.

There are two types of interchangeable core locks: those that are not available for conventional hardware configurations, and those that can be integrated with conventional systems. In some situations, it may not be possible to add IC into an existing system. There are limitations within IC systems within the master key environment as well as security implications when using IC. These and certain design rules are outlined below.

- **IC systems have limitations with regard to the number of available combinations and those that may be utilized for master and control keys;**
- **The expansion of IC systems may be limited;**
- **If interchangeable cores are utilized throughout a system exclusively, then severe keying limitations may result;**
- **There may be key interchange and control key issues;**

Many years ago, Best utilized the TMK as the control key by withdrawing it one chamber position. This created significant

keying problems;

- **In all IC systems, the control and TMK should be different in all positions;**
- **Parity should be maintained between the TMK and control key; Within the Best A3 and A4 systems, parity does not apply. The Best A2 system requires two-step progression;**
- **If parity is not maintained, then there is no assurance that the change key will not inadvertently act as a control key. The lack of parity can also lead to difficult keying situations because the build-up pin may not exist. The control key in such an event becomes a change key. In addition, the core may be removed with a change key by pulling it out of the lock slightly;**
- **If parity is maintained, then a problem may also occur that can allow the TMK for one system to be used as the control key for another. A detailed discussion is beyond the scope of this work.**

11_5.10.2 Master Rings (MR)

Corbin is still producing locks with master ring technology, although the demand is almost exclusively limited to maintenance of installed systems. The master ring offers significant advantages over conventional single shear line systems of up to four keying levels, but somehow has been forgotten as other designs became popular for master keying. There are a number of security advantages that this hundred-year-old technology offers that have become relevant since recent disclosures regarding the compromise of master key systems through the extrapolation of top level master keys from change keys. Detailed information has therefore been included in **LSS+**.

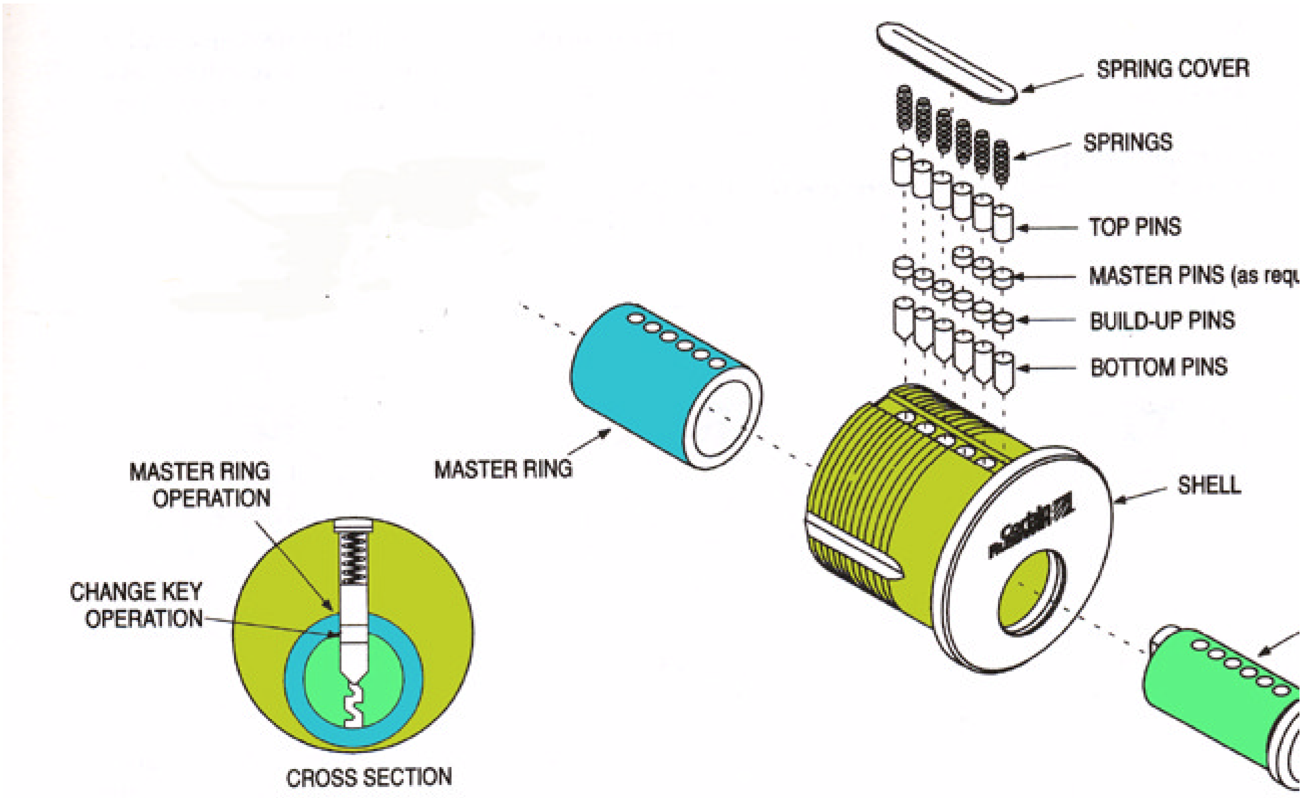
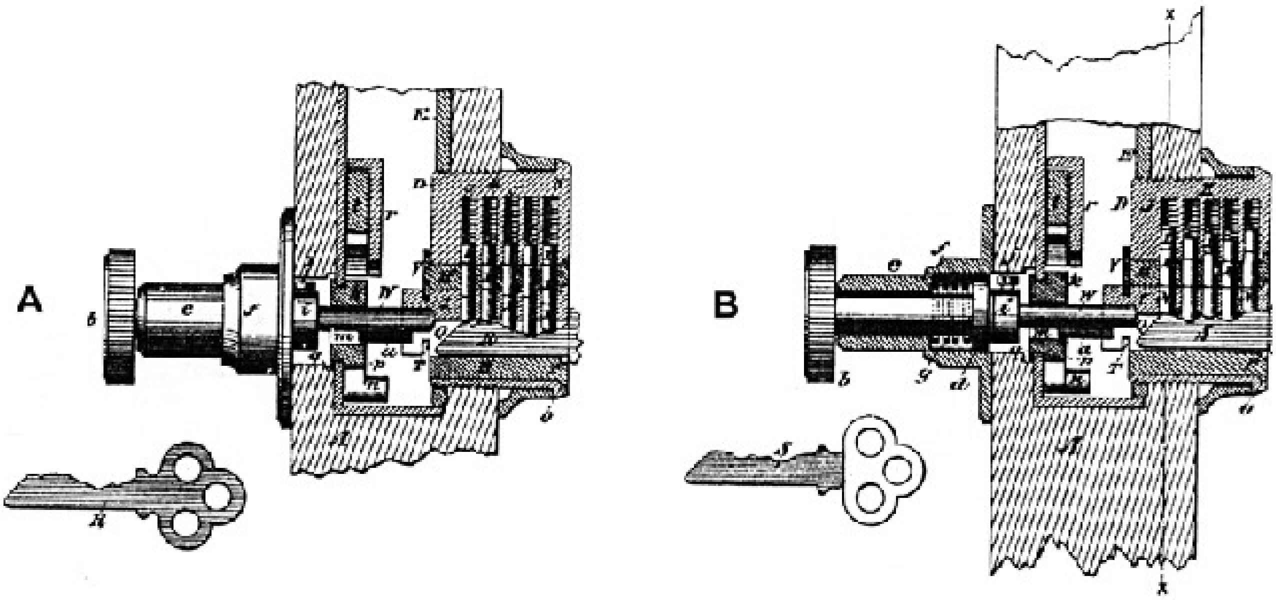


Figure LSS+1134 Diagram of a master ring cylinder, courtesy of Corbin Russwin.

The concept of the master ring was invented by Edward O'Keefe, a New York City locksmith, and disclosed in his patent, granted in 1889 (**414720(139)**). The patent rights were subsequently transferred to P&F Corbin. Corbin and other manufacturers have introduced the concept of a **master ring** or **sleeve**, as an effective means to eliminate cross-keying while maintaining high pick resistance. A round metal sleeve or jacket fits over the plug, creating a second shear line. Physically, the plug is inserted into the sleeve; then the plug-sleeve assembly is inserted into the shell of the lock. Cross-keys and incidental master keys cannot occur in the master ring locks unless an extra master pin is inserted in the pin stack below the ring shear line. Two distinct physical shear lines are created, thus preventing a composite of lower pins and master pins from splitting at **one** physical shear line.



It may be helpful to compare the master ring to the interchangeable core lock, first patented by Best (**3206958(140), 3206959(141), 3603123(142), 4386510(143), 4444034(144)**). Both have two shear lines. In the ICores, the plug shear line is also called the **operating shear line**. Change keys and master keys always work at the plug shear line in these locks. The control key works at the **control shear line** to permit core exchange. It can be master keyed at the plug shear line and also at the control shear line (for control master keys).

In the **MR**, there is no control key. All change keys operate at the **plug shear line** level; all **master keys** operate at the **ring shear line**. In operation, the change key will lift its corresponding set of tumblers to the level of the plug. The master key will lift the tumblers and master pins to the level of the master sleeve that rotates around the plug. When the change key is used, the master ring remains fixed with the shell. When the master key is used, **both the plug and master sleeve rotate** because the plug shear line is blocked. The only theoretical difference in shear lines between ICore locks and **MR** locks is the build-up dimension between plug and the second shear line, and the function of the second shear line. In the IC, it is to remove the core; in the master ring locks, it is to prevent the creation of incidental master keys or composite pin combinations.

The tumblers cannot be split as in a conventional keying

arrangement **between** the plug shear line and the master sleeve shear line. In other words, the plug **and** the master sleeve can never rotate simultaneously; thus, the possibility of creating incidental master keys is eliminated.

11_5.10.3 Differences Between Conventional and Split Ring Master Keying

There are significant differences between setting up a conventional cylinder and one with a master ring within a master key system. These distinctions are summarized below.

- **Incidental master keys, as a composite combination between change and master key, do not exist in the master ring environment;**
- **Progression of bittings is entirely different for a dual shear line system;**
- **Master ring cylinders are more flexible for keying;**
- **The equivalent of approximately one added chamber is achieved with master ring in generating theoretical combinations. Thus, a six pin master ring lock is roughly equivalent to a seven pin conventional cylinder;**
- **Every chamber in the master ring lock has two shear lines;**
- **The plug shear line is usually reserved exclusively for the change key;**
- **The ring shear line is utilized for all master keying levels;**
- **There are few constraints in the traditional relationship between master key and change key;**
- **After the introduction of System 70 (in 1970), fewer new master ring keying systems have been installed;**
- **Master ring locks are particularly well suited for construction and selective master keying;**
- **Master ring reduces the problem of cross-keying;**
- **The number of levels of keying does not pose any significant restrictions for the master ring lock;**
- **There are generally a far greater number of change keys available in the master ring system than with conventional systems;**
- **Not all Corbin Russwin hardware can support master ring locks, due to the larger diameter cylinder;**
- **Additional planning is required to integrate single shear line**

cylinders into a master ring system, and it is rarely possible to do so after the fact;

- **Master ring cylinders are generally keyed for up to four levels (GGMK);**
- **Depending upon keying level, double pinning may be employed at the ring shear line if the bitting values between MK, GMK, or GGMK are different from each other;**
- **TMK values can be safely shared with change keys;**
- **Change key combinations can be randomly assigned to any master key with none of the restrictions imposed in a conventional system;**
- **Parity rotation can be used to increase system security and the number of useable combinations;**
- **The top pin is always .171";**
There are never any master pins at the plug shear line;
- **Bottom pins will always be equal to the change key bitting values;**
- **A master ring lock can be more complex to pin for three or more levels of keying because of the requirement to introduce added master pins;**
- **A ring lock that is keyed to three more levels can be easier to pick than a conventional cylinder;**
- **Key interchange and cross-keying can occur if added master pins are inserted at the ring shear line;**

11_5.10.4 Differences in the KBA for Master Ring Locks

There are significant differences in the logic employed in deriving combinations for the master ring lock in comparison to the conventional single shear line cylinder. Essentially, traditional progression techniques utilizing a KBA are employed to generate master key and change key combinations, but there is no required linkage through the division of the key between the two sets of combinations. Virtually any change key combination can be associated with any master key. Additionally, almost all of the available depths within a cylinder can be utilized in the derivation of change keys. This includes the depths that are reserved to the TMK; a vast departure from the progression methodology employed in conventional master keying.

The key bitting array for the master ring lock contains two separate progression matrices: master key for generating combinations at the ring shear line, and change key for producing combinations as the plug shear line. These two areas must be mutually exclusive to prevent key interchange. This can be accomplished by changing one bitting in one position.

In practice, master key combinations are derived by progressing the master key portion of the KBA. The key bitting array shown in the first illustration (section **11_5.10.4.1**) maintains parity during progression. We shall compare this KBA with a conventional cylinder to highlight the differences in logic.

The TMK combination is shown at the top of the array. Note that the first position (2) is held constant for all master keys. In the TPP method, we derive a total of 4 x 4 x 4 x 4 x 4 = 1,024 theoretical MK combinations. The change key is derived from the bottom portion of the KBA, and can produce 5 x 5 x 5 x 5 x 5 x 4 = 12,500 change key combinations, in contrast with a maximum of 4,096 change keys from a conventional lock with one shear line. Note that all of the progressives with the **exception** of (2) from the TMK are utilized for generating change keys. This will prevent key interchange and any master key from operating at the plug shear line, and any change key operating at the ring shear line. A true master ring system can produce an expansion specification of 1-1,024-12,500.

11_5.10.4.1 KBA with Parity Maintained


MASTER RING KEY BITTING ARRAY
CONSTANT POLARITY

TMK	2	5	8	3	0	7
MASTER KEYS ONLY	2	1	0	1	2	1
		3	2	5	4	3
		7	4	7	6	5
		9	6	9	8	7
CHANGE KEYS ONLY	0	1	0	1	0	1
	4	3	2	3	2	3
	6	5	4	5	4	5
	8	7	6	7	6	7
		9	8	9	8	9

The first group of eight master keys using the portion of the KBA dedicated to their progression would produce the following combinations:

210121	**210141**
210123	**210143**
210125	**210145**
210127	**210147**

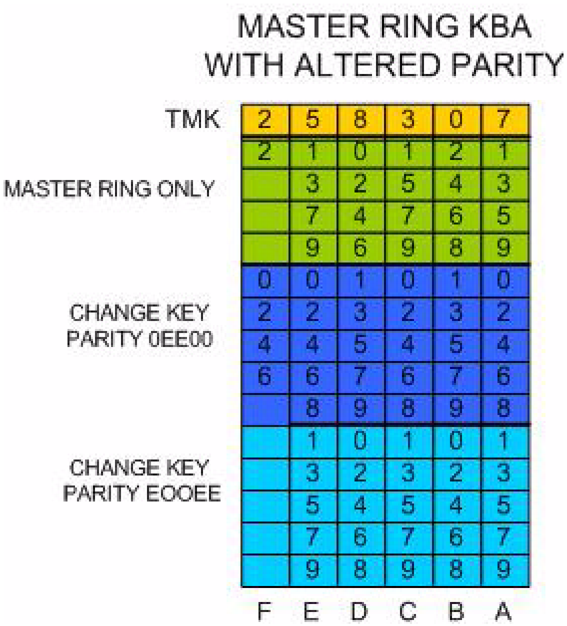
Likewise, the first ten change keys in sequence could be:

010101	**010121**
010103	**010123**
010105	**010125**
010107	**010127**
010109	**010129**

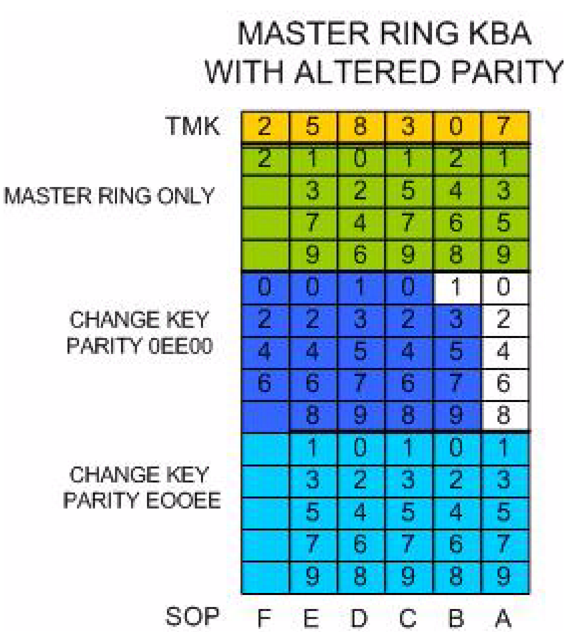
Unlike a conventional system where master keys are, by definition, associated with change keys, any of the master key combinations can be associated with any of the change keys in the master ring system.

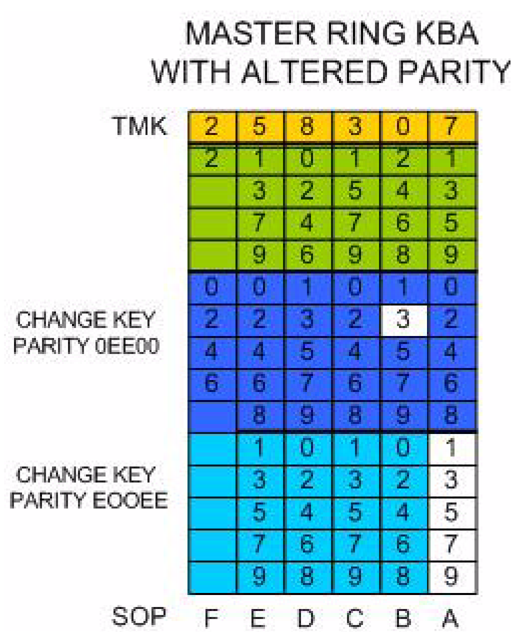
11_5.10.4.2 KBA with Altered Parity

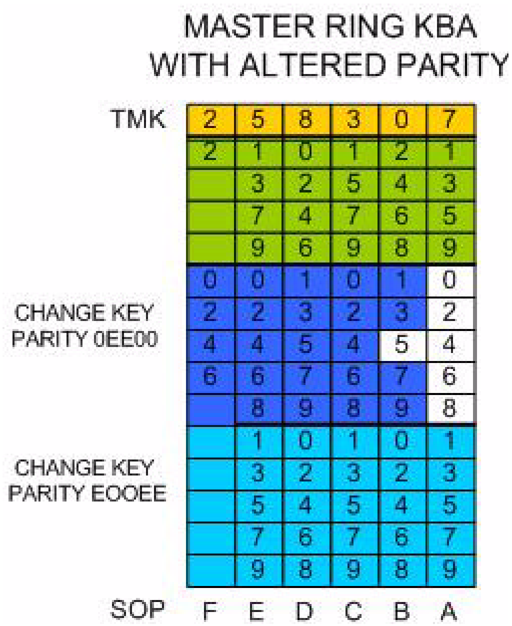
A second method for deriving change key combinations involves the periodic alteration of parity in all but one column during the progression sequence. The technique may be considered as a corollary to rotating constant, but relating to parity. In effect, a **rotating parity** system has been created. In the KBA shown below, the master key portion is identical with that shown in the constant parity model, above. However, there are now two parts to the change key matrix. In order to use parity to employ all progressives, the parity of all previously progressed columns must be changed simultaneously as each new column changes. Although it may appear that key interchange will ultimately occur, the first column (F) keeps this from happening. Remember, one cut can prevent interchange.

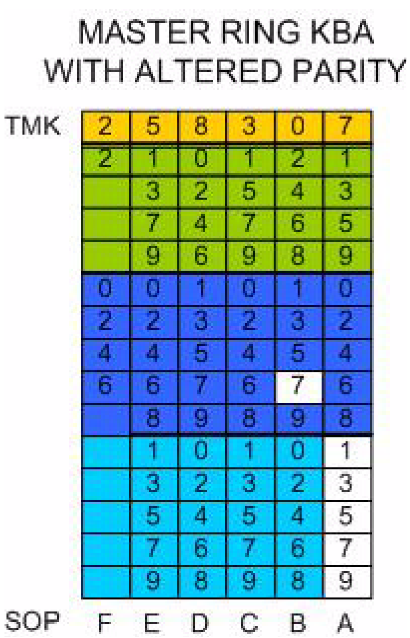


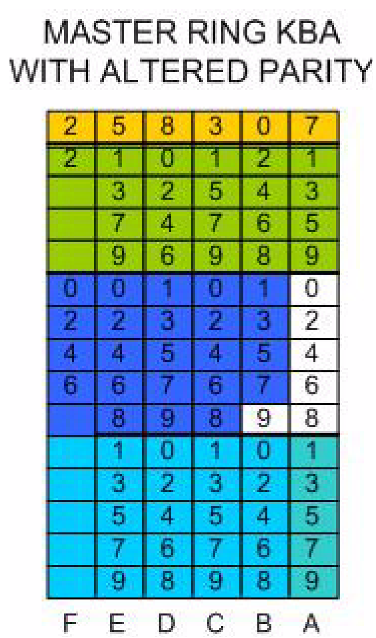
Graphic illustrations of how the KBA is progressed are shown below. In the color-coded tables, each vertical group of progressives is highlighted (white) to show the sequence of progression.



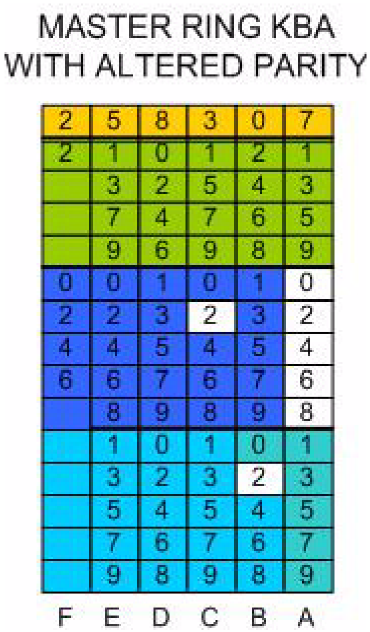


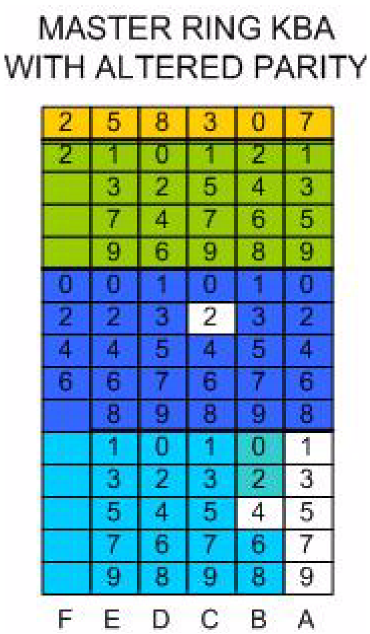

MASTER RING KBA
WITH ALTERED PARITY
TMK
CHANGE KEY
PARITY 0EE00
CHANGE KEY
PARITY EOOEE
SOP
F E D C B A

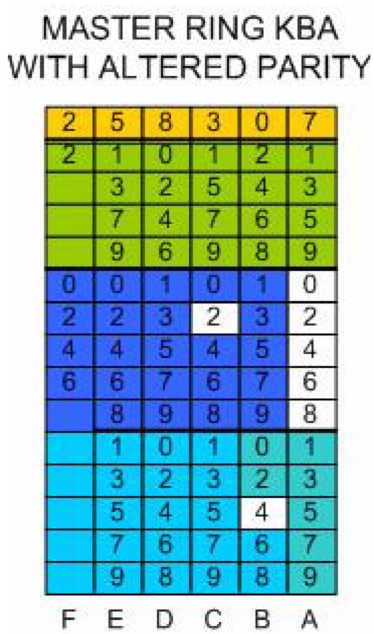

MASTER RING KBA
WITH ALTERED PARITY
TMK
SOP
F E D C B A

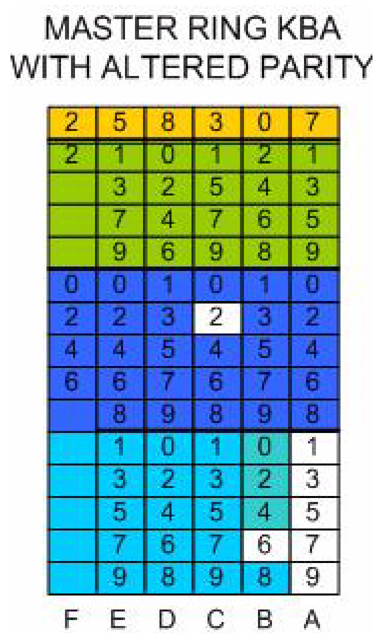

MASTER RING KBA
WITH ALTERED PARITY
F E D C B A


MASTER RING KBA
WITH ALTERED PARITY
F E D C B A


MASTER RING KBA
WITH ALTERED PARITY
F E D C B A


MASTER RING KBA
WITH ALTERED PARITY
F E D C B A


MASTER RING KBA
WITH ALTERED PARITY
F E D C B A


MASTER RING KBA
WITH ALTERED PARITY
F E D C B A

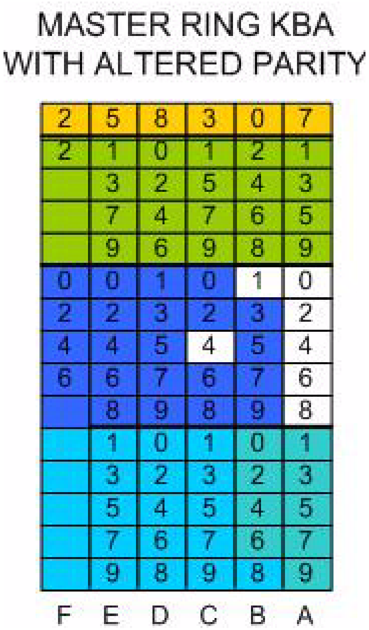
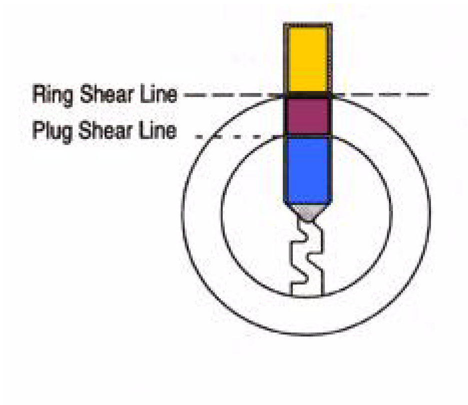


Figure LSS+1135 Master ring charts showing altered parity.

11_5.10.5 Pinning and Decoding Master Ring and Interchangeable Core Locks

LSS204: Brian Chan discussing the pinning of a Best IC lock

Master ring mechanisms have two physical shear lines; they are keyed slightly differently than conventional locks. In contrast, within the ICore there may be several distinct keying levels at the plug shear line, in addition to the control key at the control shear line. The diagrams show the difference in construction between master ring and interchangeable core.



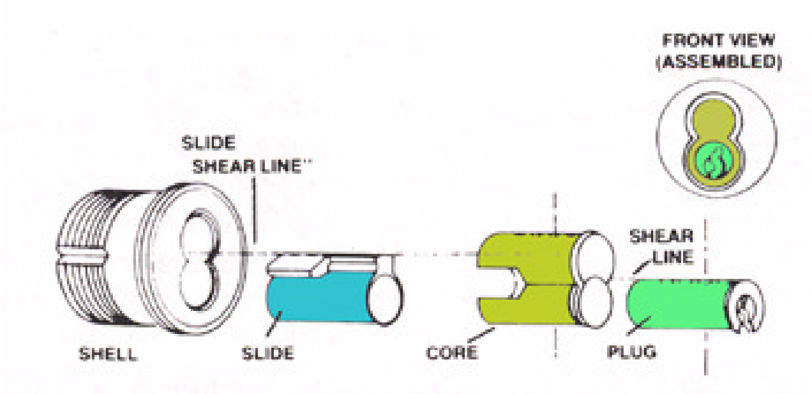


Figure LSS+1136 Both master ring and interchangeable core locks have two distinct shear lines. However, their use is for very different purposes. Courtesy of Corbin Russwin.

11_5.10.5.1 Master Ring Locks

Corbin master ring locks have up to four sets of tumblers in each chamber: top, master pin, build-up, and bottom. All but the top pins will be utilized for master keying. The same length top pin is used in each chamber (.171").

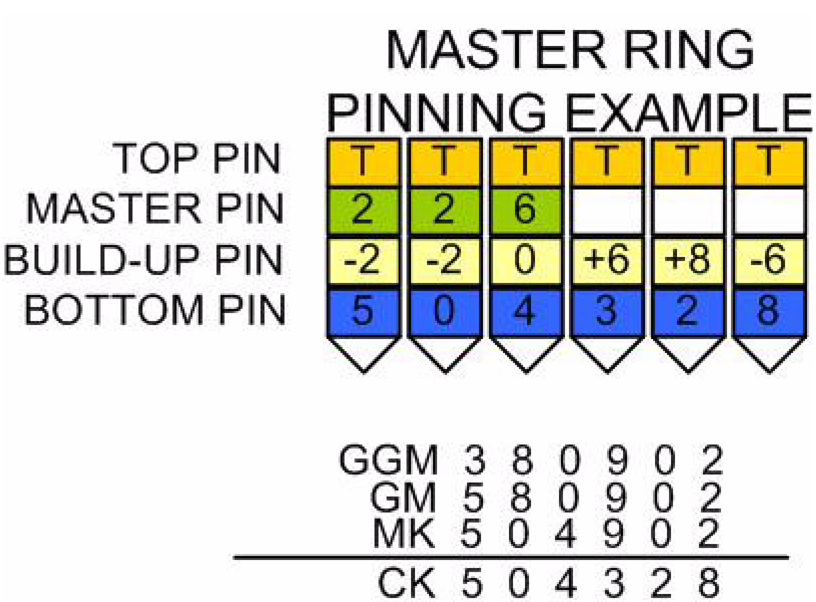
Individual change keys will have corresponding bottom tumblers that are raised to the conventional plug shear line. In order to program the master key, however, the overall length of at least two and sometimes three pins must be considered. The purpose of the build-up pin is to make up the difference in the pin-stack between the bottom pin and master ring. The length will be computed from the change key bitting to the **shallowest** master key bitting in each chamber, assuming the system has three or more keying levels. When more than one master keying level is utilized, master pins are also used to compensate for the

difference in master keying levels.

The Corbin master ring has a thickness of .142" for a .552" plug diameter. Therefore, the effective diameter at the master ring shear line would be .694". Thus, the length of the lower, build-up and master pin for any master key bitting depth must equal the combined diameter of the plug and master ring. The diameter of the ring shear line is equal to ten depths in the pre-System 70 system, and five depths in System 70. It can be seen that the depth increments that are utilized for bottom and master pins are equivalent. If, for example, the first chamber has a bottom pin value of 4, and the value of the master key cut is also four, then (4-4 = 0) the build-up pin length would be 0 (ten depth increments).

Depending upon the change key and master key(s) bitting, the build-up pin will be assigned differing values. The thickness of the master ring is equivalent to a "0" value build-up pin. If the change key bitting depth is **less** (shallower) than the master key, then the build-up pin will have a **positive** value. Conversely, if the change key cut is lower than the master key, then the build-up pin will have a **negative** value.

The following chart illustrates:



In the three examples below, the change key bitting has a value of 3, but the master key depth is 3, 5, and 1. Note how zero,

negative, or positive values are inserted for build-up pins to bring the master key to the ring shear line.

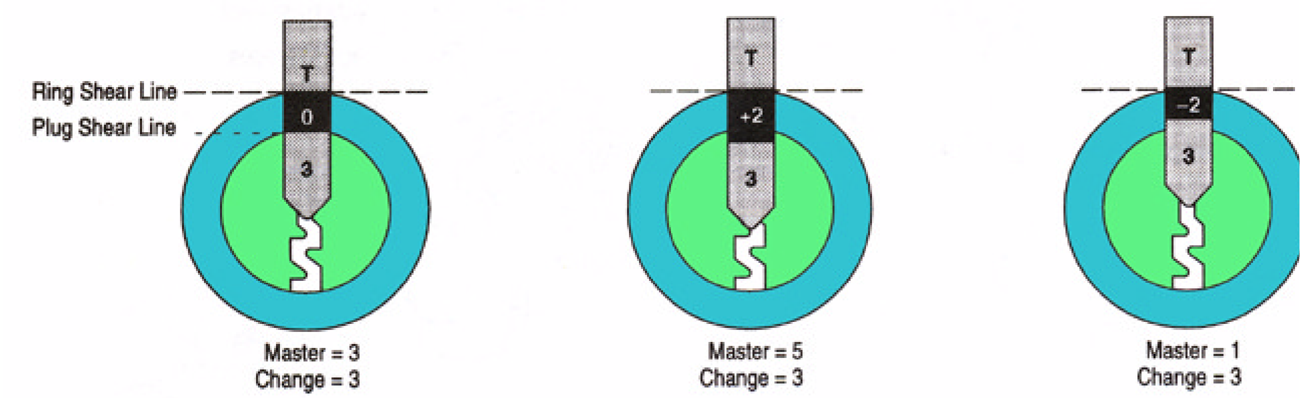


Figure LSS+1137, Build-up pins are required in order to add or subtract values in order to raise pins to the ring shear line. Courtesy of Corbin Russwin.

11_5.10.5.2 Decoding ICore Locks

This section deals with the decoding of ICore locks relating to three issues: extrapolation of the TMK within a master key system, extrapolation of the control master key, and decoding the bitting value of the pins that are operating at the control shear line. As previously noted, the ICore and master ring locks are similar in that they both have a second physical shear line. The function of the second shear line is, however, quite different for each lock. The master ring lock utilizes its equivalent of the control shear line for all master keying levels, thereby eliminating the link between keying levels and the ability to decode the pin stack in the context of our current discussion. In the ICore lock, the control shear line allows the removal of the assembly that contains all locking components that are directly controlled by the operating and control key.

11_5.10.5.2.1 Decoding the TMK

Within the interchangeable core environment, all keying levels will be pinned at the operating shear line. In this respect, the lock is no different to decode than a conventional cylinder. Once a change key is obtained, the TMK can be derived by sampling each position with each bitting value that can be utilized within the keying system. The presence of the control shear line is irrelevant to the process and it cannot be decoded, either intentionally or by error. It should be noted that there is no

correlation between the top master key and the control key. In fact, knowing the code for the control key will not yield any information regarding any master key. Nor can the control key be utilized to extrapolate the TMK, intermediate master keys, or change key.

11_5.10.5.2.2 Decoding the Control Shear Line

The control key bitting values can be determined easily but require that the lock be disassembled so that the top pin for each chamber can be measured. We shall utilize a Best A2 system for our examples. The decoding process for the control key will work in any interchangeable core lock if the following conditions are met:

- **The combined pin stack height must be constant for all chambers. In the case of the A2, it is 23; for the A3 it is 16, and for the A4 it is 14;**
- **The overall pin stack length within each chamber in the target lock must not deviate from the factory standard;**
- **The number of depth increments between the operating and control shear line must be known;**

The formula to compute the pin lengths in the A2 is shown below. Formulas for the A3 and A4 would vary according to the overall pin stack height requirements for each core. There is a fixed relationship between the control and operating key, based upon physical spacing between the operating and control shear lines. For Best locks, it is possible to decode the control key by knowing the overall pin stack height and the length of the top pin.

As with the Corbin master ring, there are a total of four pin types: **top, control build-up, master, and bottom pin**. All master key levels will have their shear lines at the plug level (operating shear line) because the lock is keyed as a conventional cylinder. In determining the pinning for the control key, the total pin stack height must be known.

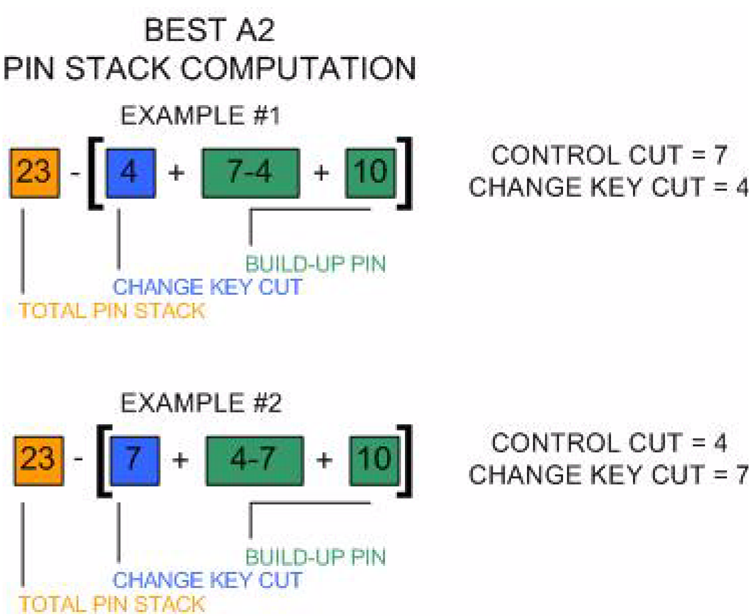


In the Best A2 removeable core lock, the total pin stack height (denoted by red to blue lines) is 23 increments. The number of increments between the operating and control shear line is 10. In order to compute the length of the control pin, the top pin is removed and measured. Its length plus 10 more increments (the distance between the operating and control shear lines), is subtracted from 23. The remainder is the value of the control pin. Two hypothetical examples show how the values of each pin are computed when pinning a lock. Note: master pins have not been shown in the examples, for clarity. However, their value would be added to the change key cut in determining the length of the control pin.

In example 1, we desire the change key to have a value of (4) and the control key to have a value of (7). In this case, there will be three pins within the chamber: the bottom pin, build up pin, and top pin. We know that the total pin stack length must be 23 for the A2. The values of each pin are denoted by colored blocks. The bottom pin, shown in blue, is equal to 4. The build up pin is the difference between the control cut value (7) and the bottom pin value of (4). This number, (3) comprises the number of depth increments that would have to be added to reach the operating shear line. In other words, if the control key is inserted with only the bottom pin, there would be a difference of (3) to reach the operating shear line. But, we are not opening the lock at the operating shear line with the control key. We need to be at the **control shear line**, so we must add another ten depth increments in order to utilize the control key at the proper shear line.

Thus, the formula is the total of the green blocks, or (13) for the build up pin.

In example 2, it is the same formula, but note that because the change key is deeper than the control key, we have to deal with a negative number. In this case, the bottom pin is (7). The build up pin is also (7) because 4-7 = -3. Add -3 to +10 = 7. Remember, we are computing the length of bottom and build up pins, which are cumulative, toward the control shear line. With only a bottom pin in the plug, the control key (4) would cause the bottom pin to protrude into the shell by three depth increments. The difference between the operating and control shear line is ten. Therefore, we can only have a build up pin with a value of (7) to make up the difference to the control shear line (3+7). In both examples, the total value of bottom and build up pins are subtracted from 23 to determine the top pin.



There are three versions of the Best ICore: A2, A3, and A4. The chart shows the number of depth increments, depth coding, number of pins, and total pin stack height for each lock.

BEST IC LOCKS			
MODEL	**DEPTHS**	**INCREMENT**	**PIN STACKCODE**
A2	10	.0125"	230-9
A3	7	.018"	160-6
A4	6	.021"	140-5

11_5.10.5.2.3 Decoding the Control Shear Line Master key

In certain applications, a series of removeable core locks may be master keyed at the control key level. For example a chain of restaurants in Chicago may require that one regional manager be able to remove the core from any restaurant in the city, and also allow the local manager to change the lock for his particular restaurant. In such an instance, an extra master pin would be placed between the operating and control shear line. The master control key can be extrapolated in the same manner as the TMK by using the local control key (equivalent to the change key in a conventional cylinder) to probe each pin stack. The only difference is that the control shear line is utilized rather than the operating shear line to derive the master control key code.

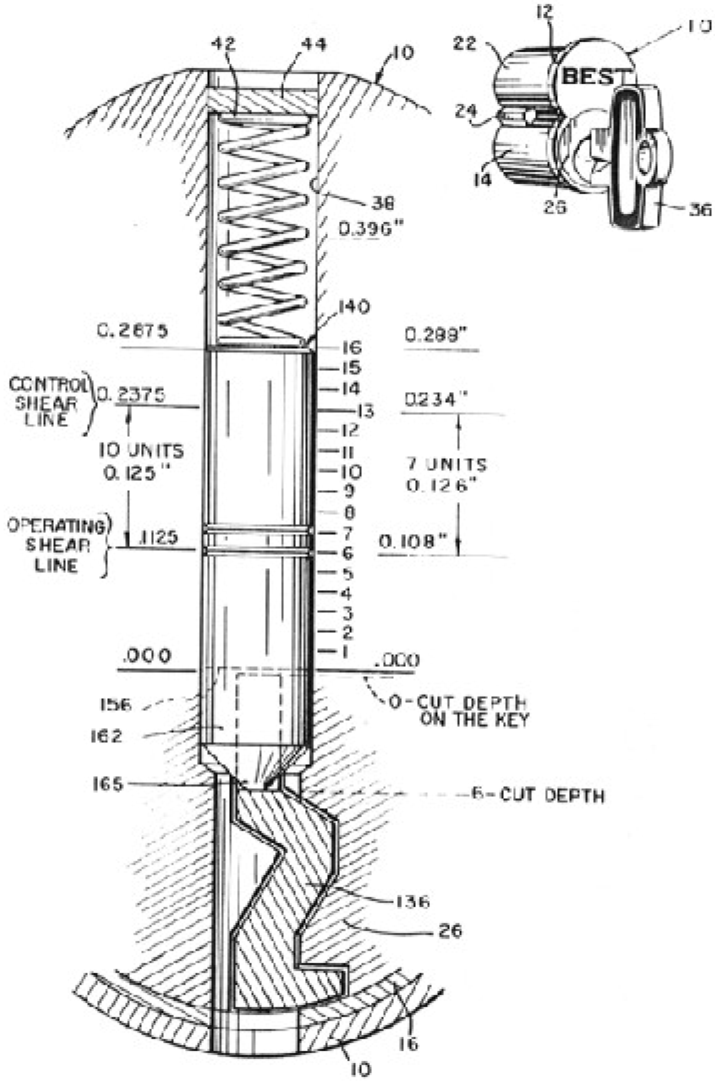
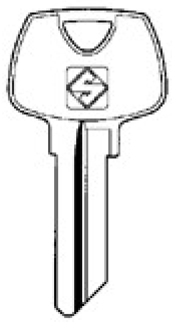


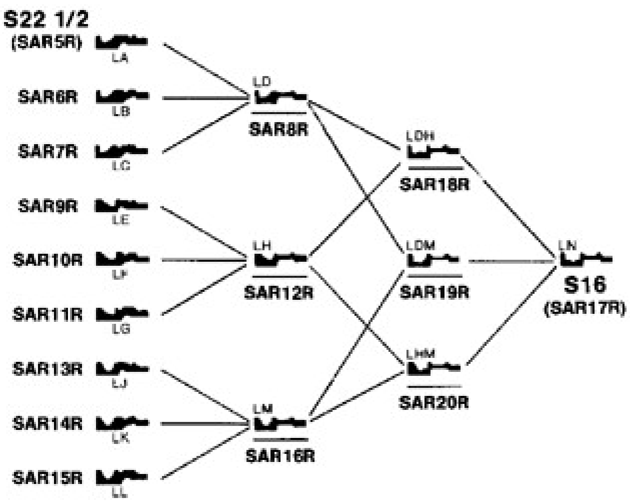
Figure LSS+1138 Best lock, model A2 and A3. This diagram shows the relationship between the operating and control shear line. In the A2, there are ten depth increments between the two shear lines; in the A3 there are seven increments between operating and control shear lines.

11_6.0 Sectional Keyways and Multiplex Keying Systems

Many manufacturers offer the capability for complex keying, through the use of sectional keyways. By definition, a **multiplex key system** is comprised of a series of different keyway subsections that may be used to expand a master key system. This is to allow the repetition of individual key combinations within

different keyway sections. Shown below and in the linked graphic is a Sargent **LN** family of keyways. The graphic representation shows each individual keyway as a grid of different keyway wards, indicated by individual color patterns.





Keyways are designed so that change keys for one subsection may not enter other sectional keyways. The effect of these systems is to greatly increase the number of possible differs without added key interchange.

Multiplex key systems may be configured in many ways. In the accompanying illustration, the milling for keyways **LA, LB, LC, LE, LF, LG, LJ, LK, LL** are all different. Key **LA,** for example, cannot enter keyway **LB, LC,** or any other keyway within the system. In like fashion, **LB** cannot enter **LA, LC, LE; LC** cannot enter **LA, LB, or LE;** and **LE** cannot enter **LA, LB, LC.** Thus, individual key code 75126 could be repeated in separate locks located in different areas of a building using keyways **LA, LB, LC.** In this scheme, the key for keyway **LA** would only open a lock with the **LA** keyway. Although keys **LB, LC,** and **LF,** for example, had the same tumbler bitting as **LA,** they would not open the lock with keyway **LA** because the keys would be prevented from entering the plug.

Key **LD** can be milled to fit keyways **LA, LB, or LC.** Likewise, key **LH** can be milled to enter keyways **LE, LF,** or **LG.** At the next level, **LDH** can access all keyways for **LD** and **LH; LDM** can access **LD** and **LM,** and **LMM** can enter all **LM** and **LH** subsets. The top section, **LN** can access all keyways within this grouping. Note that as the hierarchy of keyways is built, the letter

designations become a composite of lower sections.

Many lock manufacturers offer **families** of sectional keyways that can restrict entrance of all but the proper keys into subsections. Three or more levels of control may be available in certain keyway families. A potential problem with such systems is compromise using multi-sectional key blanks rather than sectional blanks. The difficulty occurs during key duplicating, especially at the retail level. Use of the wrong blank can result in unauthorized access to keyways.

If a multiplex keying system is encountered during a burglary or theft investigation, it may be prudent to determine which sectional key blanks are available locally in order to identify possible system compromise. Multiplex keying systems are ideally suited to large office complexes that are comprised of many buildings in different locations. Security and organizational control can be maintained with such systems.

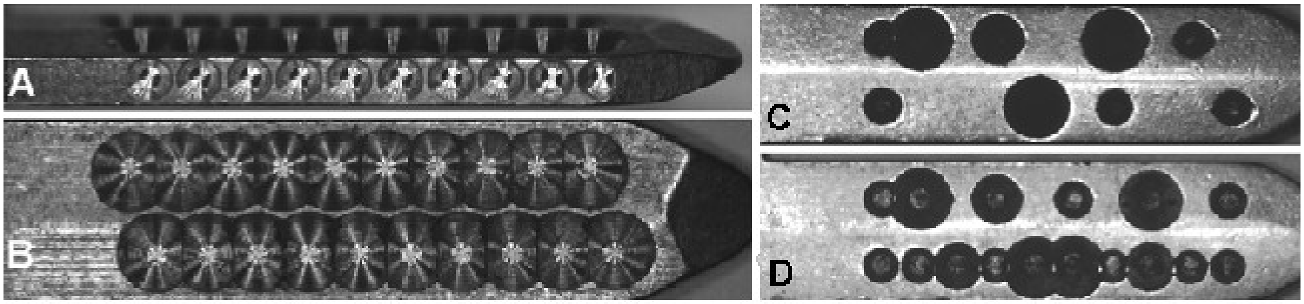
11_6.1 Special Keyway and other Configurations

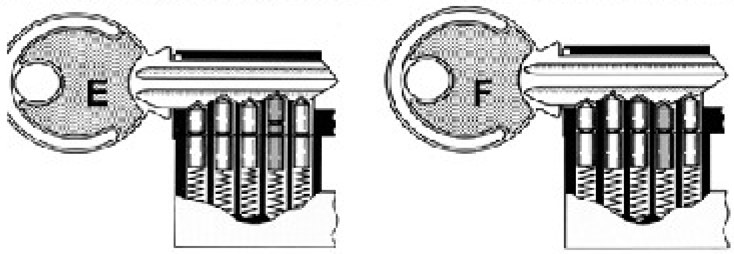
Some high-security lock manufactures incorporate special designs within their cylinders to accommodate very large master key system installations, without compromise in security. EVVA is such a company. They produce a cylinder, described in detail in **Chapter 19**, that utilizes pin tumblers in combination with eight rotating magnetic discs. In addition, their unique keyway design allows for 32,000 different theoretical keyways.

The combination of magnets, pins, and keyways allows extremely large keying systems to be implemented. Thus, a major hospital complex in Vienna, Austria required 40,000 lock cylinders with 257 master key subgroups. Using the magnetic cylinder, EVVA was able to meet these requirements without difficulty. Few other lock manufacturers could claim to do so.

11_6.2 Dimple Locks

Cylinders utilizing multi-surface keys, such as the Keso, Kaba, and DOM pin tumbler locks, can offer complex keying through the placement of tumblers within different pin chambers. This is called **positional master keying**. See **Chapter 17** for a more detailed discussion of these locks.





Within most dimple locks, there are actually many more pin chambers than are actually used **for any one key.** Thus, a cylinder may have twenty pin chambers but only seven pins in actual use. The number and location of the pins are staggered, depending upon keying plan.

There may always be, for example, thirteen "empty" chambers in any given lock. An empty chamber will generally have a shallow pin that requires no cut in the bitting surface of the key. Different keying combinations are obtained by staggering the combination of tumblers. Although different length of pins may be placed in any chamber position, every lock in the same master key series must have that same pin length for a specified chamber position in order for the master key to work. **The master key simply reflects a composite of every possible chamber position and pin length that is used in any individual lock within the system.**

High-security dimple lock manufacturers employ a number of safeguards to reduce possible compromise, including the maintenance of close tolerances, patent and copyright protected blanks, complex bitting configurations, and special key machines. It may be argued that the positional system offers a higher level of security than the conventional split pin system, due to the large number of pins, complex design, and lack of multiple shear lines. Perhaps most significantly, the system cannot be compromised through the disassembly of only one cylinder, as with conventional systems.

11_6.3 Magnetic Locks

Locks that use magnetic cards to control locking mechanisms are of two basic designs: those that employ a stripe that contains flux reversal information (such as a credit card) that is passed across a read head to sense the pattern of reversals, and those that utilize a material to store magnetized spots that mate with corresponding pins within a matrix inside of the lock.

Within certain magnetic card locks that use barium ferrite vinyl (BFV) or similar materials, positional master keying is utilized and can pose a serious threat to the security of a master key system. In one magnetic card lock for example, twenty magnetic pin positions are available for use. The design requires that pins in each location be raised above shear line through the action of repulsion by like magnetic fields.

Typically, an individual magnetic keycard will have up to eleven magnetic "spots" or domains that correspond to magnetic pin positions. Each lock within a system will always have eleven magnetic pins, but the combination (location) of pins will be different for each lock. Thus, magnetic pins will be placed in different chambers throughout the system, according to a predetermined plan. Additionally, the polarity of each magnetic pin for each chamber will be varied: some north polarity, some south.

The security of this lock relies upon the **position** and **polarity** of each pin. It can be seen, then, that the master key will be a composite of all pin locations and their polarity. For the master key to operate all locks, the polarity for each pin position must remain constant. Thus, with a sufficient sample of different locks within any positional master key system, the master key can be derived.

The author conducted an investigation involving a very popular magnetic lock at a major hotel in the United States. Within ninety minutes, the keys to eighteen rooms and the hotel master key was derived without ever taking any lock apart. The time required to derive the magnetic "signature" of each room was under ten seconds. The procedure developed by the author was impossible to detect, was essentially without noise, and left no trace within the lock. Other magnetic locks suffer the same security problem.

11_6.4 Axial Pin Tumbler Locks

Methods have been devised to master key axial pin tumbler locks. Such a technique was described by Falk in 1973 (**3738136(145)**) and utilized by Fort Lock Corporation. The system involved the use of different-shaped pins and edge cuts on the key. Multiple levels of keying can be achieved with this scheme and with more traditional techniques.

11_6.5 Sidebar Locks

There are many methods to increase the number of theoretical combinations within a sidebar lock. Multiple sidebars, multiple gates and sidebars, different sidebar profiles, and the design of the geometry of the pins and their relationship to the bitting surface of the key can affect the way in which master keying is executed. A unique design has been implemented by Medeco in their M3 locks. See **chapter 17**.

11_7.0 Servicing and Examination of Master Keyed Locks

Examination and servicing of one or more locks within a master key system may be necessary during the course of an investigation in order to determine if they have been previously disassembled or tampered with. The addition or removal of locks in a complex keying system may also be required.

11_7.1 Taking Apart the Master Keyed Cylinder

Disassembly of any master keyed cylinder requires extreme caution in order to insure that the tumbler combination and pin stack for each chamber is not disturbed. It is mandatory that a setup tray be used for this purpose. Although data regarding disassembly of pin tumbler locks was presented elsewhere in this text, added information pertaining to the master keyed cylinder is required to avoid irreversible errors.

Working with a cylinder that is suspected of containing more than a lower and upper set of tumblers requires special precaution, especially if pins are not taken from each chamber through the spring-retaining clip. Locks with one or more master pins in each chamber must be disassembled correctly, or the pin stack order may be altered. The controlled removal of the follower tool

from the lock is imperative if pins are to be withdrawn through the interior of the shell.

It may not be necessary to disassemble certain cylinders in order to derive all pin stack combinations and pin lengths. Methods of shimming of a cylinder and the use of systems keys are discussed elsewhere in this text.

11_7.1.1 Detailed Procedure

Starting at one end of the lock, very gradually withdraw the follower, barely exposing the pin stack within the first pin chamber. The author prefers to have the lock positioned so that the pin chambers are oriented in such a way that the pins release in an upward direction. Thus, the lock is held in an upside down position in the left hand which is also used to control movement of the follower tool. The tweezers are controlled by the right hand.

Using a special pair of tweezers (HPC-TPT-5 or equivalent) apply downward pressure on each tumbler with the center pin of the tweezers. As the follower tool is slowly withdrawn, the pin will begin to eject from the chamber due to the forward bias created by each spring. The follower is controlled to maintain a constant pressure on the side of each tumbler, thereby preventing the pin from flying out of the bore. This pressure, in conjunction with the use of the center pin of the tweezers, can be used to control release of each tumbler.

Very slowly allow each pin segment to move out of a chamber, then move the follower back in position over the chamber hole, inhibiting further release of pins. As each tumbler is released, remove it from the shell and place it in the setup tray **in the order removed.**

Start at the bottom of the tray for the proper chamber number. When all of the pin segments have been removed for chamber number one, the precise pin stack order should have been reproduced. After the first chamber is empty, move the follower to the next chamber and repeat the above procedure until all pins have been removed from the lock. When the pins have been withdrawn from all chambers, the setup tray will exactly replicate the horizontal and vertical positioning of all pins within the plug.

11_7.2 Changing the Keying Level of a

Cylinder

Whether a lock is to be set to a higher or lower level of master keying within a system will determine the difficulty of such change. Although it is a simple matter to remove one or more master pins in order that the master key will not open a particular lock, the cylinder must be keyed according to the KBA and predefined levels.

The proper method to downgrade a lock so that only a change key will open a previously master keyed lock, for example, would be to completely re-pin the cylinder. Thus, all master pins would be removed and a new set of lower pins installed that correspond to the combination of **only** the change key. Combinations for the change key, master key, and TMK must be known prior to working on the cylinder.

11_8.0 Construction Master Keying

11_8.1 Introduction

Several techniques have been developed over the last fifty years to protect new locks and keys from compromise at building sites and to regulate and change access to locks in other specialized environments. In the case of new buildings, the problem is caused by the need for workers to have keys while construction is in progress.

Control, duplication, and return of keys at the conclusion of a job is often difficult to enforce, resulting in the circumvention of all key control and the defeating of inherent security features of any lock. Construction master key systems have also found application in schools, dormitories, institutions, and for use during labor disputes and temporary emergencies where access must be instantly controlled, allowed, or denied.

There have been several approaches to construction mastering, including special pockets to hold extra bearings, the insertion of special key sections into the keyway, the use of locks with a second set of bores, and creation of temporary master pins. In addition, lockout devices have also been developed which block the entrance of any key into the cylinder until the special blocking device is removed.

11_8.1.1 Cylinders Containing a Second Set of Bores

Cylinders have been developed with a second set of bores drilled in the shell. Once the option is enabled (by rotating the plug with a control key) they can facilitate:

- **Access control;**
- **Allow the use of a regular key;**
- **Block all regular keys and master keys and only allow the use of a special key.**

The Russwin cylinder will be used as an example of this type of keying. A similar principle has been applied within the hotel industry by TrioVing of Norway, and is described in **Chapter 17.**

The Corbin and Russwin cylinder consists of a shell containing two sets of bores, one set in the standard vertical plane at 12 O'clock and the other, offset by several degrees, at 11 O'clock. The **plug** will contain **one** set of bores.

There are usually six cooperating bores in the plug and shell, oriented in the normal 12 O'clock position. However, there will only be five offset chambers in the shell at the 11 O'clock position; the sixth bore position will be solid. There are driver tumblers and springs in both the standard and offset bores. There are bottom tumblers and one or more master pins in the plug.

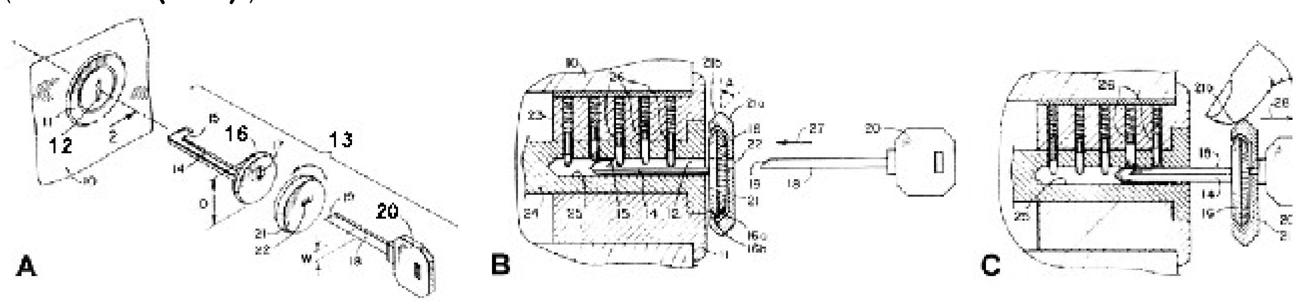
In normal operation, the change key will work the lock by raising the tumblers in the 12 O'clock bore position to shear line, allowing rotation of the plug. The absence of a bore in the sixth position of the offset chambers will prevent the change key from being withdrawn in the 11 O'clock position, because there is no place for the last pin in the plug to go. Therefore, the key cannot be withdrawn.

To lock out the normal change key, the special block-out key is inserted, the plug rotated to the 11 O'clock position, and the special key is withdrawn. It is possible to withdraw the block-out key from the plug in the 11 O'clock position. This is because the last tumbler position on that key has been filed, so that there is no steeple or rising angle encountered by the sixth tumbler within the plug. Thus, this pin is not raised above shear line as the key is removed. To return the cylinder to normal operation, the block-out key is inserted at the 11 O'clock position, the plug then rotated back to the 12 O'clock home position, and the key withdrawn.

Cylinders utilizing this scheme can be master keyed in the normal manner. However, the master key cannot be used as a block-out key. In addition, there is the possibility of system sabotage, in that a change key can be altered by filing the last tumbler, in effect creating the block-out key. If the plug is then rotated to the 11 O'clock position and the key withdrawn, the lock cannot be operated without use of the special key. Furthermore, it may be possible that a **cross-key** could be created to work as a block-out key. In this case, a completely different and unanticipated tumbler combination could be created and parked in the offset position. In that instance, a key with that combination would have to be used to return the lock to normal operation.

11_8.1.2 Special Keyway Insert

Many years ago, Schlage introduced a form of construction keying that required the placement of a special insert into the keyway to block all but the lock-out key. The special key would open all of the locks, just as the regular master key would. Upon completion of construction, the insert would be removed, disabling the lock-out key and returning the system to normal operation. Other companies have offered similar schemes. Many patents have been granted for these mechanisms, notably to Schlage and Yale. See the patent issued to Check in 1962 (**3059462(146)**).



11_8.1.2.1 Principle of Operation

The insert is a specially cut key with some of the keyway and bitting material removed. In the Schlage system, these inserts will usually be made to raise the last one, two, or three tumblers to shear line. When the special construction key is inserted, it merely picks up the remaining tumblers to the proper level, allowing the plug to rotate.

Placing the insert into the keyway effectively blocks any but

specially cut keys from entering the lock. The inserts can also be back-cut, making them difficult to withdraw without the proper removal key. Schlage has offered construction mastering, utilizing the insert principle, for their old series wafer locks as well as their pin tumbler cylinders.

When construction is completed, a plastic removal key is inserted, causing the construction piece to lock onto the end of the removal key. Both are then withdrawn from the plug, returning it to normal operation. DOM utilizes a similar scheme with their dimple locks.

11_8.1.3 Corbin: Temporary CMK Master Pin Using Side Pockets in the Plug

Corbin produces a cylinder that features a special construction master key (CMK) arrangement that allows the pin stack to be altered irreversibly upon the completion of the project. During construction, the CMK is utilized for access. The operation of the special master key is cancelled when it is no longer needed. This is accomplished through the use of a specially designed plug that has two small pockets or bores, drilled forty degrees from the center of one chamber (usually the last chamber). The diameter of these bores is too small to accommodate master pins or top pins; only the bearings will fit into the holes. Three .045" ball bearings are utilized as a master pin, as shown in the diagrams below, during the construction process. The bearings are permanently "parked" in the plug after construction when the lock is returned to its normal operation. Once the bearings drop into one of the pockets, they cannot be removed unless the lock is disassembled. Note that the steeple of the last cut (tip) on the CMK is removed to prevent key picking or jiggling.

The system utilizes a bearing equal to a master pin having three depth increments (pre-System 70 lock) or 1.5 increments (System 70). The theory of operation is quite simple. The bearings are placed directly above the bottom pin, or the master pin. So long as the construction master key or change key does not raise the bearings above shear line, the lock continues to function in the construction mode. However, if at any time the plug is turned with the bearings **above** shear line, then they will fall into one of the pockets upon rotation. At that moment, the pin stack will be returned to its normal configuration, and the CMK will never work again. The ball bearings can be placed above the bottom pin, or above the master pin with the same effect. Depending upon

their position, the change key or TMK is used to reset the system.

The combination of the CMK is usually set so that one progressive is different by three depth increments (pre-System 70) from that of the TMK, as shown in the KBA for this lock. The CMK corresponding bitting position is always set for a depth of 5 1/2 for a System 70 lock, or a 7 in the pre-System 70 configuration.

The lock can be configured in one of two ways, both with the same result. In the diagrams, the bores for the bearings are color-coded blue, the bottom tumbler is green, the ball bearing is red, the master pin is yellow, and the top pin is brown. Cylinder **A** is shown in an idle state. In **B**, the CMK allows the plug to rotate freely because the ball bearings are placed above the bottom pin, and are below the shear line. They can never make contact with the side bores because they are encapsulated in the pin stack. In **C**, the **change key** is turned in either direction to cancel the CMK. Note that the CK only raises the bottom pin thereby placing the ball bearings at shear line. As the plug turns, they drop into one of the bores and disappear. In **D**, the CMK is reinserted, but cannot work.

In the diagrams of cylinders **D**,**E**,**F**, the master key is used to reset the system. In cylinder **E**, the lock is in the idle state. In **F**, the CMK is able to operate the cylinder. In **G**, the master key is turned so as to bring the bearings to shear line, and park them into one of the corresponding bores upon rotation. In **H**, the CMK is inserted but is blocked from operating because the master pin does not split at the shear line.

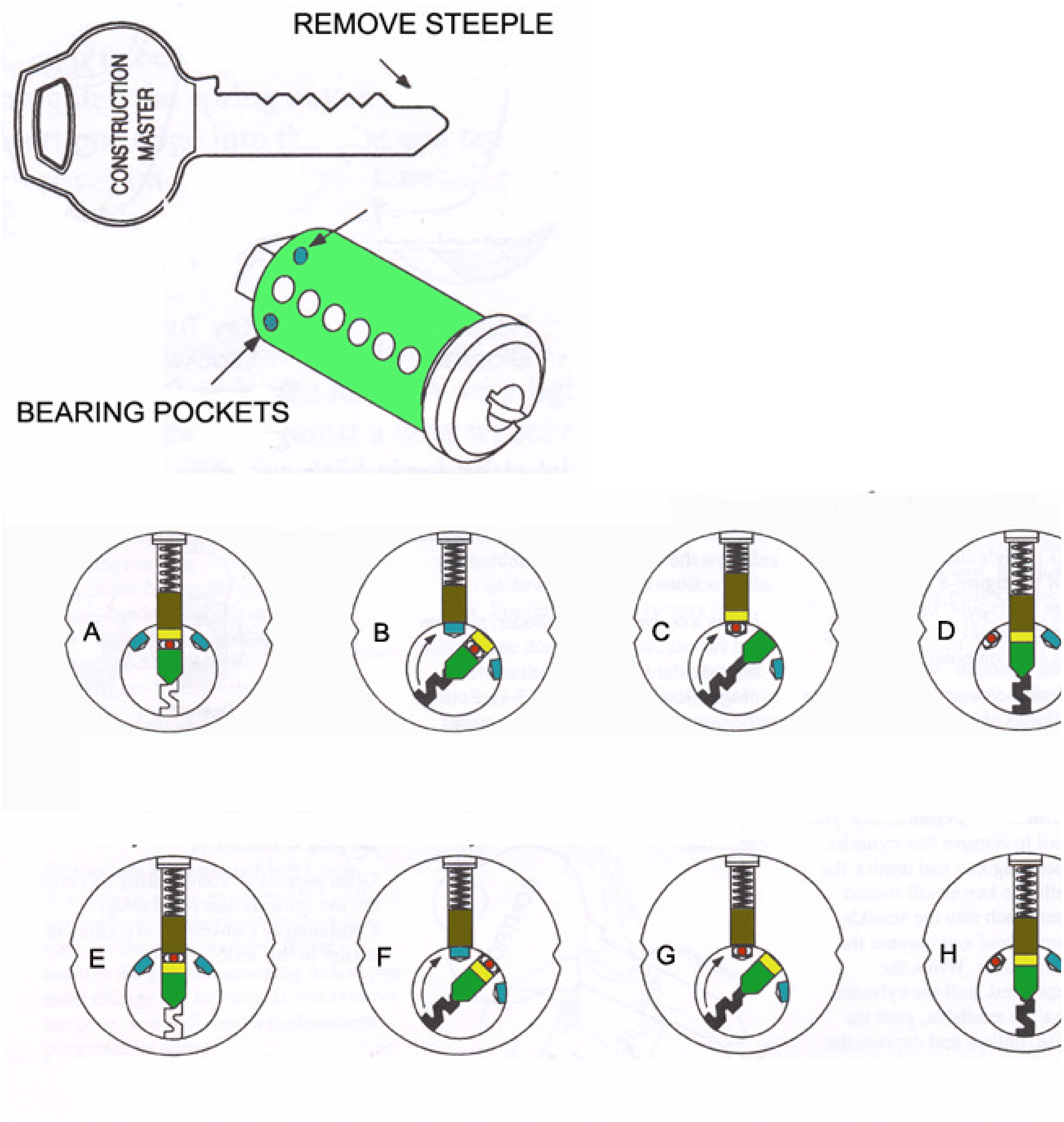


Figure LSS+1139 shows a Corbin construction master key system that relies upon ball bearings to be parked in small bores drilled off center from one chamber. In A,B,C,D, the bearings are placed below the master pin, and are controlled by the operation of the change key. In E,F,G,H, the master key performs the reset function. Courtesy of Corbin Russwin.

The KBA for the construction master is slightly different than for a conventional cylinder. In a two-step progression for a pre-System 70 lock, one of the progressives in the sixth column is lost because of the use of that value for the CMK. In this instance, the sixth position of the CMK is set at 9, which is three depth increments deeper than the TMK position.

KBA FOR CONSTRUCTION MASTER

CMK	1	4	9	7	2	9
TMK	1	4	9	7	2	6
	3	6	1	9	4	0
	5	8	3	1	6	2
	7	0	5	3	8	4
	9	2	7	5	0	

Figure LSS+1140 KBA for the construction master key system. This example is for a pre-System 70, and provides for a total of 3,072 combinations (4 x 4 x 4 x 4 x 4 x 3). The value of the CMK cut is 9. A depth of 8 cannot be utilized because it only varies by one depth increment from the CMK value.

CHAPTER TWELVE: HARDWARE SURVEY

Basic Lock Configurations: Hardware

Master Exhibit Summary

Figure LSS+1205 Various HPC door guards produced to protect narrow aluminum doors.
Figure LSS+1206 Rim cylinder (left) and mortise cylinders (right) in two standard sizes.
Figure LSS+1207 Key in knob lock.
Figure LSS+1208 Examles of dead bolts in different configurations.
Figure LSS+1209, examples of single and double-locking night latches.
Figure LSS+1210, a guard ring assembly protects the cylinder from attack.

Figure LSS+1211 Internal and external support hardware to increase resistance to attack.

Figure LSS+1212 Improved strike box and plate.

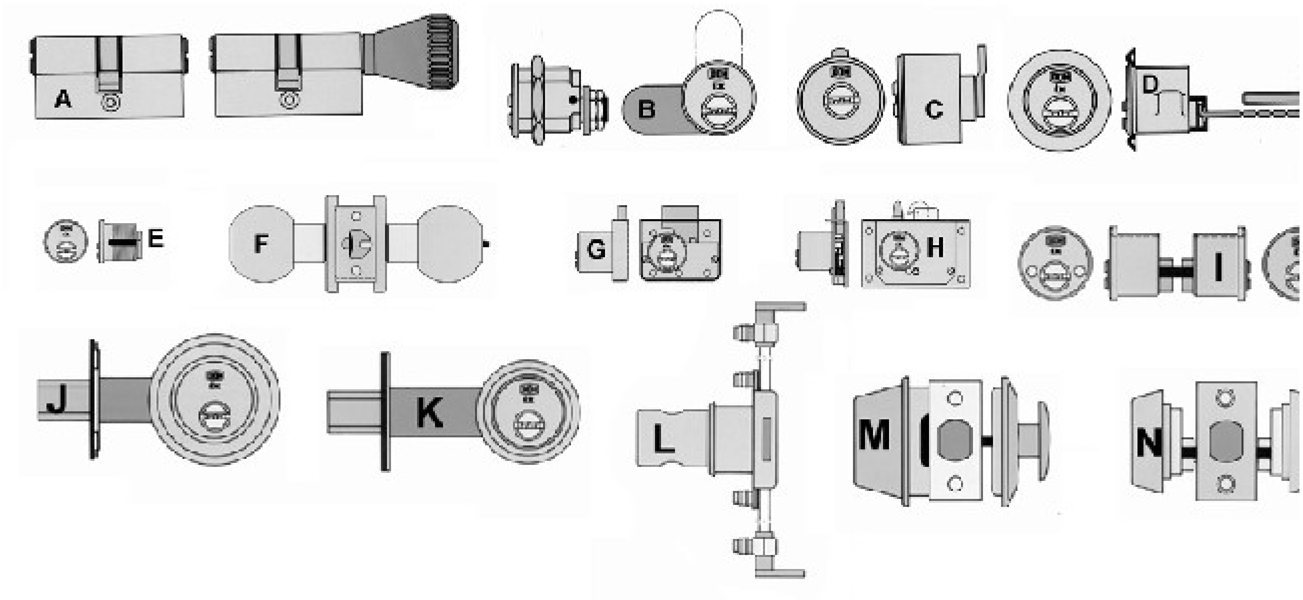
Figure LSS+1213 After-market hardware to protect door and frame from attack.

Figure LSS+1214 The cutout required for the locking hardware shows the weakening of materials.

Figure LSS+1215 Little effort is required to compromise a jimmy-resistant bolt.

12_1.0 Introduction

This chapter provides information about and identification of the hardware components that comprise every locking system. These include locks and lock covers, latches, bolts, and related locking mechanisms. For an excellent description of early locking hardware, the reader is directed to **Chapter Nineteen** of the Price book, contained within the Infobase. Doors, frames, and other hardware are discussed in **Chapters 38-39**. In those chapters, detailed information is presented about each locking component in the context of burglary and robbery prevention.


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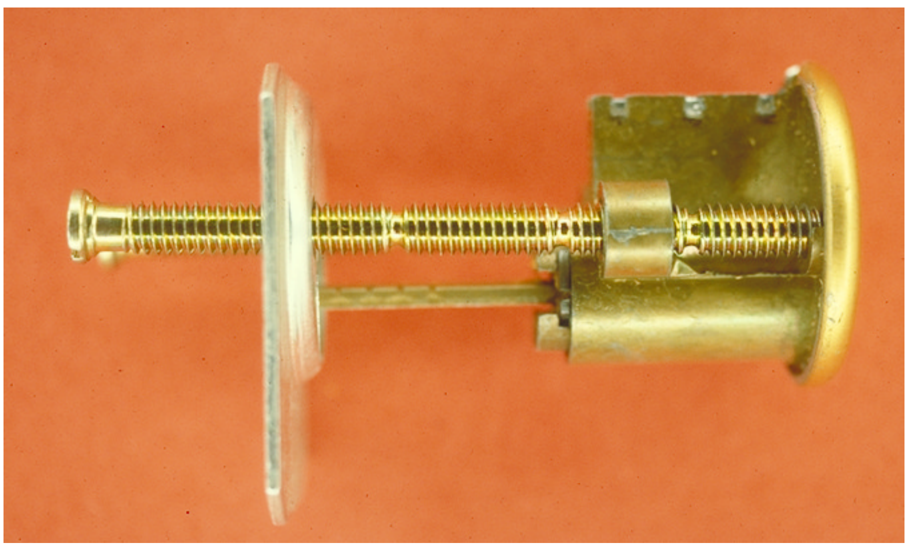




Figure LSS+1206 Rim cylinder (left) and mortise cylinders (right) in two standard sizes.

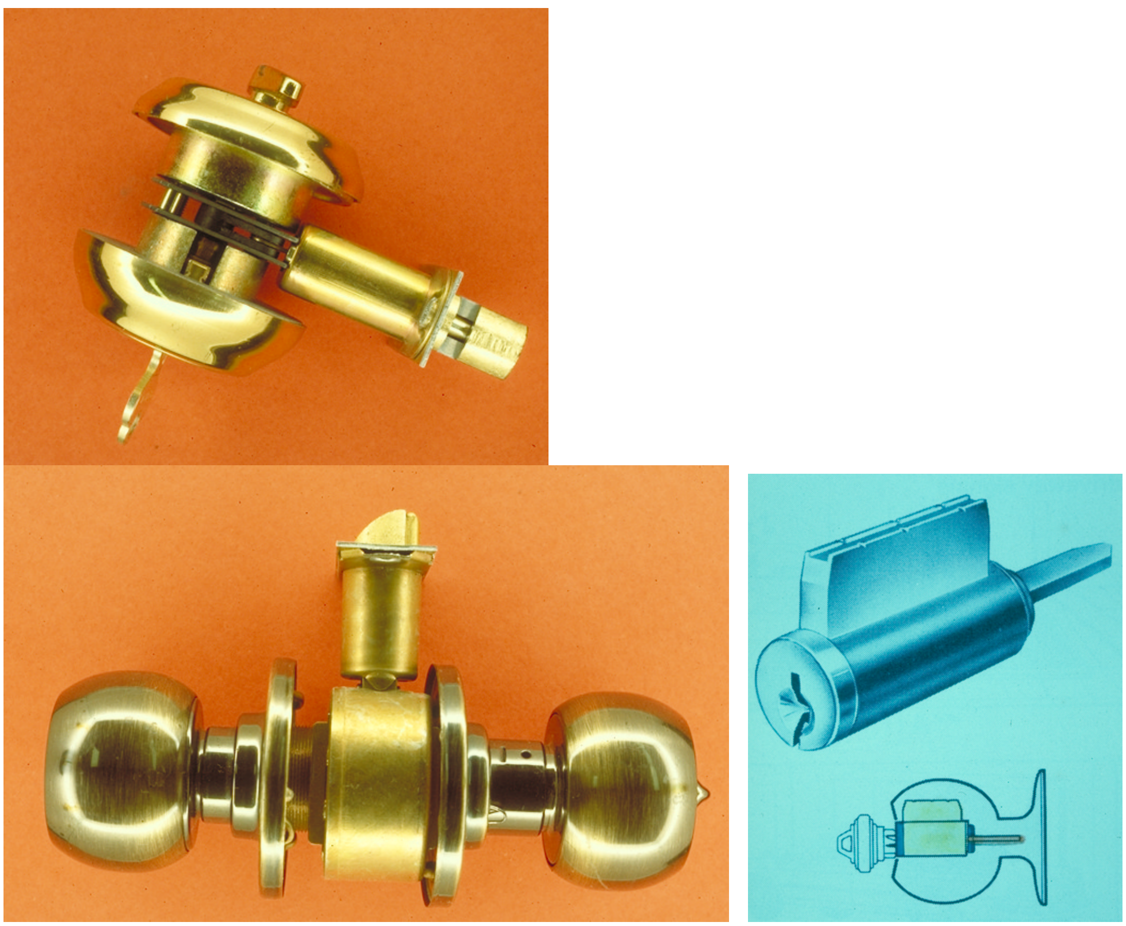


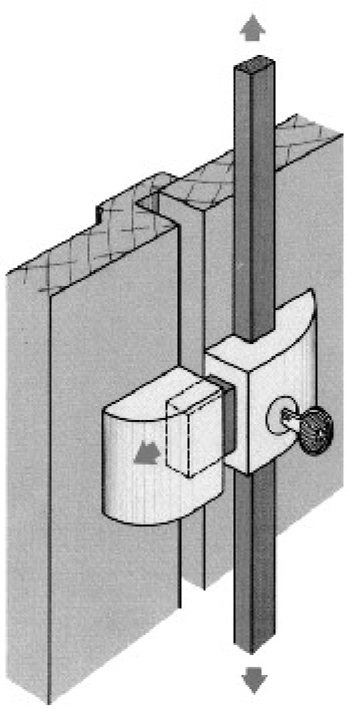
Figure LSS+1207 Key in knob lock. Courtesy of Illinois State Police, Bill

Sherlock.

There are many types of locks and lock configurations. The diversity of products result from different requirements related to security, convenience, mechanical configurations, and the purpose for which the lock is used. Additionally, each area of the world has developed different methods and approaches to security, reflected in the unique use of materials and designs. Within each country or region there is standardization of locks and related hardware with respect to mechanical configuration. Information regarding European and American testing standards for door locks is presented in **Chapter 37.** Certain classifications of locks are defined by ANSI, based upon a specific use. Thus, there are entrance, store, classroom, communicating, dormitory, and hotel locks. Specialty locks, such as cam, padlocks, tubular, mailbox, telephone, and combination are discussed in **Chapters 17-23.**

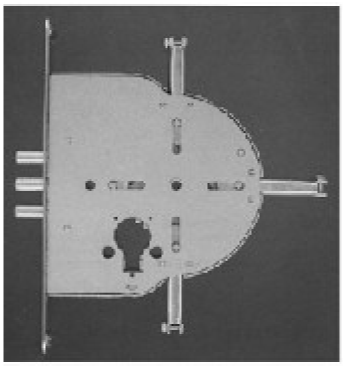
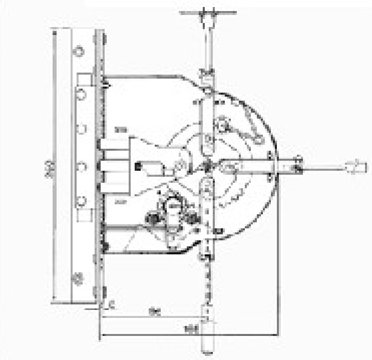
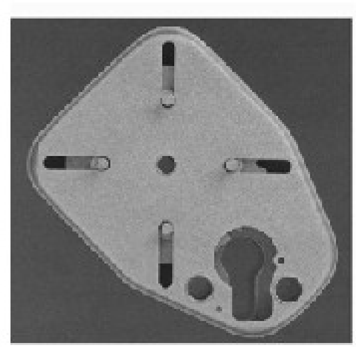
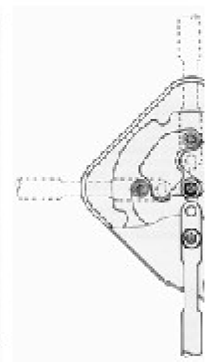
12_1.1 Bolts and Strikes

There are a number of different types of bolts, depending upon the lock, jamb, and strike design. These are defined below.



12_1.1.1 Bolts

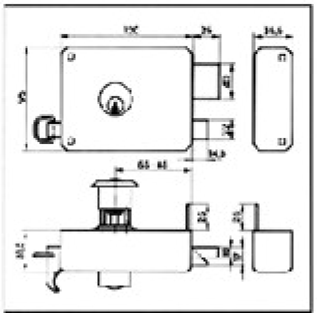
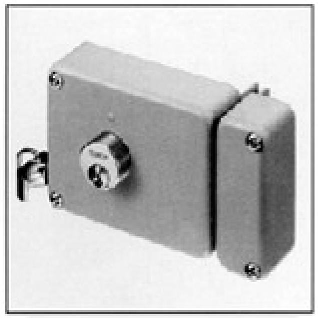
A **bolt** is a metal bar that when actuated is either projected horizontally or vertically, or swings into a solid mass to prevent any door, window, or other object from moving or opening. Bolts may take a rectangular or hook form or may be comprised of several interconnected pieces operating together. The term can be found in the literature as early as 1753, although in 1400 it was described as part of a lock.

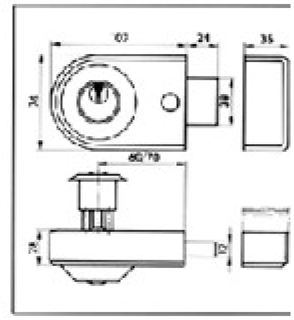





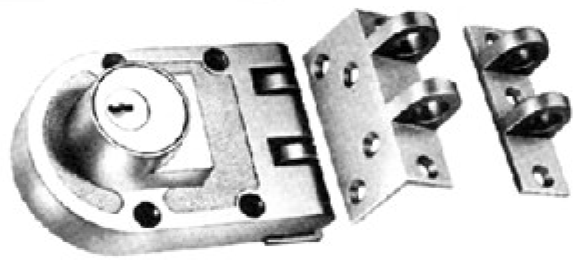
Extra strong bolts can be employed to lock a door at the top, bottom and sides. For example, **cross-bolt** or **double-bolt** locks are fitted on the inside surface of the door to increase security. Features such as solid steel bolts on both sides, bolt projection of 80-100 mm controlled by a gear wheel, and lock mechanisms with multipin cross profile or profile cylinder are examples of complex bolt arrangements.

12_1.1.2 Latches

A **latch** is a type of bolt that can take several forms. It is a device for retaining a door or other moveable surface to which a lock is attached. The use of the term can be found as early as 1382. **Lache** was used in 1420 and **latche** in 1575. In 1611, Shakespeare spelled it **latches**. A **latchbolt**, unlike a dead bolt, is a standard, angled or beveled projection.





The **night latch**, a form of **deadlatch** lock, is a spring loaded bolt that may be withdrawn by knob from the inside and by key from the outside. The latch can be set to the unlocked position or it can be locked in place against end pressure. It is usually associated with a rim lock.



LSS+1201 A Yale nightlatch, circa 1909. This is perhaps the most popular locking device even introduced. Its companion rim lock is shown below.

12_1.1.3 Actions of Bolts and Latches

There are a number of ways of describing the actions of bolts and latches relating to whether they are spring loaded, how they are thrown and retracted, and how they lock. There are deadlocking bolts and latches, night latches, secondary bolts, and various combinations of night latches and dead bolts.

12_1.1.3.1 Deadlatch

A **deadlatch** is a specific type of latch that has a beveled edge. It can be automatically or manually locked against end pressure when in the thrown position. The term may have several meanings:

- **Night latch that may be deadlocked;**
- **Night latch with a secondary locking bolt to prevent use of celluloid to bypass it;**
- **Arrangement with a night latch secondary bolt that may be locked from the inside.**

12_1.1.3.2 Deadlocking

Deadlocking generally refers to a special added locking action that may be initiated to prevent the bolt from being withdrawn because of external pressure or the use of the handle. Generally, deadlocking is activated by an extra turn of the key that throws the bolt an added length into the strike.

12_1.1.3.3 Dead bolt

A **dead bolt** is a lock bolt having no spring action. The bolt is usually rectangular or square and is moved into the locked and unlocked position by a key from either side of the door. This is contrasted to a **spring-loaded bolt** that may extend automatically. The dead bolt, when projected, is locked against end pressure; the bolt thus deadlocks when thrown. To complicate the definition, there are single, double, one-way, classrooms, and standard door lock bolts.






Figure LSS+1208 Examples of dead bolts in different configurations. Courtesy of Illinois State Police, Bill Sherlock.

12_1.1.3.4 Auxiliary Deadlock Latchbolt

An **auxiliary deadlock latchbolt** comprises an additional bolt that is depressed by the strike when the door is closed, to automatically deadlock the bolt against end pressure.

12_1.1.3.5 Secondary Bolt

A **secondary Bolt**, also referred to as an **anti-thrust bolt or anti-pick latch**, is a spring-loaded auxiliary slide attached to the main bolt that cannot be retracted when the primary bolt has been extended into the locked position. Its purpose is to frustrate attempts to withdraw the main bolt by thin plastic or metal shims, wedges, or the application of end pressure. A secondary bolt is not the same as an **auxiliary deadlock latchbolt.**

12_1.1.3.6 Deadlocking Night Latch

In a **deadlocking night latch**, sequential actions are required to double lock or unlock. Thus, the first action throws the bolt; the second either throws it further or physically blocks it from being withdrawn.

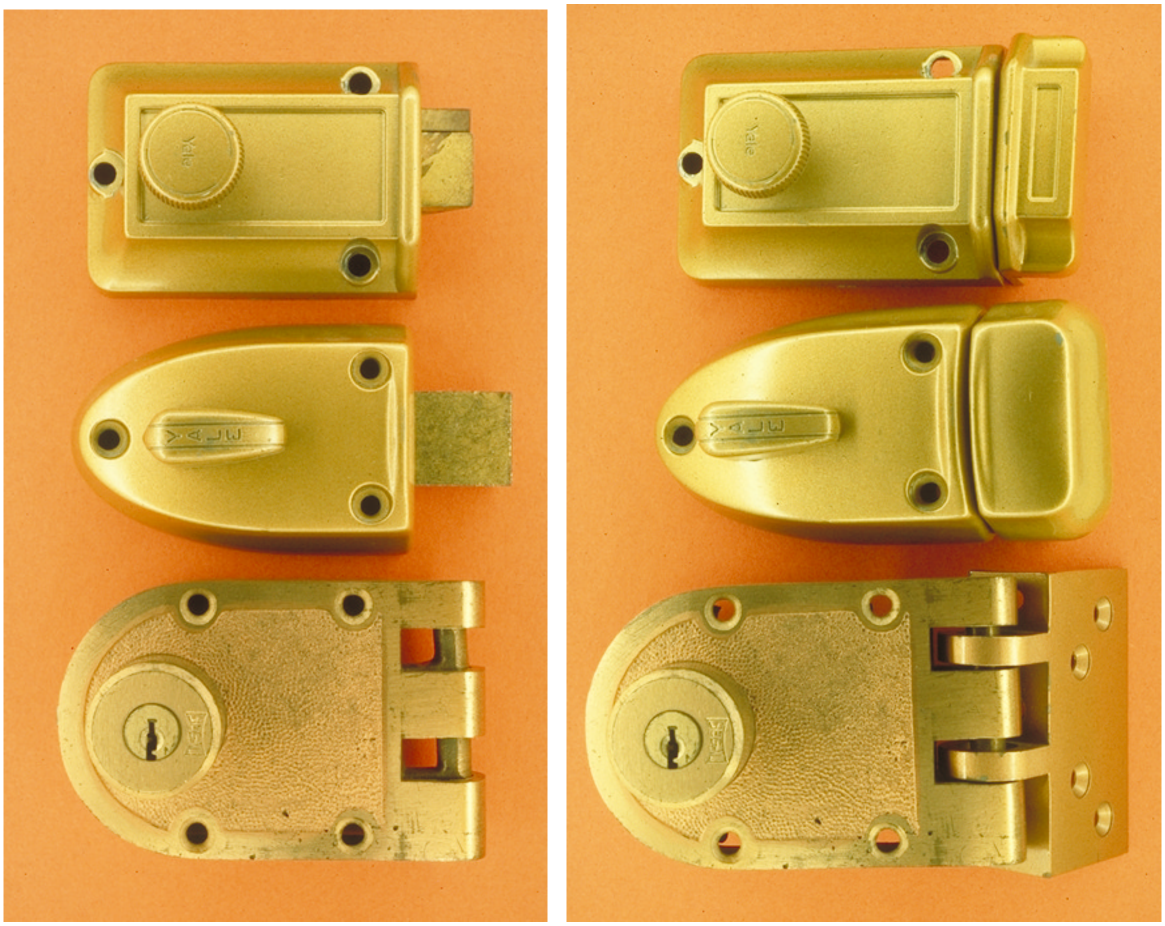


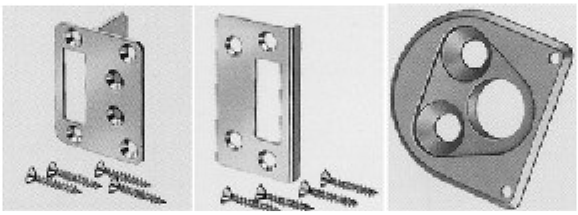
Figure LSS+1209, examples of single and double-locking night latches. Courtesy of Illinois State Police, Bill Sherlock.

12_1.1.3.7 Double-Cylinder Deadlatch

A **double-cylinder deadlatch** is a deadlocking latchbolt, retracted by a key from either side of the door.

12_1.1.4 Strike

A **strike** is a metal plate that is mortised into, around, or on the doorjamb to accept and restrain the bolt. The strike may be as simple as an opening in the jamb or of a more sophisticated design, even incorporating high-security features. A **jamb** is the inside vertical face of a door or window frame. Like all parts of the **escutcheon**, the strike plate must be made for the type of door. Strikes are designed to withstand forces from kicks, pushing pressure, pry bars, or wedges.



12_1.1.4.1 Breakaway Strike

A **breakaway strike** is a remote controlled electric door lock in which the strike is electromagnetically retracted to operate. A security strike plate is used with additional anchors in the wall to provide resistance to forced-entry.

12_1.1.5 Handing

The **hand of a lock** defines on which side of the door the bolt is located and extends. It is referenced to the keyway of the lock. For example, when the keyway is oriented right side up and facing the viewer and the bolt is to the left, then the lock is said to be left-handed. From the back of the door, the hand of the lock is determined from the way the door swings. The definition is equally applicable to safes and vaults with respect to the orientation of the combination lock.

12_2.0 Locks and Associated Hardware

There are two types of door locks: primary (main) and secondary. In the United States, the main lock is generally a key-in-knob or mortised cylinder. Secondary locks provide added security and can take many forms. In Europe, profile locks and mortise locks are predominant.

12_2.1 Mortise

A mortise is the opening in a door that is made to receive a lock or other hardware. The term does not find use prior to the middle to the end of the eighteenth century. A mortise lock is designed to be cut into the edge of the door or other frame. Locks are **mortised** or **surface** mounted. A **rim cylinder** is mounted **on** the surface of a door, rather than being inset. Cylinder mortise locks are simply mortise assemblies into which a locking cylinder has been inserted.

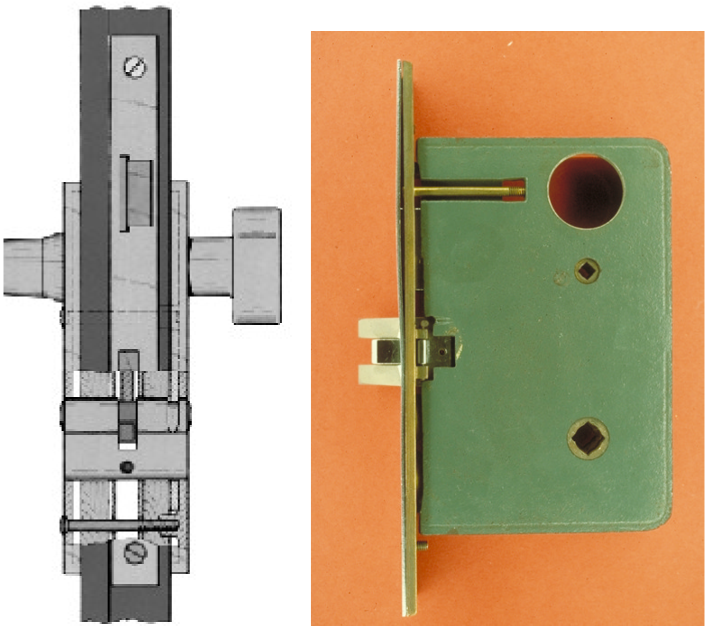
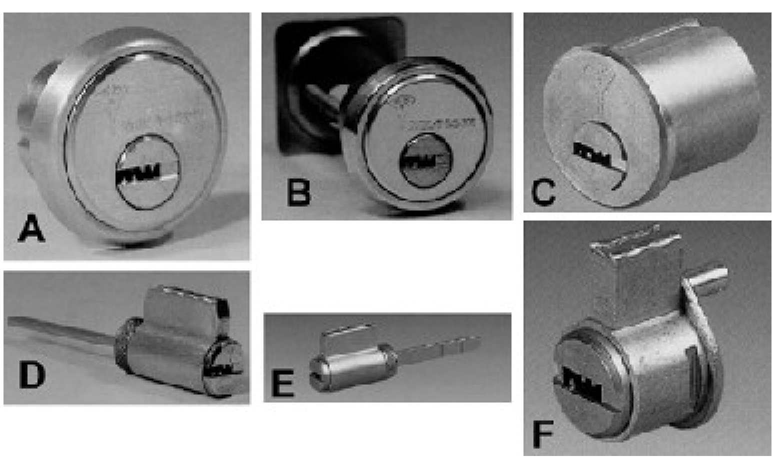


Figure LSS+1204 (ISP 46-2963) Example of a mortised lock, and the mechanism for holding the cylinder.

12_2.2 Cylinder and Security Locks

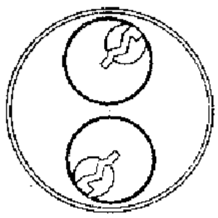
Mechanisms are often referred to as cylinder or security locks. Like keyhole locks (European), they are not complete lock sets, but rather lock **inserts** for simple mortise configurations.



12_2.2.1 Cylinders

A **cylinder** is a round lock that is designed to screw into standard fittings that are mortised or inset into the door.

Cylinder locks are generally pin tumbler, although other locking mechanisms may be used. A **bicentric** lock has two plugs and sets of pins or wafers within one cylinder, such as manufactured by Winfield.



Most cylinder locks are similar and interchangeable. Their diameter, threads, and length are all of standard design so they will fit most door frames. A longer cylinder can always be made to fit doors requiring shorter length by utilizing an expansion ring. The converse is not true: too short a cylinder cannot be made to work properly.

Cylinder connecting bars have also been standardized: they are either square or rectangular and can generally be cut to the required length.



LSS+1202 A Yale rim lock, introduced in 1909.

12_2.2.1.1 Mogul Cylinder

The **mogul** cylinder is a special variety of the standard pin tumbler configuration; it is typically used in prisons. These locks have very large pins, springs, and plug for increased security and physical strength. See **Chapter 17.**

12_2.2.1.2 Interchangeable Core and Removable Core

Interchangeable Core (IC) locks, key changeable locks, and removable core locks are quite popular in commercial environments.

12_2.2.1.2.1 Interchangeable Core

The interchangeable core lock allows removal of the entire core from the cylinder with a control key. The core thus removed can be interchanged with many of the IC lock manufacturers.



12_2.2.1.2.2 Key Changeable

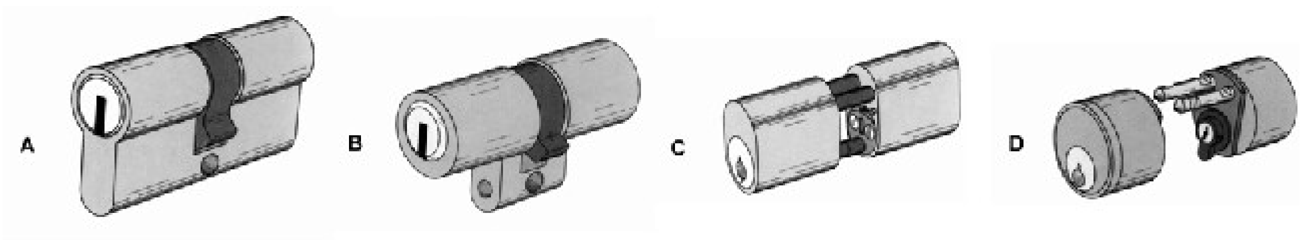
The **key changeable** lock is a cylinder that can be recombinated through the use of a special change key, and without disassembly. Winfield makes such a product for the hotel industry. See **Chapter 22.**

12_2.2.1.2.3 Removable Core

The removable core is a lock assembly that contains all pins and springs and which can only be installed in a specific type of lock housing such as a mortise cylinder or key-in-knob lock.

12_2.3 Profile Locks

Profile locks, found in Europe and other parts of the world, perform the same function as the U.S. cylinder lock. All of the door-mounting surfaces and hardware are designed to accept one of four recognized European configurations. These locks are identified as **profile cylinders**, **Swiss profile**, **oval cylinder**, and **round cylinder**.



12_2.3.1 Escutcheon

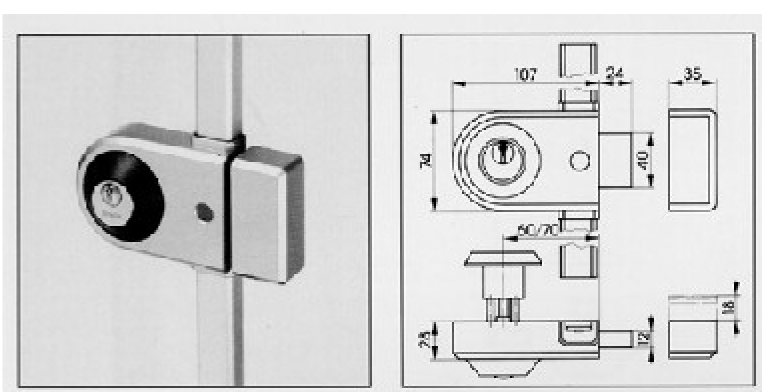
The **escutcheon** is a surface-mounted metal or plastic trim that can add to appearance, security, support, and protection of the lock. Generally, cylinders will not protrude from the escutcheon by more than 2 mm. The **rosettes** or shields will not be screwed onto the door from the front, if they are to prevent forced removal in burglary attempts. Rosettes are necessary to protect cylinders mounted in doors with slender metal profiles.

12_2.4 Rollstud Lock

A **rollstud lock** provides multipoint locking in conjunction with a central locking mechanism. They are typically installed into the door frame for greater security.

12_2.5 Tubular Frame Mortise Lock

Tubular frame mortise locks are used in thin metal frame doors. They are generally equipped with one of three kinds of bolts: **dead bolts**, **swing bolts**, or **hook bolts**. A dead bolt in the tubular frame door can only be locked once with a bolt penetration into the jamb of 10-12 mm. In some special locks, the throw can be increased to 20 mm. This limited throw is often not sufficient to offer any significant security.



12_2.6 Swing Bolt Locks

A **swing bolt lock** can achieve higher security through the design of the bolt. When idle, the bolt rests in the vertical position. The advantage is that the shape of the housing does not limit the length of the bolt. Upon locking, the bolt swings to a horizontal position, with up to one half its length extending into the strike for approximately 30 mm. The other half remains in the lock housing. These bolts are also found in swinging doors. Finally, swing bolt locks with **hook bolts** are utilized primarily on sliding doors. The bolt actually hooks into the strike plate, preventing movement.

12_2.7 Lock and Bolt Guards

Many manufacturers, including HPC, produce door and bolt guards to protect cylinders, latch bolts, and jambs from forced attack.

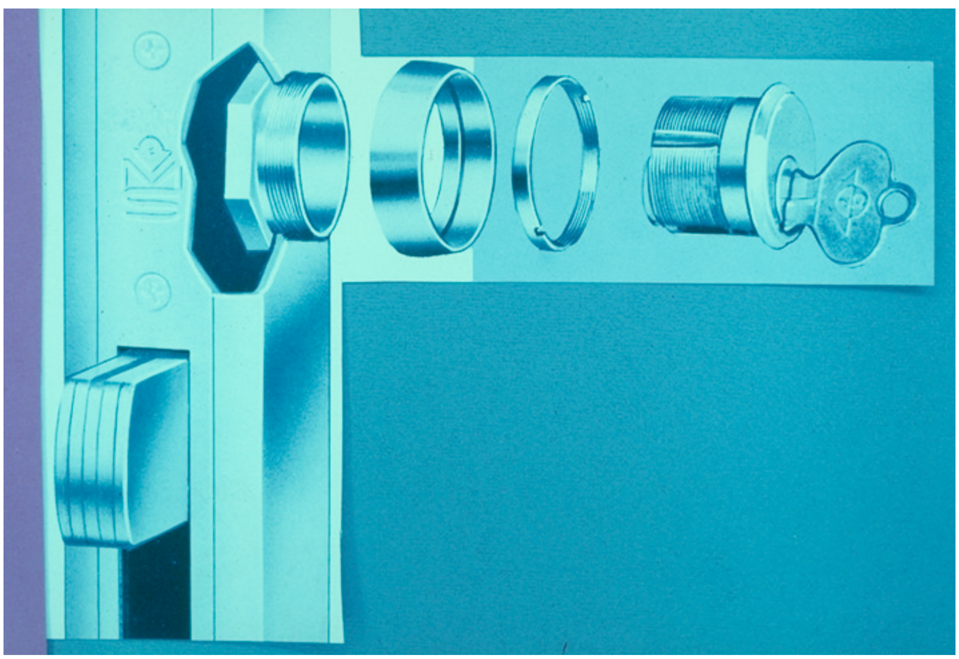


Figure LSS+1210, a guard ring assembly protects the cylinder from attack.

The cylinder is one of the most vulnerable components, especially when mounted on a narrow aluminum door. If left unprotected, the cylinder can be easily removed by pulling, wrenching, or twisting. See **Chapter 32** for specific techniques. The various lock guards protect against lock and plug pulling and drilling.

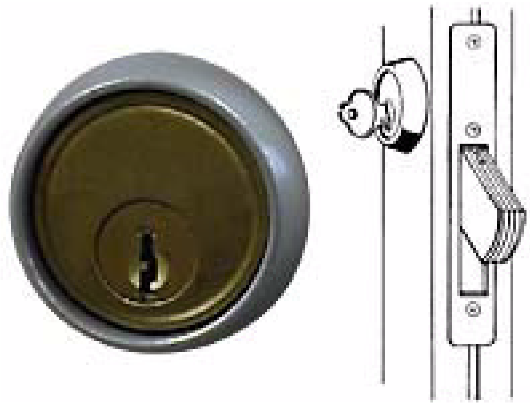


Figure LSS+1203 An HPC cylinder guard.

Door guards provide barriers to prevent door opening by a knife, saw, celluloid strip, or shove knife. They protect latches and bolts. Narrow aluminum doors are also vulnerable to pry bar and jamb spreading, described in **Chapter 32.** Interlocking door guards can solve the problem.

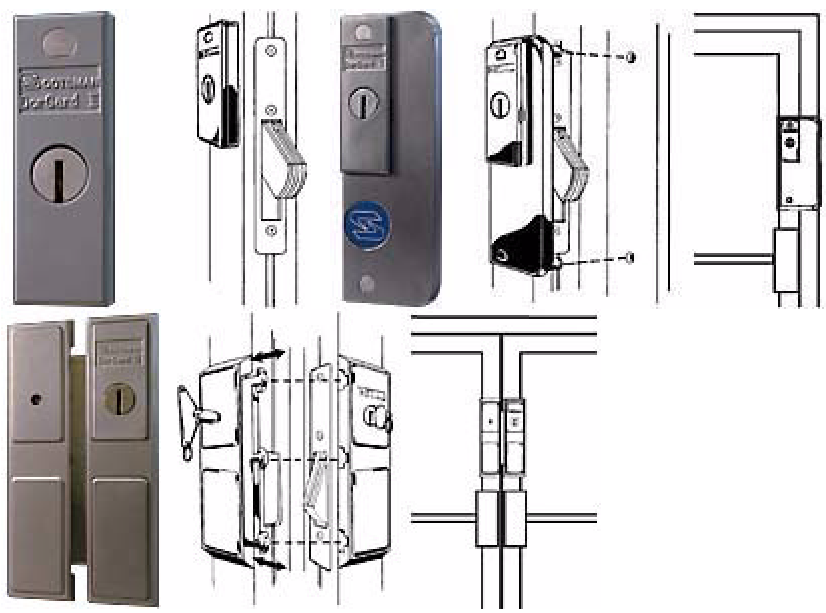


Figure LSS+1205 Various HPC door guards produced to protect narrow aluminum doors.

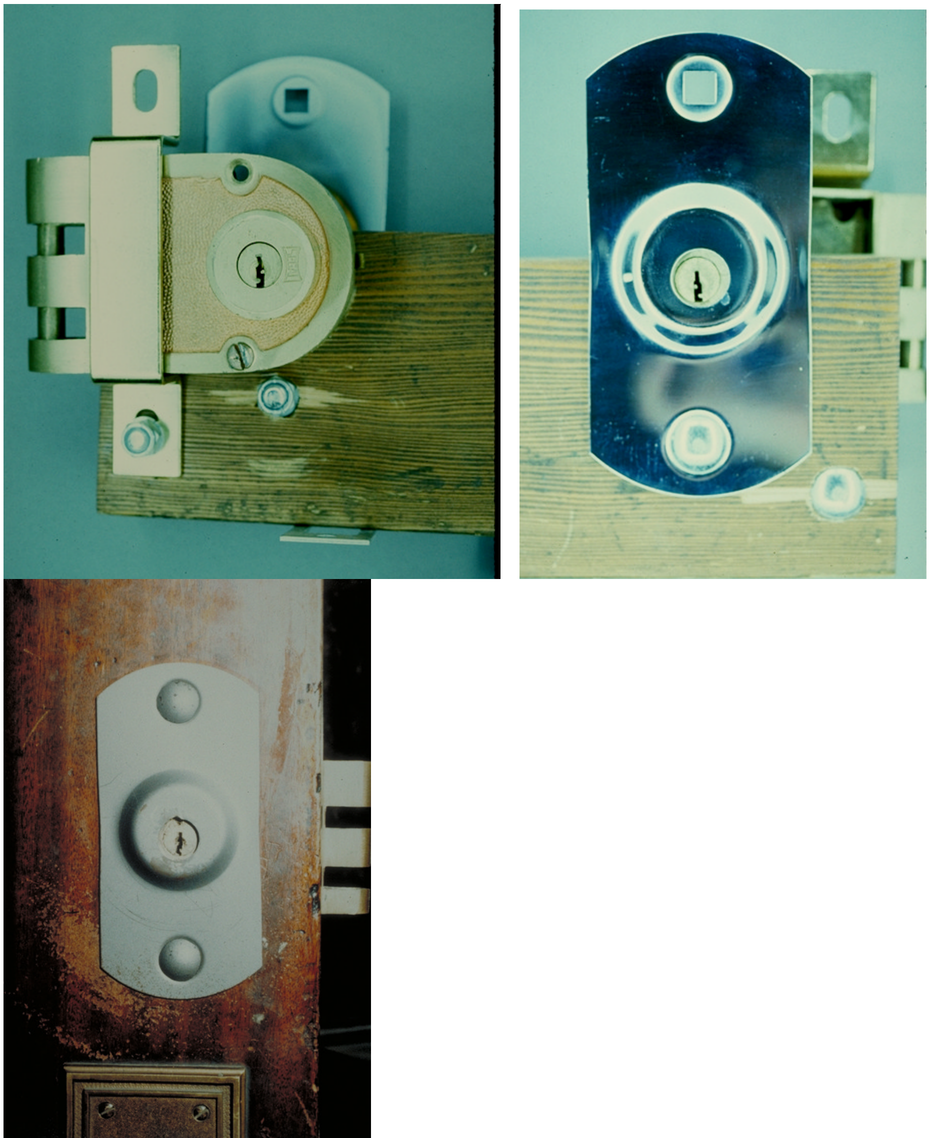
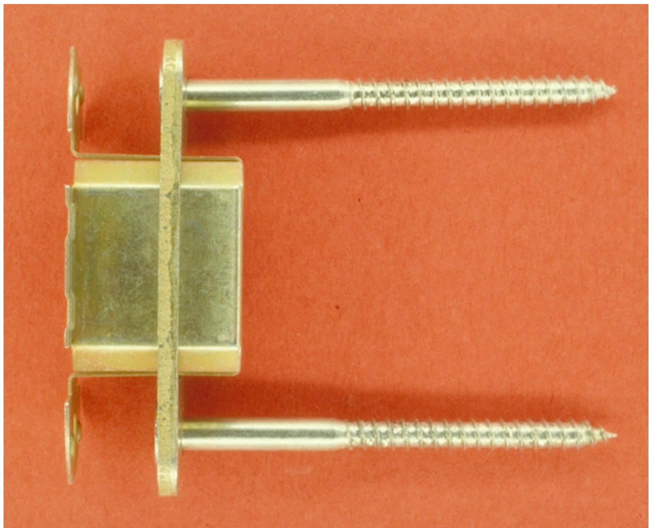
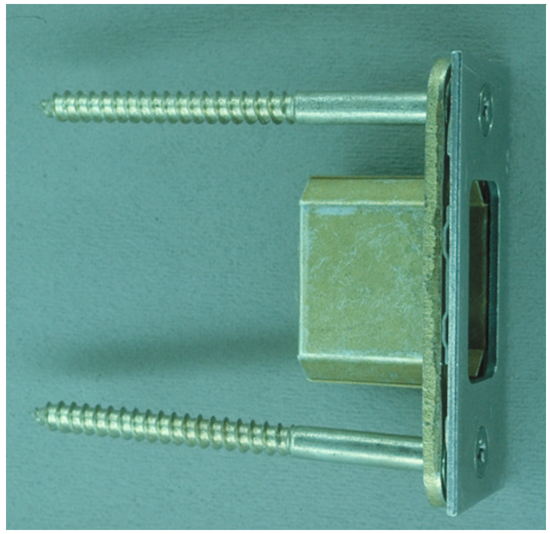


Figure LSS+1211 (ISP 30-3529 left, 31 center, 32 right). Internal and external
support hardware to increase resistance to attack.





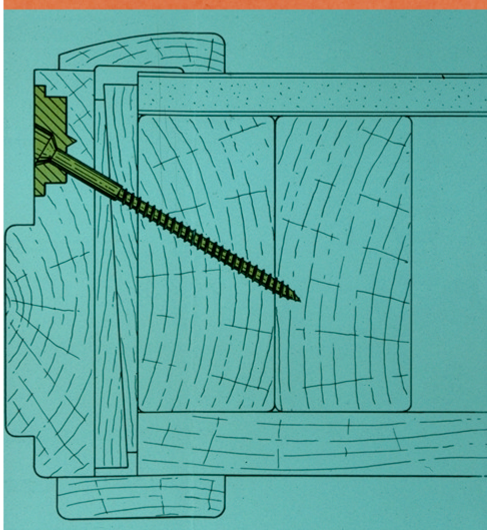


Figure LSS+1212 (ISP 45-3529 left, 46 center, 47 right) Improved strike box and plate.



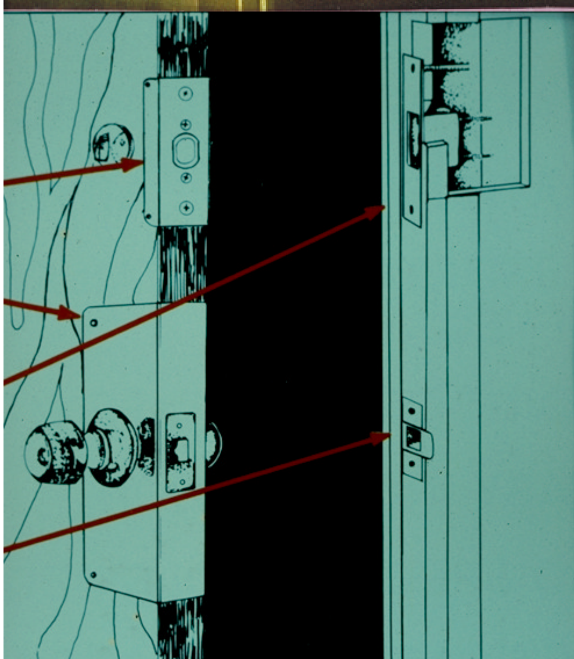


Figure LSS+1213 (ISP 48-3529 left, 49-3529 right). After market hardware to protect door and frame from attack.



Figure LSS+1214 (ISP 38-3529 left, 40 center, 42 right). In 38, the cutout required for the locking hardware shows the weakening of materials. The

result is the requirement of little force to fracture the mounting material and gain entrance.



Figure LSS+1215 (ISP 43-3529 left, 44 right). Little effort is required to compromise a jimmy-resistant bolt.

12_3.0 High-Security Locks

High-security locks are discussed in detail in **Chapters 10,** and **25-26-27.** They are utilized increasingly in commercial facilities to provide added resistance to both forced-entry and surreptitious bypass. High-security locks are classified because of a number of common characteristics, including:

- **Patent protection;**
- **Proprietary key sections;**
- **Keyways and blanks;**
- **High differing potential;**
- **Double independent locking systems (such as pin tumbler and sidebar);**
- **Special physical protection against forced-entry;**

- **Pick resistance;**
- **Key control;**
- **Resistance to penetrating tools, including impressioning, forcing, drilling, sawing, prying, pulling, and driving.**

Locks must be available in standard configurations for rim, mortise, key-in-knob, and padlocks. UL 437 Standard defines tests for high-security locks and is discussed in **Chapter 37**.

12_4.0 Knockoff and Inferior Quality Locks

In high-quality cylinders, brass or bar stock is used for the body and plug. Both may be drilled and reamed at one time to maintain closer tolerances. There is a vast difference in quality and materials between properly machined and produced parts and the knockoff. Inferior copies or **knockoffs** and poorly produced OEM locks and keys have flooded the U.S. and European markets. Although they look to be secure and well made, such appearance is often deceiving. In fact, inexpensive locks may offer little protection against forced or surreptitious entry.

Generally, inexpensive locks mean less quality control relating to tolerances. Simply stated: the maintenance of tolerances costs money. In locks, as with any other manufactured part, the consumer gets what he pays for. Predominantly manufactured in Asia, inferior locks can be readily identified by a number of traits. Poor quality, composition, tensile strength, thickness of metals utilized in production, and poor maintenance of tolerances is typical. In addition, the lack of adequate temperature control during the manufacturing process can affect metal crystalline formation and hardness, ductility, and strength.

Many production and design problems directly relate to the ability of a lock to withstand forced and surreptitious attack. Lock plugs and bodies, especially those that are die cast, can exhibit characteristics that will make them especially susceptible to picking. Typical defects include:

- **Poor hole alignment;**
- **Oversized pin chamber holes;**
- **Surplus chamfer on the top of the bottom**

pin and chamber;
- **Excessive clearance between the plug and the body.**

These locks provide less resistance to forced-entry. It is axiomatic that inexpensive cylinders, keys, strikes, and other hardware will fail under the stress that is encountered during an attack. Many factors contribute to such deficiencies, including:

- **Absence of drillpins or other protection;**
- **Heat treatment of the components;**
- **Quality and purity of metals;**
- **Strength and hardness of metals.**

PART C: General Locking Systems

Specific Principles of Operation

Part C deals with the most basic lock designs that are commonly found throughout the world. Each fundamental variance is described, from the simplest warded lock to the most complex electronic system. We begin with a discussion of the warded lock, followed by detailed information in subsequent chapters regarding the logical and necessary technical refinements to this simplest of mechanisms.

The Simplest Lock

Our discussion of the primary locking mechanisms must of necessity begin with two fundamental and interrelated questions: **what is a lock?** and **what is a key?** In order to grasp the following material and the information presented in the chapters detailing techniques of bypassing the various locking mechanisms, the reader must always be mindful of and ask these questions. Whenever working with a lock, these two fundamental questions have to be considered and understood before success can be achieved. This is regardless of whether a key is being produced, the combination changed, the lock is being rekeyed, or it is to be bypassed through picking, decoding, or impressioning.

Additional questions will generally explore related issues that are pertinent: **how does this particular locking mechanism work?** and **how does the correct key perform its function in this mechanism?** A thorough understanding and conceptualization of the

inner workings of each type of lock, and what precisely occurs as the key performs its function, is essential if one is to be successful in performing any operation involving locks and keys. Such an understanding is especially critical for success in picking or bypassing locking mechanisms.

So, what is the answer to our initial questions: **What is a lock** and **what is a key**? In its simples of forms, a **lock** is a mechanism contained within a physically secure enclosure of any size or configuration. It is fastened or secured to a door or other moveable piece. Its primary element is a **bolt** of varying size and length that can be shot into a staple or recess and rigidly held there until it is required to be withdrawn. Whenever the bolt is thrown, the door will be prevented from moving. A **key**, in whatever shape it takes, is simply a device for operating the mechanism within the lock in order to actuate or move the bolt to the locked or unlocked position.

The concept of a bolt being thrown through the control of a key is an idea that took many centuries to develop and implement. In the modern lock, many designs are utilized to add security to the bolt. These take the form of levers, wafers, discs, pin tumblers, sidebars, rotating wheels, or other sophisticated mechanical or electronic mechanisms. The **security** of any lock has two primary components: the capability to resist physical attack and its ability to reject all but the proper key, combination, or access code. As the number of permutations of keys, combinations, or codes increase, the lock can offer higher security, assuming other basic manufacturing criteria are met.

Each of the chapters in Part Two details a primary locking mechanism. The reader should keep in mind that in every design, regardless of the kind of lock, the goal is to make more difficult or complex the task of simulating the actions of the correct key to throw the bolt. **Picking** a lock is the correct and precise simulation of such action and will result in its being opened.

Four thousand years of evolving lock design, from the most elementary mechanisms to those incorporating the most sophisticated electronics, can be reduced to one relevant issue: **the difficulty in simulating the actions of the correct key to throw the bolt.**

Our discussion of the **warded** lock will begin to focus on the methods employed by lock makers to make "throwing the bolt" more

difficult without the correct key.

CHAPTER THIRTEEN: THE WARD

Warded Locks

Master Exhibit Summary

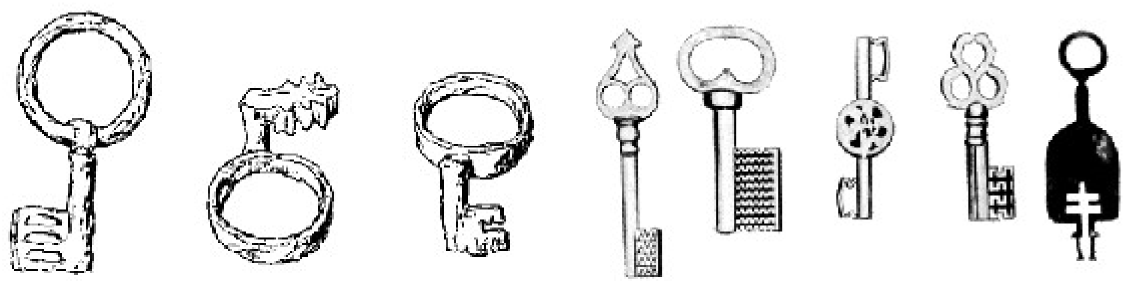
13_1.0 Introduction

The warded lock is the most basic mechanism and is used in applications where security is not the prime concern. As we shall learn, this lock has been in existence for thousands of years, and was the first facet in the lengthy development of modern locking devices. Inherent limitations in the original concept set the stage for future refinements and innovation in locking mechanisms. From simple wards, craftsmen and inventors over hundreds of years would conceive of levers, wafers, pin tumblers, discs, and other locking technologies to improve upon the wards limited security. The result: sophisticated mechanical and electronic locking devices that offered previously unimagined security and technology.

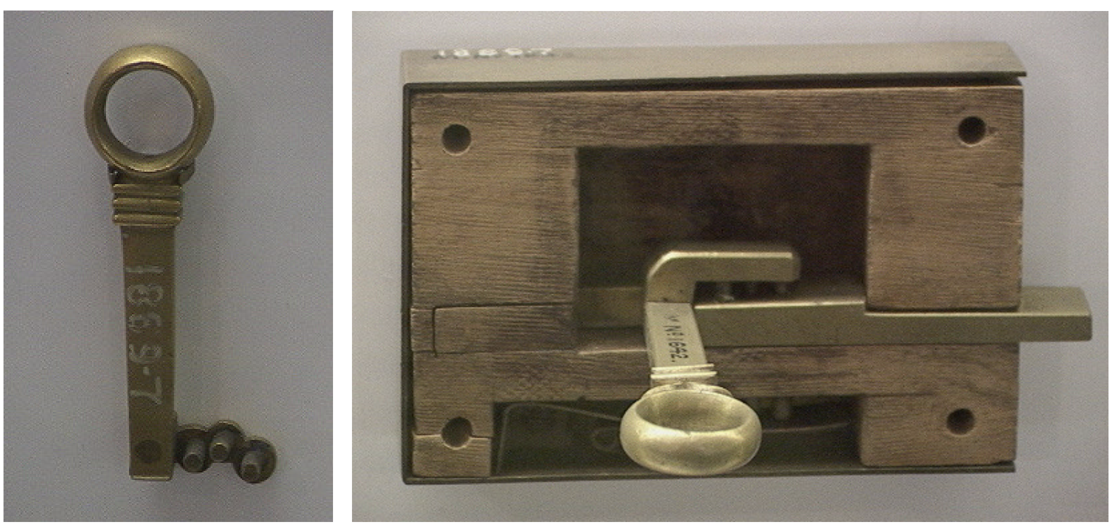
13_1.1 History and Development of the Warded

Lock

It is unclear where the warded lock was first designed and produced. Warded-type **keys** were found in the volcanic lava that buried Pompeii, Italy, in 64 AD. It is likely that the Romans were first to develop and employ wards as a means of making a lock more secure. Perhaps the Etruscans in Northern Italy conceived the warded design, although it is known that the Greeks and Egyptians also knew of the mechanism.



Romans were skilled in their work with metals. They realized that large keys and bolts were impractical. It was a relatively simple matter to bypass such large components to open early locks. Thus, mechanisms with smaller openings and throw bolts were fashioned.



LSS+1301 Example of Roman key and lock, from the ruins at Pompeii, 79 A.D.



Figure LSS+1302 Examples of early Roman keys.

The logic appears to have been that the complexity in the design of a key made for more security. As the ward developed, keys became extremely complicated and intricate, creating a maze of angles in the bitting.

We know from remnants of Pompeii that keys rotated less than 360°, once inserted into door locks. Thus, it would appear that the Romans also invented the spring-loaded bolt. These door fastenings were different than employed by the Greeks or Egyptians. Like a padlock hasp, the latches joined short lengths of chain to effect fastening. The combination of complex keys and bolts made for much more secure locks.

The ward, comprising one or more hidden devices, would block entry and frustrate the movement of any except the correct key. During the Middle Ages, locksmithing flourished and ward designs became increasingly complex as well as works of art.



The need for more and more security grew as robber barons pillaged the countryside. For the landowners and men of wealth, possession of handsome locks guarding castles and their valuables was a status symbol; the locks were things of pride and prestige.

As society generated and accumulated more wealth and riches, lock development and refinement continued. The craftsmen responsible for security hardware were the locksmith guilds, originally formed during the Middle Ages. These powerful groups regulated terms of apprenticeships, rules and conduct for journeymen, and all manner of production from prices of locks to the number of rivets. Such strictness helped to maintain the integrity of the trade. Locksmithing would remain a father-to-son enterprise until the nineteenth century.



Figure LSS+1303 A key from a French lock, fourteenth or fifteenth century.



Figure LSS+1304 An Australian door lock, eighteenth century.

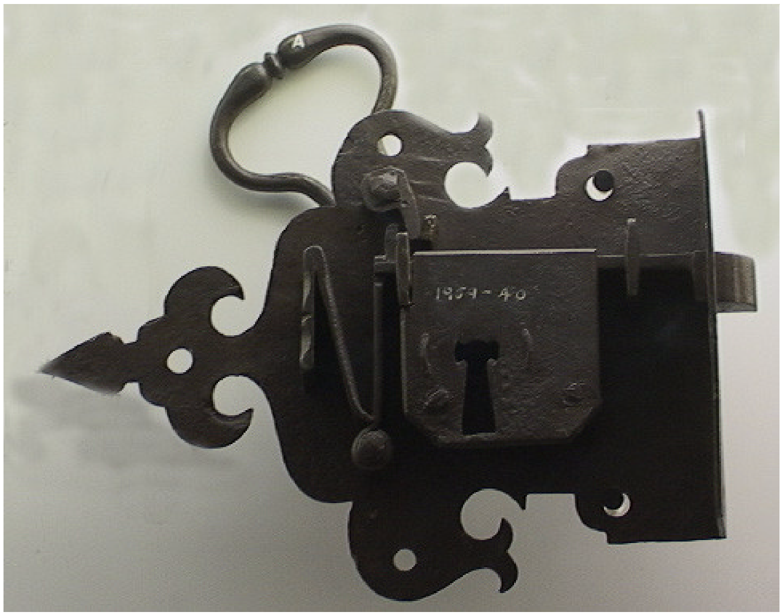


Figure LSS+1305 A Flemish door lock, seventeenth century.

The warded lock was the only reliable security device for several centuries until the development of the lever and then the pin tumbler lock. It was an extremely popular locking device and remains so to this day and in many applications. The lock provided a powerful tool to the guilds, allowing them to offer security to their clients.

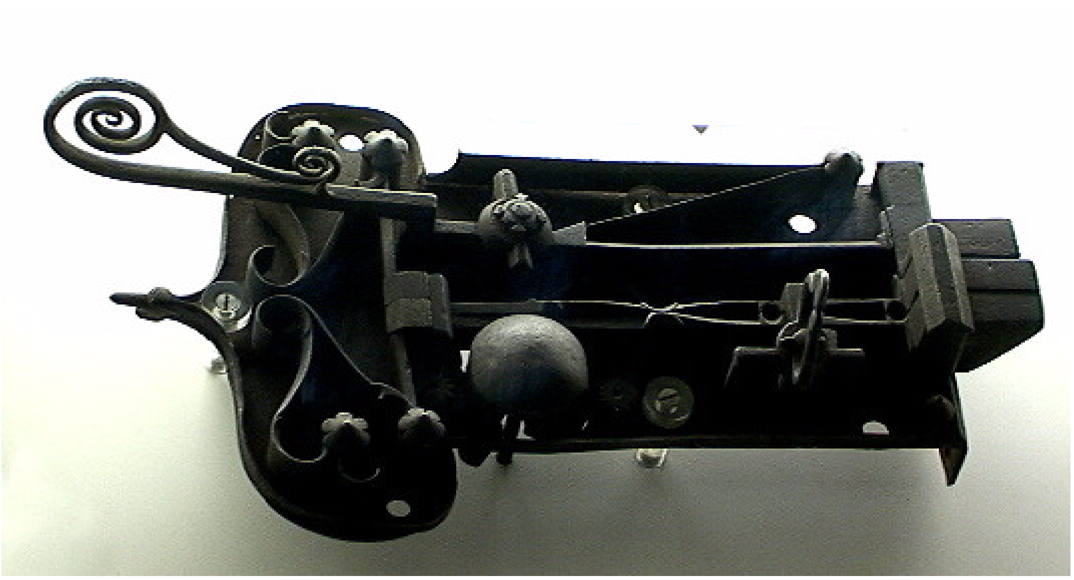


Figure LSS+1306 German door lock, seventeenth century.

The science of locksmithing did not progress much after the

nineteenth century beyond more intricate designs to confuse the thieves. False keyholes, false wards, and lots of "gingerbread" were the order of the day. Chests that cut off fingertips, fired pistol shots, had secret panels, or ejected murderous knives were produced. However, the basic design of the warded lock remained the same from the Roman period until the Renaissance, when the lever lock was invented.

The problem with the warded lock was that it left very little opportunity for truly improving the security of the device, past the many gimmicks noted above. One of the locksmithing development centers of the world was in Willenhall, England, and later, Wolverhampton. The Willenhall locksmiths understood that any warded lock could be picked. This realization would ultimately lead to the conception of the lever.

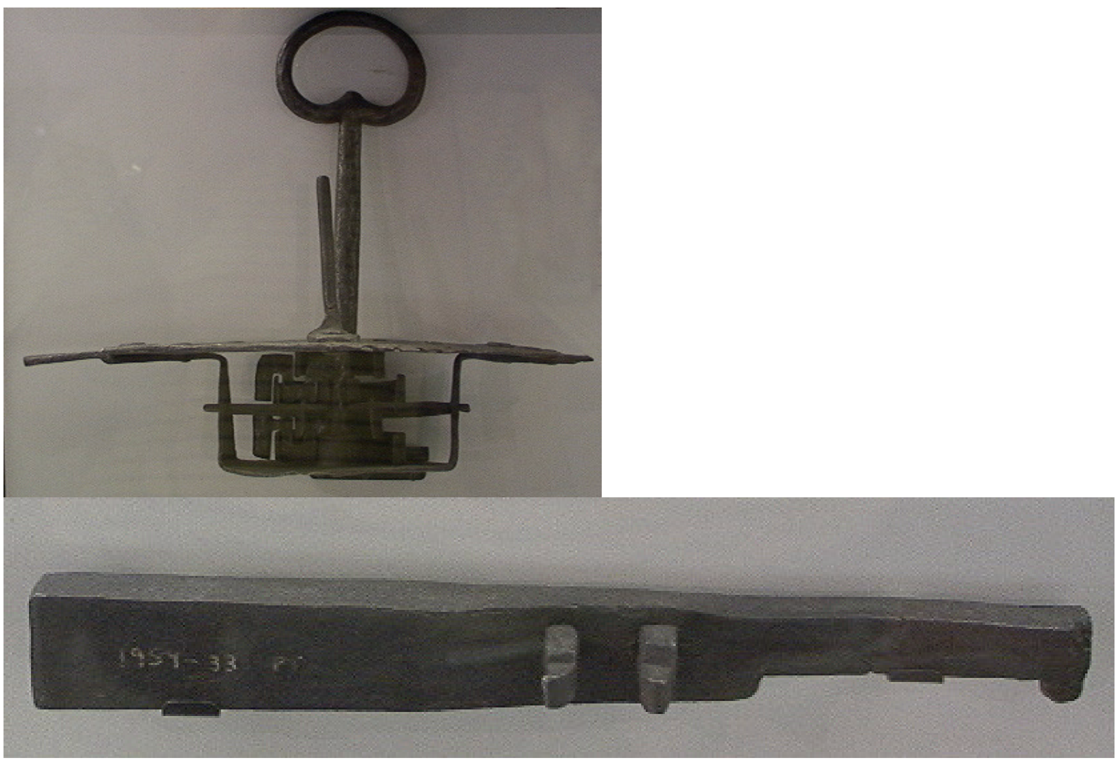


Figure LSS+1307 An English door lock and key, eighteenth century.

What the warded lock design provided was the first essential component in the modern, secure locking device: the concept of a **keyway**. Wards are an obstruction to prevent the key from entering or turning within the lock. Although wards are placed in various "hidden" positions, in some ways the same effect is obtained by a combination of wards forming a keyway. Their

purpose is to block all but the properly grooved blank from entering. In modern locks, keyways have replaced other forms of fixed wards.



Figure LSS+1308 An English lock and its key, sixteenth century.



Figure LSS+1309 Another example of an early English lock and its key,

13_1.2 Applications of the Warded Lock

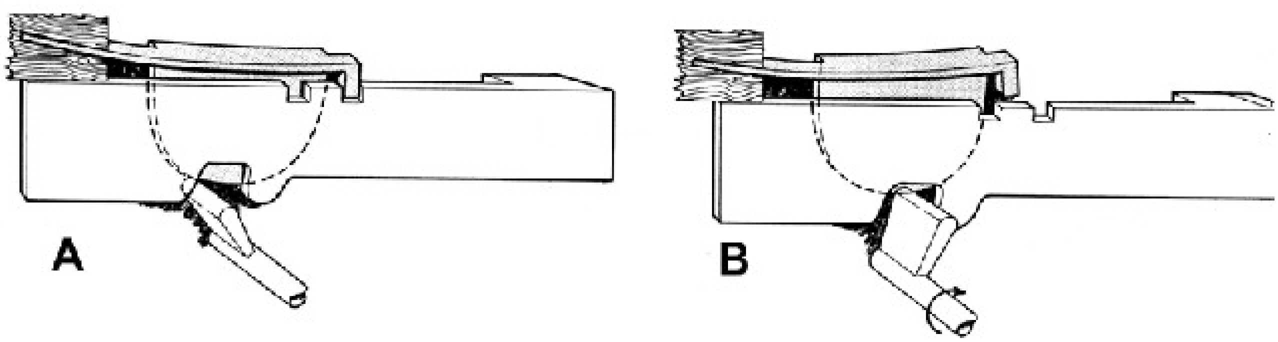
Warded locks are found in applications requiring minimal security. They are primarily employed in padlocks and in older homes and hotels using a mortise configuration. Luggage, cabinet, handcuff, and some jail and prison locks all utilize the warded principle. The Master laminated padlock is perhaps the best known application of the principle. Every schoolboy has at one time used such a lock to secure his locker or bicycle. Specially designed higher-security warded locks have been used in

some jails and prisons. Today however, lever or pin tumbler devices have mainly replaced them.

Simple master keying systems have been developed for warded locks. A limited number of different key combinations are available, and thus, keyways may often be varied where many change keys are required. Master (skeleton) keys are designed to pass all different keyways and wards within a particular system.

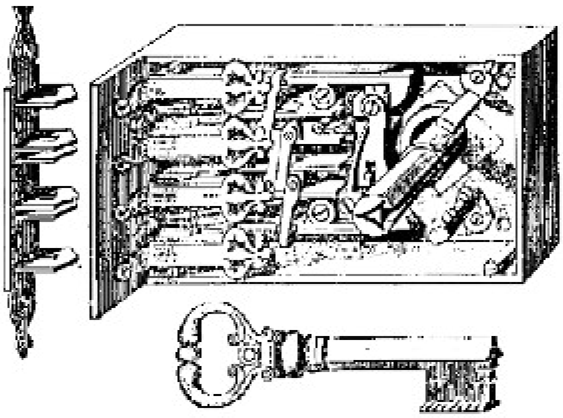
13_2.0 The Warded Lock: General Operating Principles

The concept of security in a locking mechanism took root in the development of the warded lock. The ward was thus an extremely important development. Prior to its introduction, security in locks and containers took many forms, relating to exterior devices to block the entry of keys. The ward was the first attempt to internally control which specific key would properly function, after entry into the lock.



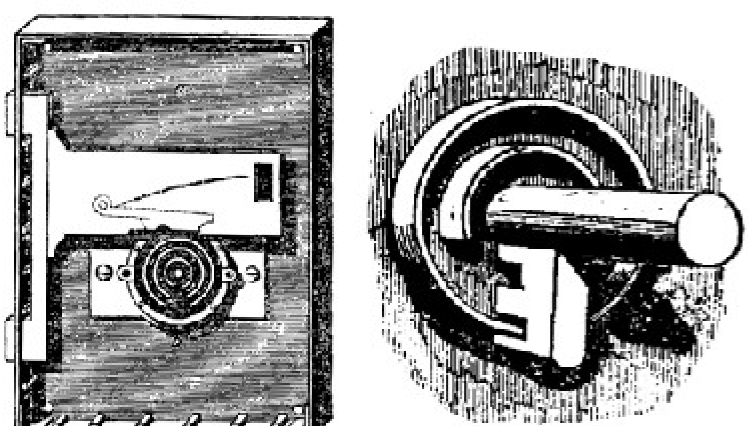
All warded lock configurations are based upon the same principle; they have existed with little modification since being invented by the Romans. Wards offer limited security because skeleton keys can be produced for them.

A lock, in its most elementary form, consists of a bolt and a method of throwing it. The warded lock introduced the first refinement to this basic principle. Its designers placed barriers or wards in secret locations within the lock to block the movement of the bolt until the correct key was inserted. Wards may take many forms; however, they all perform the same function.



Within the mortise lock, for example, wards are generally circular raised metal strips and placed concentrically around the keyhole post. They will prevent the insertion of all but the correct key, and until all wards are passed, the key cannot make contact with the bolt. Thus, for the correct key to operate a warded lock, it must have corresponding ward cuts to allow its entry and rotation. This will permit contact with and actuation of the bolt.

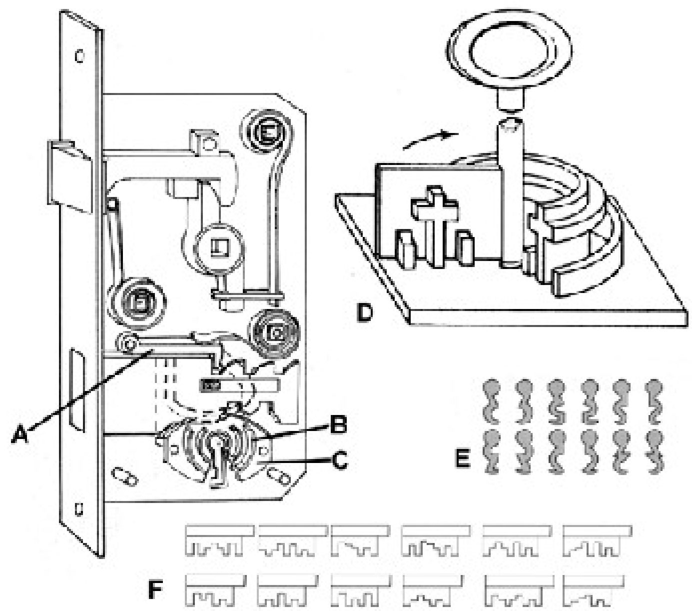
The security of the lock lies in the placement and number of the wards. Depending upon the design, there may be few or many of them. Producing locks with different keyways may further enhance security. This will prevent keys with the same ward pattern, but different keyway configuration, from entering the lock.



A B

The much-heralded security of the warded lock was rather short lived, for it did not take long for thieves to learn how to bypass these mechanisms. It was found that they were simple to

pick, impression, and produce skeleton keys that would circumvent all wards.



Exploded view of different keyways.

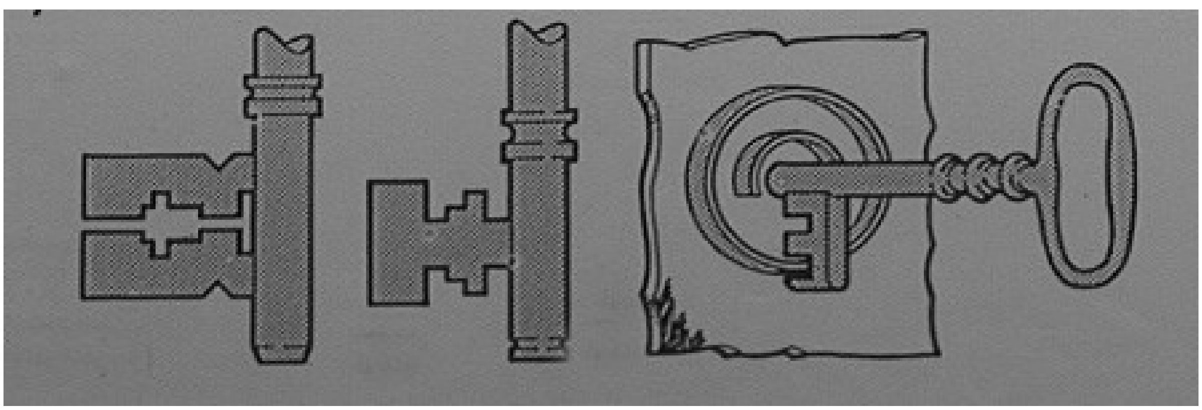


Figure LSS+1310 A detailed view of the typical warded key, and its interaction with fixed wards within the mechanism. For every obstruction within the body of the lock, there must be a corresponding absence of material on the bitting of the key.

The design of wards within cabinet locks closely resembles the basic design of the mortise lock, although with a less complex key design. The ward configuration for the padlock differs in the relationship between the key and the bolt/shackle-release mechanism. The basic principle, however, is still the same: metal barriers are utilized to keep the key from rotating until

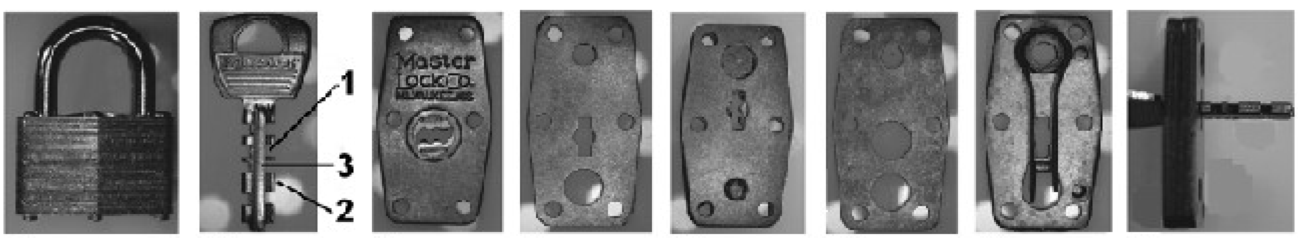
corresponding sections of metal in the key are removed.

13_3.0 The Warded Lock: Basic Design Configurations Operation

Warded locks come in three basic configurations: **padlocks**, **cabinet locks**, and **mortise locks.** Although each design applies the warded locking principle, construction and operation is slightly different for each.

13_3.1 Warded Padlocks

Padlocks probably comprise the largest single use of the warded principle, at least in the United States. Master Lock Company manufactures the most popular warded padlock. It is constructed of laminated steel sheets, which determine the location of wards.



A B C D E F G H

13_3.1.1 Definition of Terms

The principle components of the warded padlock are defined below.

Key: The critical portions of the key are the **bow, blade, ward cuts, and tip.** The bow provides a handle; the blade is the bitting surface; ward cuts are made on the blade; and the tip provides an anchor and reference seating for the key.

Keyway Plate: This round insert actually forms the keyway. It is a stamped piece of metal creating grooves that block entry of all but the correct blank.

Pass Plate: This lamination allows an uncut key to rotate without obstruction. The plate simply has a hole cut in the center, in contrast to the **ward plate** which actually blocks rotation of all but the correct key.

Ward Plate: This piece will block rotation of a blank key. In order to rotate around the ward plate, the key must have a corresponding cut.

Tip Stop and Guide Plate: This component is located at the far end of the keyway and is the last plate to make contact with the fully inserted key. Its purpose is to center and stop the key.

13_3.1.2 Specific Principles of Operation

Several wards or obstacles form part of the body of the lock and act as a blocking device to the key's rotation. When the proper cuts are made, the key is allowed to turn and release the shackle. The compression of one or more spring steel bands retains the shackle in a locked position. The bands are spread when the key rotates, thus allowing the release of the shackle. There can be any number of wards placed in the padlock, enabling the manufacturer to offer many different key combinations. The keyways can also be varied, thus adding to the number of differs.

Wards are formed using ward plates stacked between pass plates. The ward plates conform to the dimension of a blank key in terms of the overall width of the blade. An uncut key is prevented from rotation until an equivalent thickness of metal is removed from the bitting, at the precise location corresponding to the position of the ward. The key will turn and release the shackle if:

- **A cut corresponding to the position of each ward is made on the blade;**
- **The key makes contact with each locking band and is free to spread them to a greater diameter than the shackle. There may be up to three spring wires or bands that hold the shackle in place.**

13_3.1.3 Keys for Warded Padlocks

The design of the padlock allows the use of skeleton keys to bypass all wards and open every mechanism. Keys for warded padlocks are either single or double sided. Double-sided patterns are normally symmetrical, so the key may be inserted and rotated in either direction to open. The keys usually appear in the form shown. Note the square cuts match the size and position of each ward.

Warded padlocks are often used outdoors and may be subjected to environmental changes without adverse impact. The simplicity of the mechanism makes them quite reliable in difficult conditions. Although warded padlocks have strong shells or casings, these have no effect upon their resistance to picking and impressioning. Their heavy protective coverings may shield them in the case of brute force attack, however.

13_3.2 Cabinet Locks

Warded mechanisms are used in cabinet and drawer locks. These operate on the same basic principle as those found in mortise locks. They offer little security and are really a convenience lock. A long post, having a hollow or pointed end with a rectangular piece of metal secured to it, characterizes the key. The pin, which projects from the center of the lock, acts as an anchor for the key and for an axis upon which the key rotates. In this type of mechanism, the wards take the form of spring steel wire set around the central pin. To allow rotation, the key must have slots cut to fit over and pass these wards.

13_3.3 Mortise Locks for Residence and Hotel

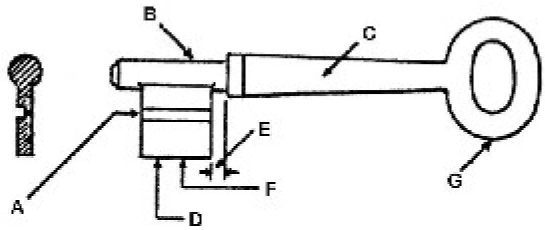
In many parts of the United States and throughout Europe, warded locks were widely used in hotels and residences. The basic design is that of the cabinet lock, except that the mechanism usually has a greater number of wards to pass, which are physically larger. There were actually two varieties of warded locks for this application. The simpler design featured different keyways as the only block to actuation of the bolt; any key having the proper keyway could move the bolt. In the more secure designs of the mortise lock, keyways could be varied as well as the position of wards.

The mortise **lever** lock would replace the warded mechanism in many parts of the world, dating back a hundred years or more. Keys for warded and lever locks can appear in exactly the same configuration. Without an examination of the internal components, if may be impossible to tell the difference from the exterior. Attempts at picking and impressioning will indicate the tumbler design.

13_3.3.1 Definition of Terms

The following terms describe the actions and components of the

warded mortise lock.



Barrel Key: A barrel key or pipe key is constructed with a long hollow shaft to the tip, where the bitting is attached to the barrel. The barrel rotates around a pin, protruding from the center of the keyway. The pin anchors the key and maintains its position once inserted.

Bit Key: This describes a key with a bit projecting from its shank, in contrast to the barrel key that has a hole in the end of the post.

Bow: The portion of the key that forms a handle.

Bullet or Bulleted: The longitudinal grooves on the bitting of a warded key that match grooves in the keyway. A key that does not have such correspondingly shaped grooves will be prevented from entering the lock.

Collar: The flange or projecting rings on the shank that prevents the key from being pushed through the lock.

Collar Ward: The ward that surrounds the circular portion of the keyway, and provides for a bearing surface for the tip of the key.

Drill Pin: A fixed stump or pin within the lock on which a pipe key fits in order to allow rotation.

Key Bit: That part of the key that enters the lock and meets the wards.

Key Blank: A key, having the correct keyway, which has not been cut and which may be shaped to fit a particular lock.

Mortise Warded Lock: A warded lock inset into a door.

Nib Ward: The simplest type of ward and which is formed by making

a depression on a metal plate. A plain slot in the bit of the key will pass the ward.

Pin of Key: A key with a solid circular shank and projecting bit. When inserted into a warded lock, it rotates around the shank.

Pipe Key: Same as **Barrel Key**.

Rotating Wards: These are made of steel wire and are placed in a circle around the keyway. The correctly-cut key moves over these wards.

Shank or Stem: The long stem connecting the bow with the bitting of the key.

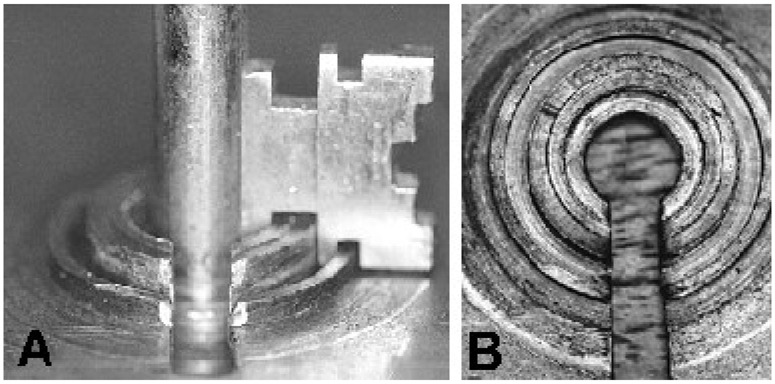
Skeleton Key: A key with much of its bitting removed in order to pass all of the wards and thereby allowing actuation of the bolt.

Ward Gauge: A device to measure ward depths for a particular key. This can take the form of a strip of metal that is cut with the different ward depths in ascending order. The ward gauge is utilized to reproduce keys.

Warded Key: A key having notches or cuts to correspond with ward locations within a lock.

13_3.3.2 Theory of Operation

The warded mortise lock operates on the same general principle as the padlock. Wards are placed internally, to form an obstacle to insertion and rotation of the key, until they are passed. These wards generally take the form of raised metal strips, which are concentrically placed around the keyhole post. To clear these obstructions, the bitting must be cut so the wards can pass through the square-shaped slots in the key. Until all wards are passed, the key cannot make contact with the bolt.



13_3.4 Handcuff Locks

Many handcuffs use a very simple form of warded lock, employing a keyway with a post. The key rotates in order to release a ratchet mechanism. These locks may be easily bypassed. Ball-point pen cartridges, paper clips, pieces of wire, and anything that can simulate the shape of the key will work if the mechanism has not been double-locked. The more inexpensive handcuffs can also be pried apart, by applying pressure at the pivot point where the halves are joined together. In addition, a fine metal shim may be utilized to bypass the ratchet mechanism. See **Chapter 23**.

13_3.5 Jail and Prison Locks

Many prisons and jails throughout the world are still using the warded lock. They are massively constructed but operate on the same principles as other warded designs. The keys are very large and difficult to duplicate. Attempts to pick these locks usually include the use of large objects such as spoons, ice-cream sticks, tooth brushes, etc.

13_4.0 Producing Keys for Warded Locks

It is never necessary to take a warded lock apart to produce a key for it. There are a number of techniques for learning the location of the wards. These methods are described in **Chapter 30**, "Impressioning." Regardless of design, all keys must perform the same function: pass all wards to allow entry and rotation, to actuate the bolt.

13_4.1 Pipe Key

In the **Pipe Key**, the stem is the hollow part connecting the bow with the bitting portion. The pipe will fit over a corresponding post in the lock. If the stem is solid, it will seat in a corresponding hole in the center of the lock. The bitting or bit is the "working" portion of the key. All bits are essentially rectangular and cut in steps, corresponding with the ward positions. Square slots are made on various surfaces of the key to pass the wards. A Warding file is used for this purpose.

Little precision is required when cutting warded keys, if the goal is simply to allow the key to open the lock. This is because wards are affixed to the shell or casing. Therefore, as long as the cuts on the key are wide and deep enough to pass the wards, the key will be able to turn and operate the bolt. So it doesn't matter if the key is cut too deep or too wide; the mechanism will still operate. The poor tolerance required of the keys contributes to the locks rating as a low- security device. Skeleton keys can be created which will open all warded locks by simply cutting away **all** of the bitting, except for that area required to come into contact with the bolt.

13_4.2 Padlock Keys

Warded padlock keys are all similar in appearance. They are cut on both sides in symmetrical form. The Master padlock is typical of such mechanisms. A set of five skeleton keys will open virtually every one of these padlocks.

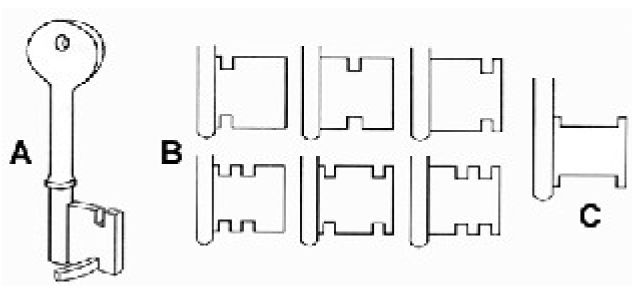
13_4.3 Specialty Warded Keys

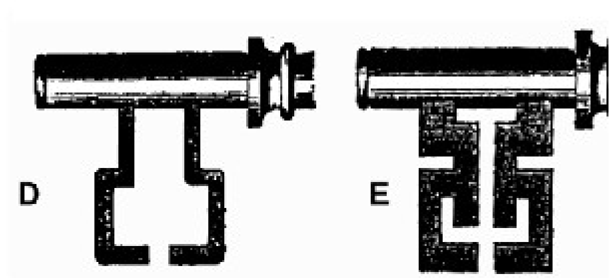
There are thousands of variations of warded keys for luggage locks. There are a number of catalogs available to locksmiths that offer precut luggage, cash box, mailbox, and other keys. For certain types of trunk keys, there is a master book that was originally printed by Bernard Zion in the 1930s, by Majestic Lock Company. This catalog has become the sourcebook for these types of keys. Locksmiths simply traced the design from the drawings.

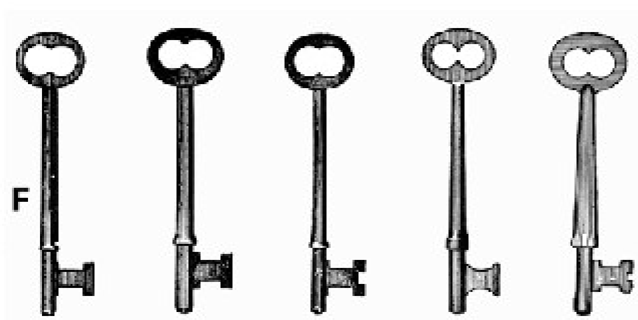


13_5.0 Security of the Warded Lock

Warded locks do not provide any level of security due to the ease in determining the location and number of wards, as well as the simplicity in picking and impressioning. Their entire security is based upon the hidden location of the wards and variations in the keyway. A maximum of approximately one thousand different change keys may be available for any particular keyway series. Key combinations cannot be changed. This means that if a lock has been compromised, as in the case where a key has been lost or an unauthorized key has been obtained, the lock simply must be taken out of service. A patent was granted to Soref in 1927 for a modified design of a skeleton key (**1645407(147)**) which the inventor called a master key. See also Pankratz for his 1921 patent of a skeleton key and method of removal of a warded key from one side of the lock (**1370552(148)**).







CHAPTER FOURTEEN: THE LEVER

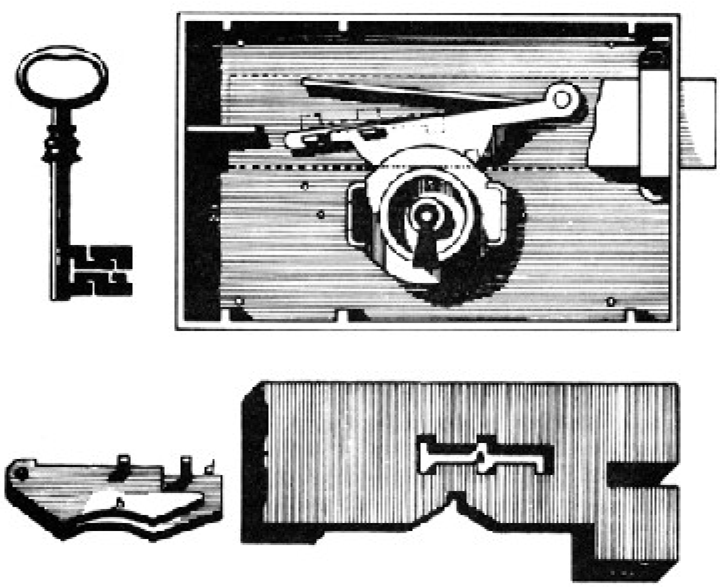
The Lever Tumbler Lock

Master Exhibit Summary

14_1.0 Introduction

This chapter examines the development of the lever lock, initially introduced during the Renaissance. It traces its subsequent evolution and refinement over the next two hundred years. The fundamental lever principle marked the first real innovation in secure mechanical locking design; it vastly improved upon the warded lock described in the previous chapter.

Usually constructed of brass, aluminum alloy, zamak, or steel, the lever tumbler lock can be found in many different applications, meeting varying security requirements. These locks are popular in padlocks, post boxes, coin telephones, safe-deposit boxes, lockers, safes, cabinets, cash boxes, jails and prisons, and other uses. The lever signaled the introduction of the first locking mechanism that offered a basic design change from the warded lock. It provided the conceptual framework for many improvements and variations during the next two centuries. The lever mechanism, by its inherent design, made possible the development of truly secure locks that would have been impossible using wards.



The lock's history and significant technical advances are chronicled here because of their impact upon the field of locksmithing. Their cumulative impact upon the lever, wafer, and pin tumbler mechanisms cannot be underestimated. A careful analysis of many of today's locks and locking concepts will show they are but variations of the original lever principles. An examination of the lever lock, from the perspective of picking and impressioning, is presented in **Chapters 29-30-31.**

14_1.1 Development of the Lever Lock

Many engineers, scientists, metal workers, and craftsmen played vital roles in the evolution of the lever lock. Barron, Chubb, Bramah, Hobbs, Newell, Andrews, Petit, Parsons, and many others will always be remembered for their ingenious contributions, culminating in the high-security lever devices available today. These men challenged each other and the world to continually develop more security. Their rivalry led to the most important design developments in 3000 years. Perhaps the greatest catalyst was A. C. Hobbs, the American locksmith who galvanized the London Exhibition of 1851, by picking the impenetrable Bramah lock. The race to design a better lock was now at a feverish pitch; the lever was one product of that impetus.

14_1.2 The Lever Lock: Initial Concept and Design

With the exception of the Egyptian pin tumbler, most locks prior to the eighteenth century relied upon a system of wards as described previously. Around the middle of the nineteenth century, the Willenhall locksmiths recognized that warded locks could be easily picked or otherwise bypassed. An alternative was required. They were searching for a mechanism that could not easily be opened, even if the burglar knew the internal design of the lock. The lever provided the concept that offered security against picking and other forms of compromise. Actually, the true benefits of the design were not completely recognized during the Renaissance.

Although we do not know who first developed the lever concept, it is clear that it was produced in response to the ease with which the warded lock could be compromised. There is a reference to the lever in an 1819 British patent, although its precise origin is unknown. Whatever the source, the introduction of the lever caused a revolution in lock design.

14_1.2.1 Banbury Lock

It appears that Banbury introduced the actual forerunner to the lever lock about 1700. In his design, the key raised the lever from a notch in the bolt, allowing it to slide and permitting a catch to fall into a second position. The bolt was then forced forward. The height of the lift was immaterial so long as the

notch was cleared. These locks were made of wood, with metal parts inserted in slots cut into the housing. The first designs had few parts. They consisted of the case, bolt, and lath, which was a piece of metal that formed a continuation of the bolt. The bolt head and the talon, or angled cut in the bottom of the lath, completed the mechanism.

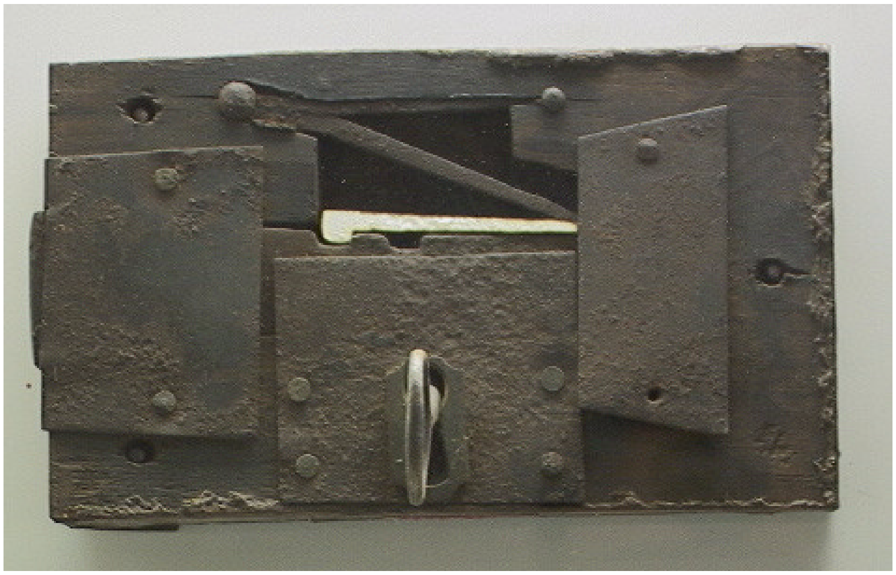


Figure LSS+1401 The original Banbury lock.

14_1.2.2 Barron Lock

In 1778, Robert Barron, an Englishman, conceived, patented and produced the **double-action** lever lock and is credited with its invention. The lock was the first mechanism to offer any significant security against picking, resulting from its design and high manufacturing tolerance. As will be noted in **Chapter 29**, the Barron lock did suffer from certain design defects with respect to picking.

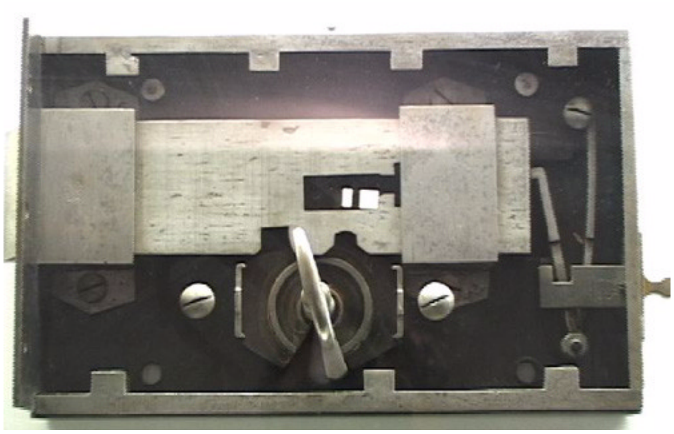


Figure LSS+1402 The original Baron lock.

Levers were not only used to secure the bolt but to surround, hold, and block its movement until the correct key was inserted. This feature distinguished the lock from its predecessors; originally, the purpose of the lever was to hold the bolt in one position. Ultimately, several levers would be added; this eliminated the use of tricks and false patterns that were common with warded locks.

The Barron lever lock is important for several reasons. Although there were earlier designs that used a bolt containing a stump to block movement, Barron actually conceived the double-action technique. This, combined with the use of two or more levers, (each of which had stumps on their end), provided the beginning of real security and fundamental changes in design. The stumps were required to pass through a slot on the bolt latch when in their correct positions.

The bolt of the Barron lock was cut with a gate or squarenotch behind which were two or more levers. Each lever end had a square corresponding projecting stump that would stop the bolt from moving. When the correct key was inserted, it would lift all of the levers until their stumps cleared the notches. The key could then be rotated further, to slide the bolt. If any of the stumps were positioned either too low or too high with respect to the levers, the bolt was held fast and the lock could not be opened.

The double-action concept is readily understood when it is realized that if the tumbler either was under or over-lifted the stump could not pass. There were two claims in the Barron patent: one dealt with the location of the lever with regard to the stump; and the other, the projection of the bolt through the

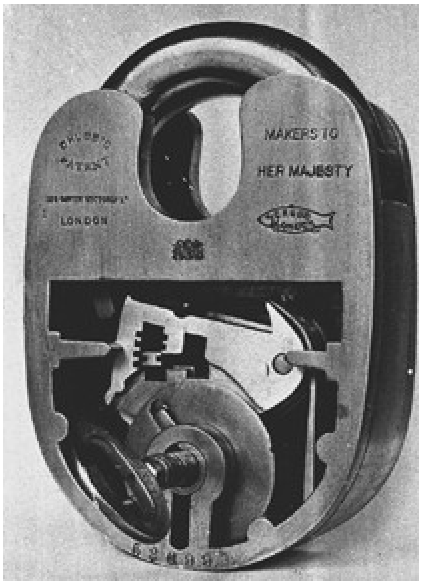
lever. Refinement of the Barron patent is evident in every lever lock in use today.

14_1.2.3 Chubb Detector Lock

The Chubb family of Wolverhampton made many vital contributions to the development of the lever lock. Charles and his brother Jeremiah eventually opened a lock factory in 1818, after patenting their immediately successful Detector lock. This facility is still in existence and is a world leader in the development and production of locks and safes. Even by the end of the nineteenth century, their products were known and respected throughout the world.

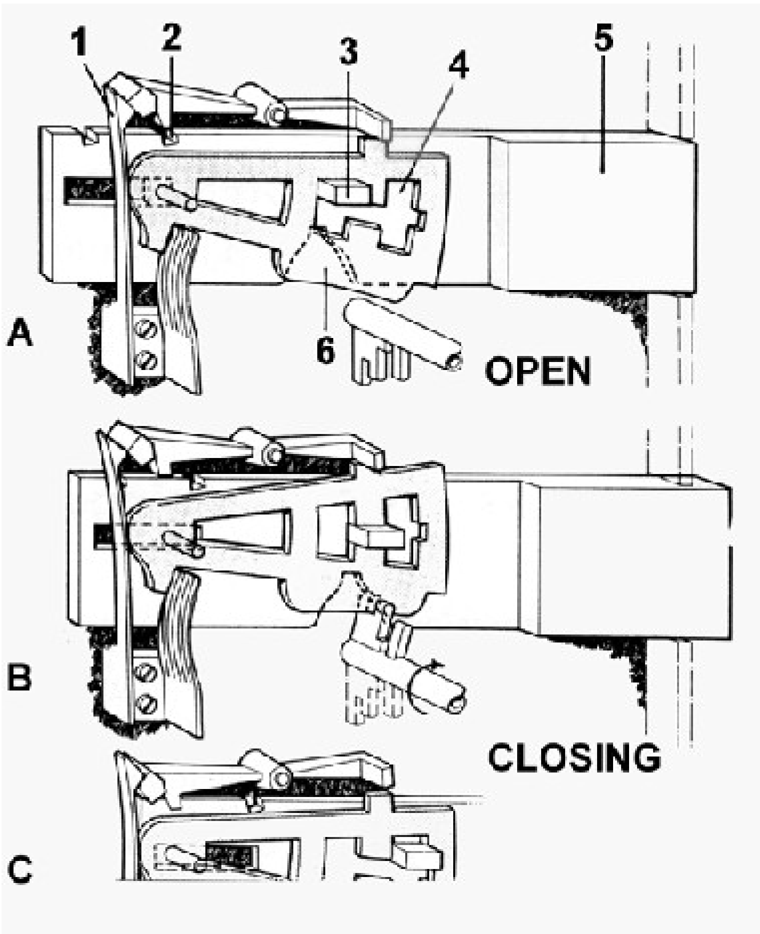
Prior to their entry into the lock-manufacturing business, the brothers, in 1804, had opened an iron-mongering enterprise in Portsea, England. There, they gained valuable experience in metalworking that would prove decisive in their later development of locks. Jeremiah analyzed the revolutionary Barron lever lock and found deficiencies in its design. As a result, the lock that Chubb first offered was quite different in practice from that patented by Barron, although the locking method was essentially the same.

In the Barron lock, the gate was incorporated within the bolt, allowing multiple stumps that were part of each lever to pass through it. In other words, stumps or projections were located at the end of each individual lever, at different vertical positions. They were aligned to one horizontal plane by lifting each lever to a different height through the action of the key and its varying depths.



Chubb decided that the locking process should be, in effect, reversed from that conceived by Barron. Chubb placed the gates on each lever with one corresponding stump on the bolt, rather than placing stumps at the end of each lever with one large gate in the stump. The locking action of Chubb and Barron are functionally the same. In the Chubb design, the gates form part of each lever. All levers must be individually raised to clear the stump, which is affixed to the bolt. It can be seen that the bolt can only slide if the stump is clear to enter all of the gates within the levers.

Chubb is best remembered for the introduction of the **detector**, around 1827. This was a special device fitted on certain locks to increase security. It provided notice of attempted entry caused by the use of the wrong key or by picking. Chubb determined that to open the lock in either case, the thief would be required to sequentially lift each lever to its proper level. In doing so, over-lifting usually would occur. There have been a number of modern improvements in lever lock design that were based upon the original detector theory. Chubb was granted a patent in 1993 for example, for a similar mechanism (GB **2264531A(149)**).



The purpose of the Detector would be to react to and record this over-lifting. It did so by locking an added lever into a special position within the bolt, which would block movement of all other levers and prevent the bolt from moving. Over-lifting of any lever above the drop-in point of the stump into a gate would trigger the Detector.

The Detector would warn a lock owner of any attempt to open and made picking virtually impossible. A special key was required to reset the Detector once triggered in order to allow the lock to be opened. In 1878, Chubb also introduced a double-sided detector latch that incorporated notched or serrated levers. This further frustrated picking attempts. Saw teeth placed in the ends of the levers that would mesh if raised improperly were also employed. Serrated levers are in wide use today in high-security applications.

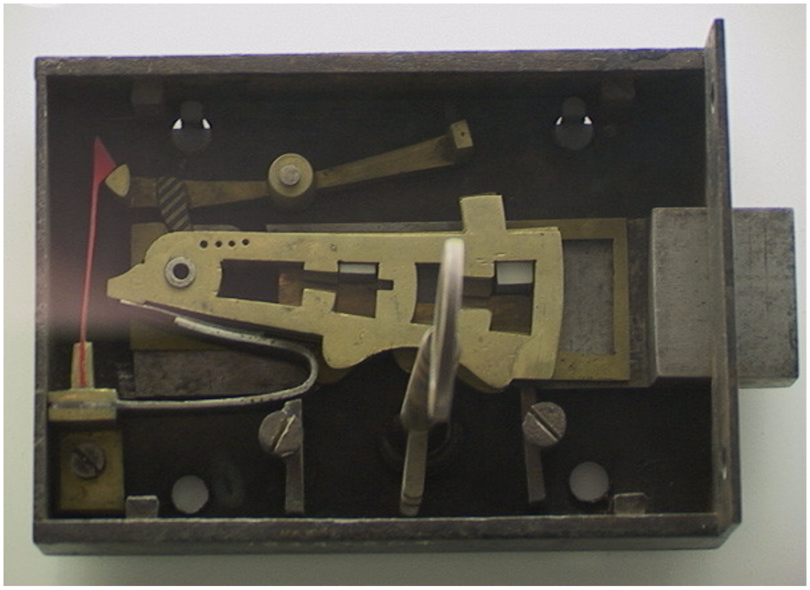


Figure LSS+1403 Chubb Detector lock, 1827 design.

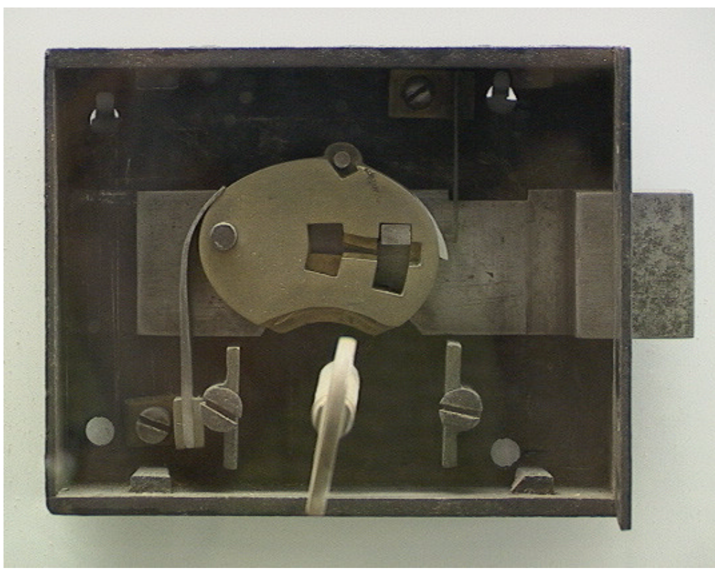


Figure LSS+1404 Chubb Detector lock, 1837 design.

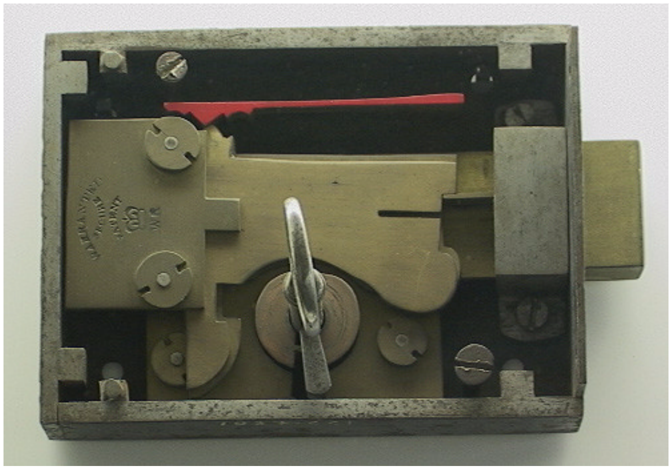


Figure LSS+1405 Chubb Detector lock, 1837 design. Note the detector arm that locks into place upon overlifting (in red).

14_1.2.3.1 Picking the Chubb Detector Lock

Chubb developed an anti-picking curtain after his lock was compromised with a lighted taper that was employed to smoke the levers. The technique is discussed in **Chapter 30.** Chubb realized that once the levers were covered with carbon, a blank could be inserted and rotated until contact was made with each lever. The points of contact could then be read by inserting a small mirror on the end of a wire with a finely focused light. It was easy to see where the bitting had contacted the bellies of each of the levers.

Through smoking, the lock picker now had vital information. He knew where the key would make contact and where the key would begin lifting each lever. With practice and patience, the levers could be lifted to the correct level without tripping the Detector. In 1883, Chubb provided the solution: the rotating barrel and curtain. This simple invention closed the keyhole when the key was turned, preventing both the insertion of a picking tool and the feeling of the interior of the lock. Security against picking and impressioning was greatly enhanced.

14_1.2.4 Tucker and Reeves Shifting Bolt Lock

Patents were issued to Tucker and Reeves, first in 1851, for a shifting bolt lock. This device was specifically designed to frustrate picking attempts that relied upon a technique of placing back pressure on the bolt. In their lock, they made the bolt so that it floated to allow one end to rise and fall. If

pressure were applied, the bolt would shift up and down, making it difficult to determine when each lever was raised to the correct level.

A second patent was granted to these inventors in 1853 for their Safeguard Lock. Four wheel-shaped levers were mounted and rotated around a central pin that was enclosed in a moveable barrel that formed the keyhole. The key actually entered the lock through a second keyway that was offset from the operating keyhole. The design of this lock made it impossible to insert picking tools to reach the levers, because the stump on the bolt could not enter the gate until the key turned the moveable barrel. Any picking attempts utilizing pressure would be frustrated.

14_1.2.5 Subsequent Refinements

Three inventors developed further refinements to the original detector lock. In 1852, a patent was issued to **Hobbs** for his six-lever protector lock. It had five traditional levers, with the stump mounted on another lever on the rear of the bolt that could not be seen. Picking would cause pressure to be applied to the bolt, triggering the sixth lever horizontal-arm to jam the action of the bolt.

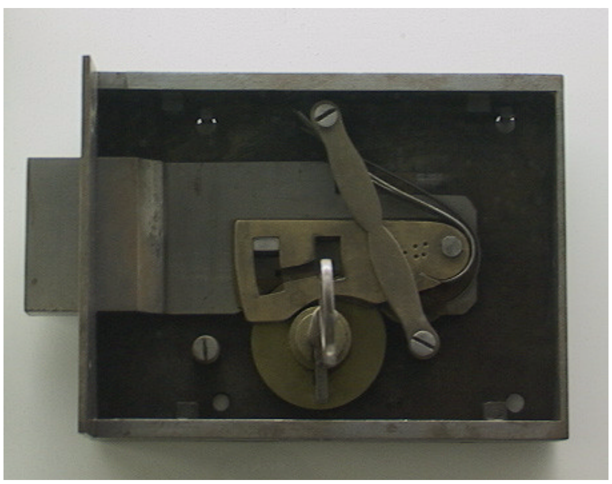


Figure LSS+1406 Hobbs six lever protector lock.

Then in 1859, the **Hamps** double-action lever Detector was introduced to improve upon the Chubb invention. The lock had two sets of four levers operating in tandem. The Detector worked on both sets of levers, thereby increasing security.

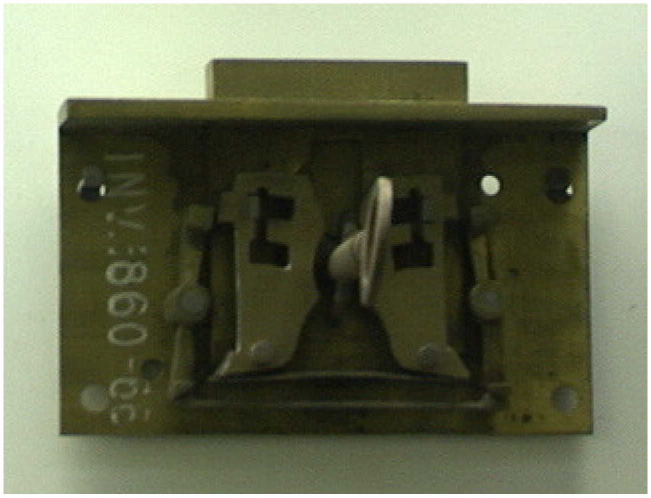
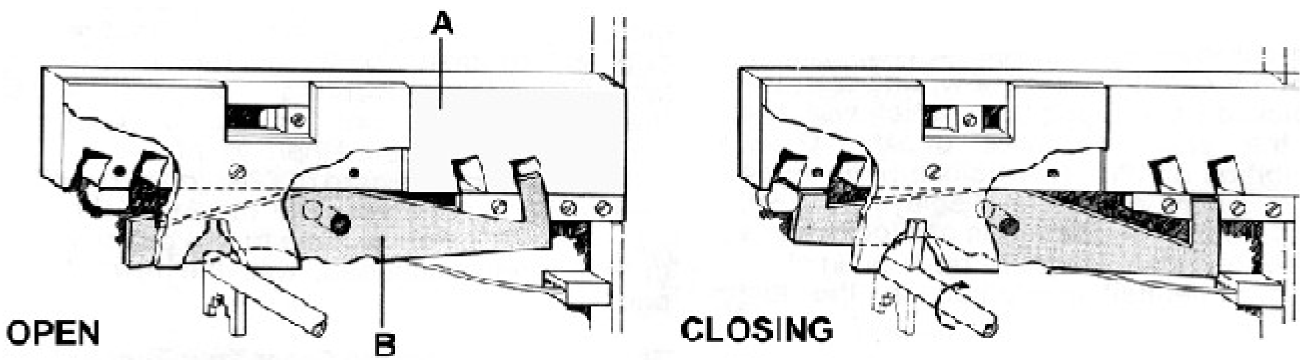


Figure LSS+1407 Hamps double-action detector lock, circa 1859.

Parsons produced his balanced lever lock in 1832, adding several innovative security features. In this device, the levers pivoted at their midpoint. The talon, with which the key engaged in order to slide the bolt, would hide the right arms of the levers.



When the key was turned, the lever arms were lowered, thereby disengaging the bolt. If any of the levers were raised too much by use of a false key or pick, the arm would be hooked into the bolt to immobilize it. This lock had seven levers. There was also a second keyhole, used when a key was inserted from the other side. The key would actually meet a second set of bellies.

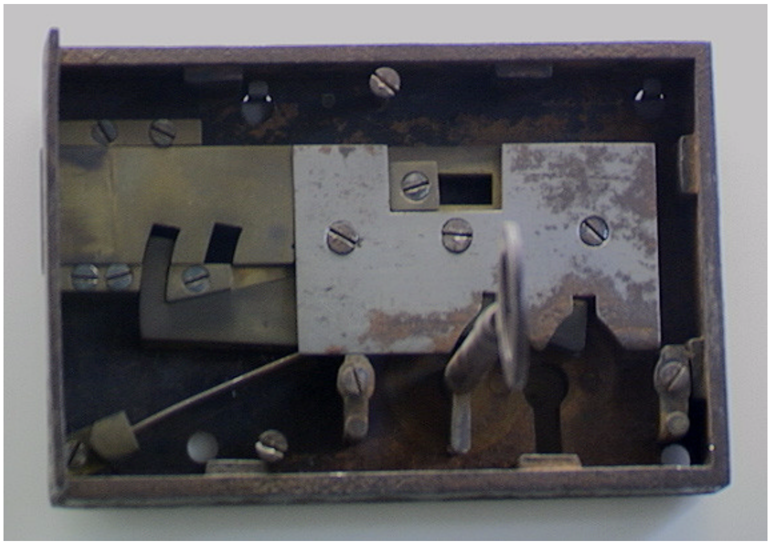
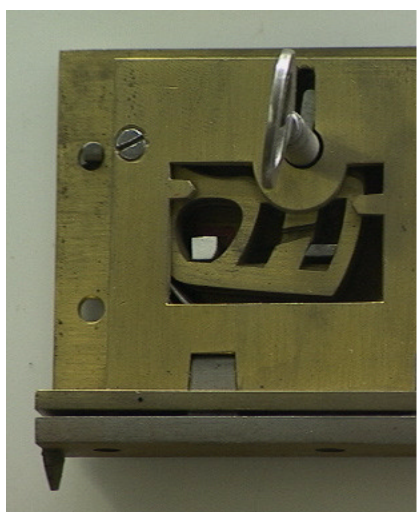


Figure LSS+1408 Parsons balanced lever lock, circa 1832.

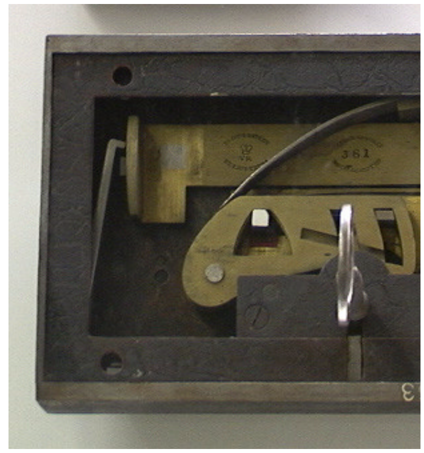
George Price was a master locksmith, inventor, and manufacturer who lived near Wolverhampton. In 1859, he introduced and patented the **ne plus ultra** Lever Lock. This design incorporated a special plate that would tilt slightly when picking was attempted, thereby inhibiting movement of the bolt.











LSS+1409 Examples of the Ne Plus Plus lock designs by George Price. Price was one of the most famous locksmiths and inventors of his era. These mechanisms were developed around 1859.

Price is also remembered for his treatise, ***Fire and Thief Proof Depositories***, written in 1856. This classic work has been revised by the author and is contained within this Infobase. Price also developed a **lock** to resist attack through the use of gunpowder blown into the lock case.

The lever mechanism, through almost two hundred years of development and refinement, can meet today's varied needs. Its design is simple, yet it can provide very high-security. The original lever concept has fostered the creation of locks based upon the gate and fence theory. The S&G combination lock, the Briggs and Stratton sidebar lock, and the Abloy wafer lock are but three examples of the clever utilization of the lever principle.

14_2.0 The Modern Lever Lock

This section details principles of operation, keying, and key systems of the modern lever lock.

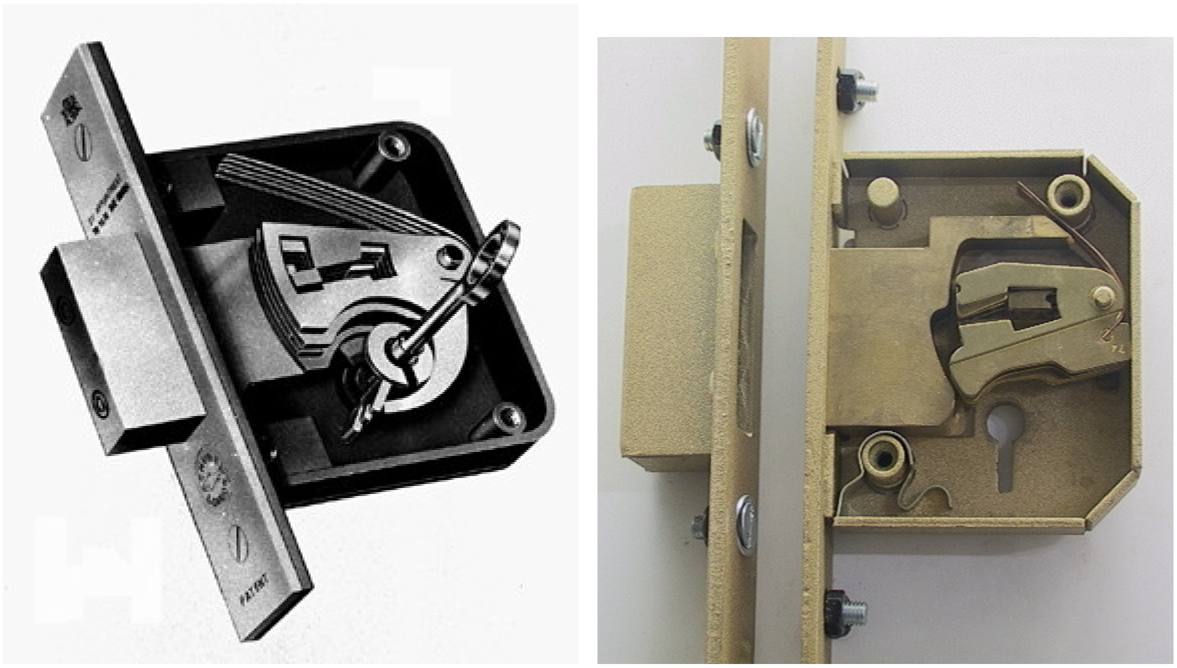


Figure LSS+1410 Chubb seven lever mortise lock, circa 1995.

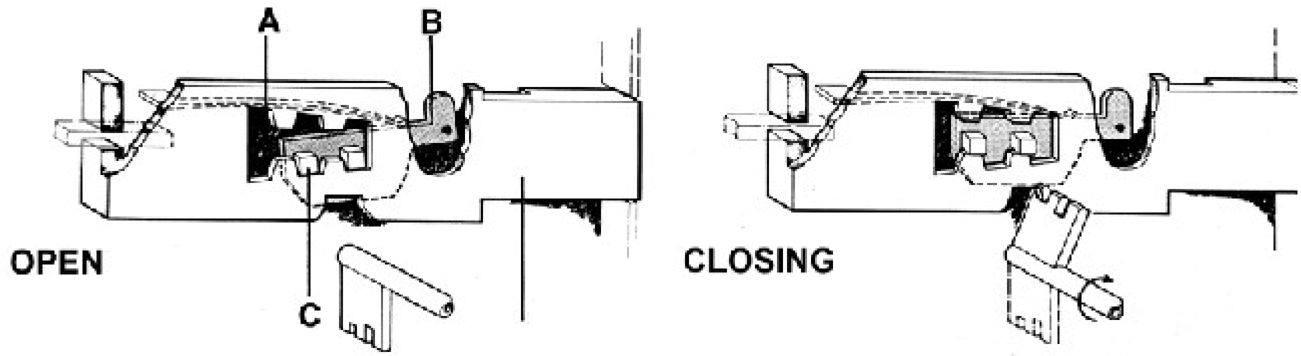
14_2.1 Principles of Operation

The basic principle of operation relies upon the movement of one or more levers in conjunction with a stump attached to the bolt. As will be demonstrated in later chapters, the lever lock operates upon the same theory as the combination lock used in safes and vaults. The only difference is that the levers do not **rotate** but **pivot** about a fixed point. Essentially, **any** mechanism employing a moving fence and gate scheme is operating in similar fashion to the original lever lock. The purpose of the lever is to block movement of the bolt until it is lifted to a precise position. A lock having one or many levers operates in identical fashion; only the security is affected.

Generally, an inset pin to one side of the lock anchors the lever tumblers. It allows the tumblers to move or swing in a vertical direction and acts as an axis point. In order to keep the levers in a "locked" position, pressure is applied to each by means of a spring steel wire projecting from the tumbler and working against the shell or housing.

The bolt mechanism contains a vertical metal bar, called a fence or stump. It is set so that when the levers are in a locked position, horizontal movement is blocked by the lead edge of each

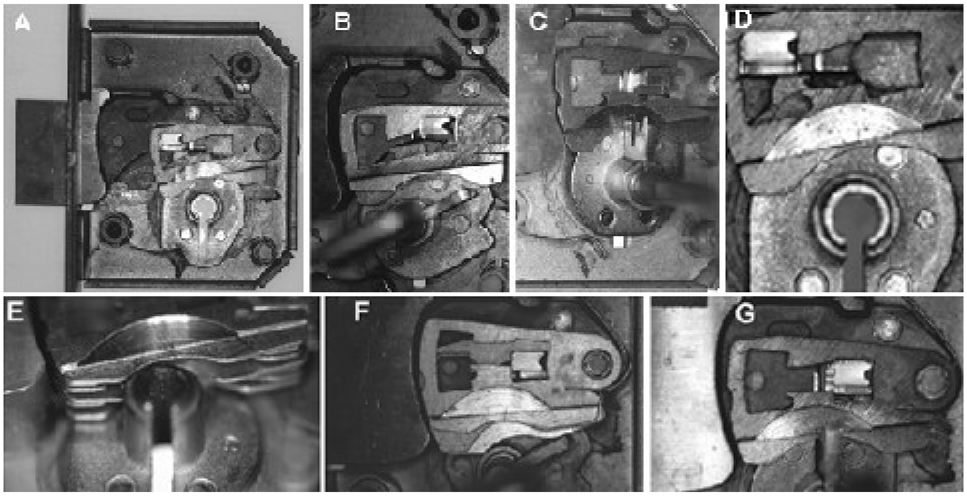
of the tumblers. In order for the bolt to be retracted to the unlocked position, it is necessary for each of the lever tumblers to be simultaneously raised to a point where all of their gates are in precise vertical alignment. This will allow the fence or stump to pass **through** the gates.



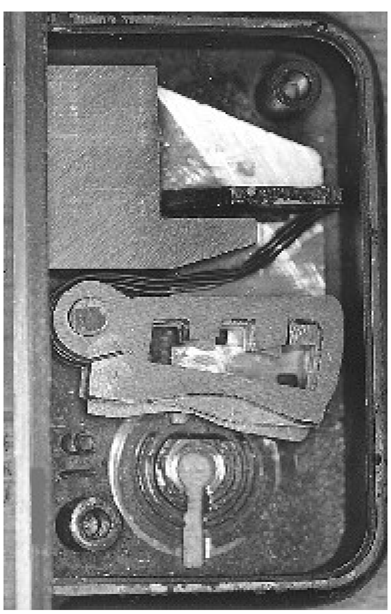
The security of the lock is based upon the "double-action" locking principle: each lever must be lifted to the precise point where the stump "fits" into its corresponding gate within each lever. If one or more levers are out of alignment with the stump, the bolt cannot move and the lock cannot be opened. This double-action design distinguished the lever mechanism from the warded lock, and signaled a fundamental change in the thought processes involved in designing locking mechanisms and in the concept of locking.

Double-action means that a lever cannot be over or under-lifted, if the lock is to be opened. Rather, each lever must be lifted to the precise point for the gate to accept the fence. Security in this lock is thus a function of the number of levers, the dimensions and designs of the gates, the size of the fence or stump, and corresponding tolerance between gate and fence.

The **key** performs two critical tasks. It lifts each lever to the correct position, and it forms the mechanical link to slide the bolt once the fence or stump is able to enter the gates. The bitting of the correct key is cut to correspond to each lever. Depending upon the vertical position of the gate, the key will lift each tumbler so that its gate is placed at the same horizontal location when lifted.



When the proper key is inserted, the bitting will cause an alignment of all of the gates. As the key continues to rotate, the tip is mechanically linked to the bolt, driving it either to a locked or unlocked position. The bolt is able to travel freely because the stump or fence is not blocked by the edges of the levers. The key is prevented from being withdrawn while any of the levers are engaged. It can be seen that different key combinations are created by the use of tumblers having their gates located in different positions. A tumbler having a high slot will require a key that raises the tumbler only slightly, whereas a tumbler with a low slot or gate requires a key with a relatively high cut.



14_2.1.1 European Lever Lock Design

A variation of the standard lever lock design has been developed in Europe. This modification features a double-bitted key, and allows for insertion in a bi-directional manner; that is, the lock can be actuated from either side of the door. These mechanisms require two distinct sets of bitting within each lever to allow multiple bolt extensions. As the key is turned to extend or retract the boltwork, the opposite side of the key comes into contact with the bellies and requires gates at corresponding positions.

In the photographs below, a Jewel eight-lever lock is shown. There are two distinct sets of levers, with the actual bolt separating them. Each time the key is turned, the moving bolt is advanced or retraced to the opposite gate position. Specific tools have been developed to pick, impression, and decode these types of locks. They are described in **Chapters 30** and **Chapter 31.**

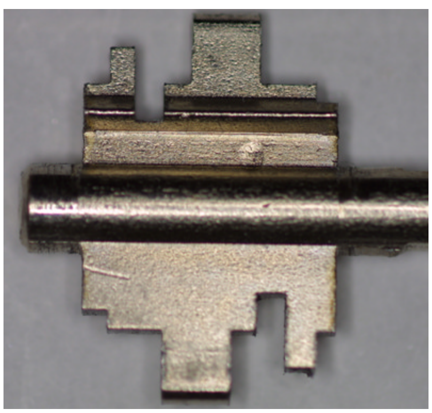
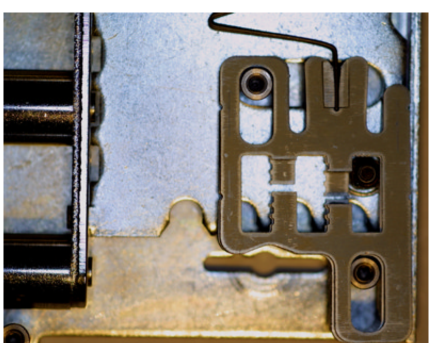
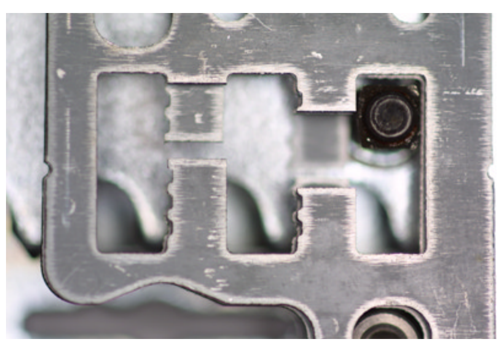


Figure LSS+1411 A European lever lock requires that are two bitting surfaces. These will make contact w distinct sets of bellies.





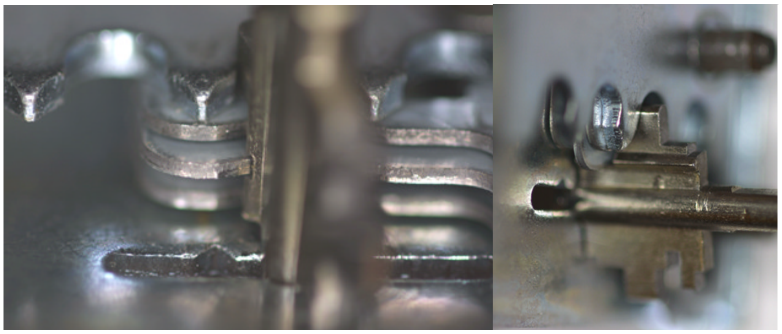


Figure LSS+1412 A European lever lock contains two distinct groups of levers to mate with the bitting on each surface of the key. The groups of levers are separated by the bolt. Each lever will have two separate gates. The photographs, from left to right, show a single lever tumbler with the fence to the extreme right. In the second photograph, two tumblers are shown. In the third and fourth photographs, the interaction of the key and the tumblers is shown. Note how the flag drives the bolt. These photographs were taken of a Jewel eight lever lock.

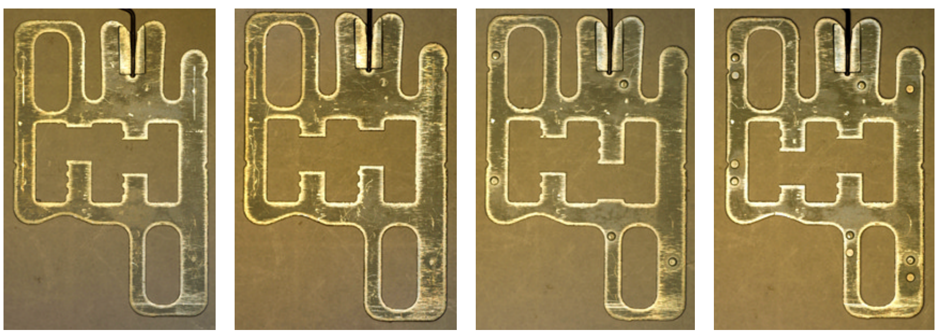
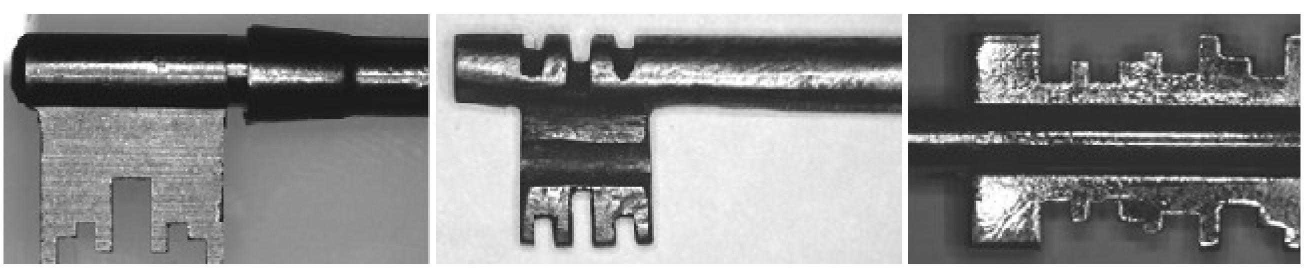


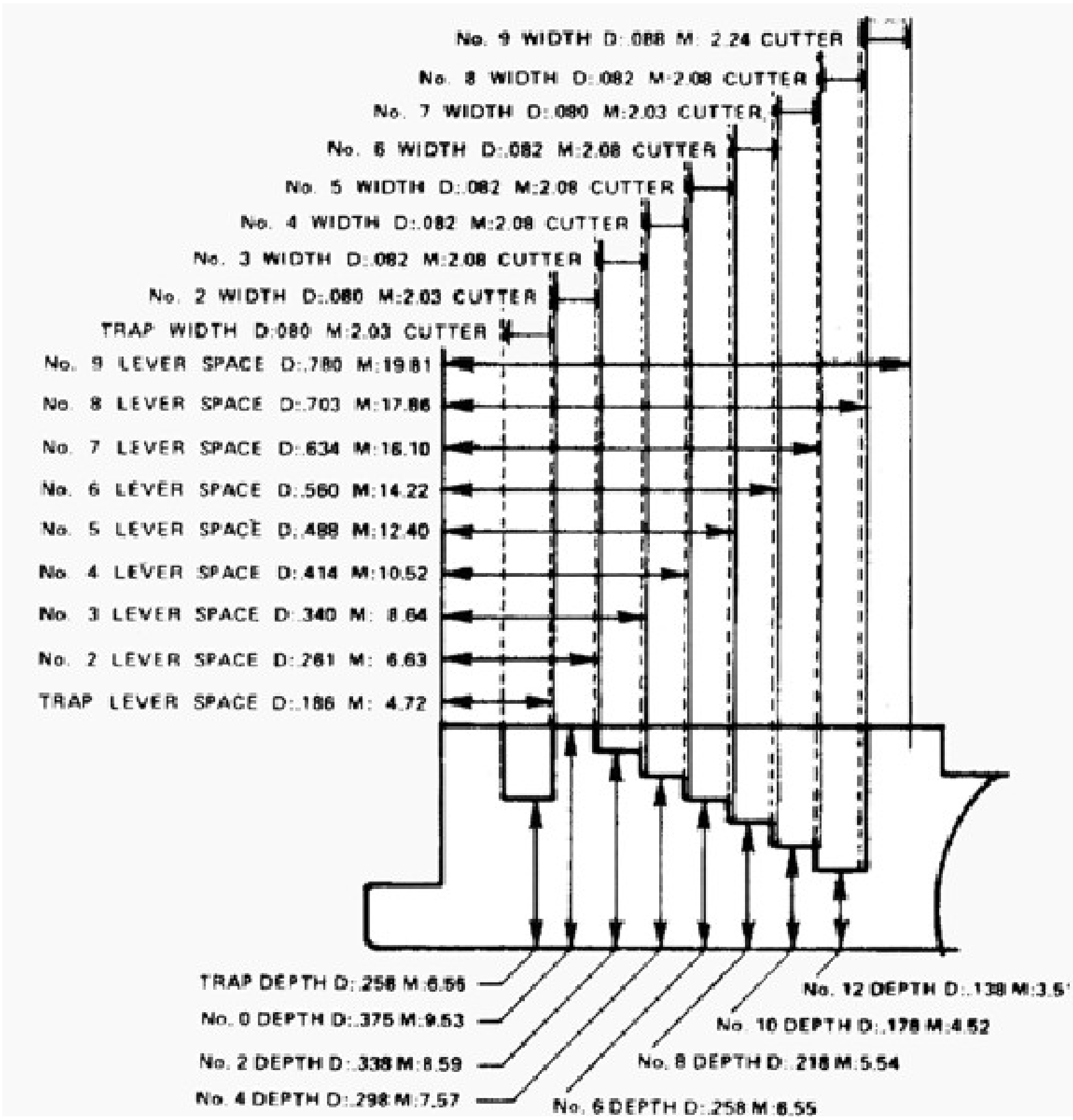
Figure LSS+1413 Four different levers from a Jewel European lever lock. Note the differences in gate configuration between each of the tumblers, and within each of the gatings for each tumbler. There are two separate gatings for each lever tumbler.

14_2.2 Keys and Keying Systems for Lever Locks

14_2.2.1 Key Combinations



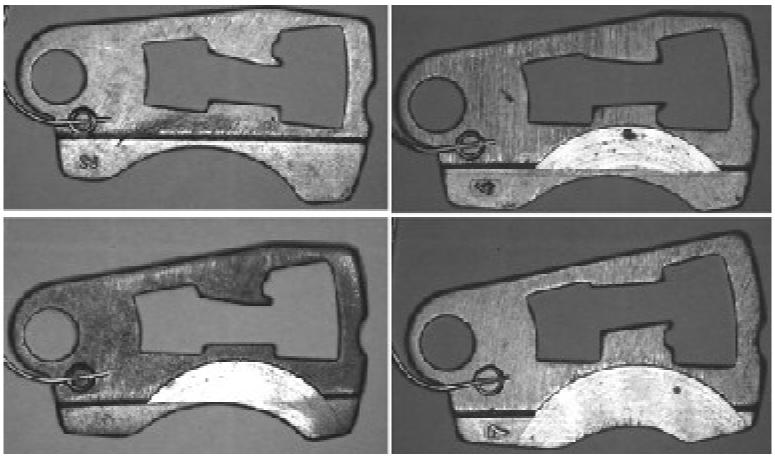
The number of tumblers found in lever locks varies from two to ten or more, contained within one or two tumbler packs. In addition, there are usually four to six different possible depths available for each tumbler. This allows for a large number of different key combinations.



14_2.2.2 Changing Combinations

Combinations can easily be changed by removing all of the tumblers and reinserting them in a different order or by

replacing them with new levers. In either case, making a different key operate the lock simply requires that the position of one or more gates be altered. Combination changing requires disassembly of the lock, unless the mechanism allows for reprogramming.

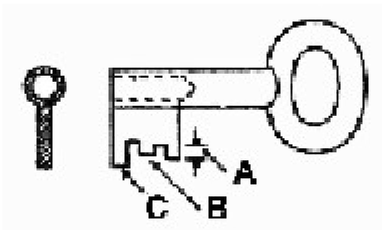


In certain lever tumbler assemblies, notably Sargent & Greenleaf safe-deposit locks, a **variable bolt stump** mechanism is utilized rather than a fixed bolt stump. This allows the lock to be easily keyed to different combinations of lever tumbler depths. See **Chapter 22**.

14_2.2.3 Duplication of Keys

Keys may be either single or double-bitted. Safe-deposit, telephone, and other low or medium-security locks having a single set of levers use blanks made of flat steel or brass. Keys for high-security lever locks used in safes and jails are often double-bitted, and may take many forms. Cuts are always rectangular and quite precise; the sides are perpendicular to each other and the root is horizontal.

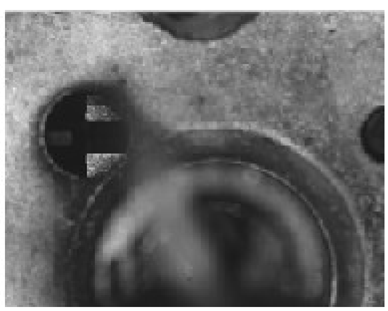
Blanks are selected based upon their length, thickness, and width, and generally may be modified to work in many different locks. Unless there is a special keyway as, for example, in Western Electric, Automatic Electric, and Northern Electric telephone locks, blanks may often be interchanged. A 6" warding file is used to cut a lever key.



Flat keys are easy to duplicate, especially if a grooved keyway is not used. In most cases, blanks may be exchanged between locks with little difficulty; excess metal is removed in order to make a fit. In fact, a piece of flat metal is suitable so long as the length is equal to the source key. Although thickness and height of the blank are not critical, they should be close to the original.

14_2.2.4 Fitting Keys to Lever Locks

Keys are fitted to the tumbler pack in the locked position. To produce a key, the proper blank must be selected and the throat determined and cut first, so that the blade can engage the bellies. After the key is inserted, it is turned about 60° to make contact with the bellies of the levers. Then, a series of cuts is made to correspond to the depth of each gate, so that all of the gates are aligned. This will allow the fence to pass.

As noted, a 6" warding file is generally used. This must be equal to or thinner than the width of **one** lever. It is important to prevent the removal of too much metal when making a cut for a particular tumbler. This can be readily understood when one considers that each individual cut must correspond to only one lever tumbler. Remember that the purpose of the cut is to allow the key to raise a single lever to its correct position. It follows that if a cut is too wide, the key will pickup more than one tumbler at one time. If cuts are too narrow, a tumbler will be picked up but not reliably to the correct level.

The file performs two critical functions: it must shape each cut, and it must remove the amount of metal required to raise each gate to the fence. In shaping the cut, each must be equivalent to the thickness of one lever: no more and no less. In practice, marks are first produced on the blank by each lever to provide a precise guide as to where to file. A few sharp turns of the blade will accomplish this. Then, in succession, cuts are made for each mark until the corresponding gate for that lever is aligned with the fence or stump. When all of the levers are raised to the proper position, the bolt may be retracted.

14_2.2.5 Key Coding for Lever Locks

Almost all lever keys manufactured today are factory-coded using the indirect method. See **Chapter 31** for a detailed discussion of decoding techniques.

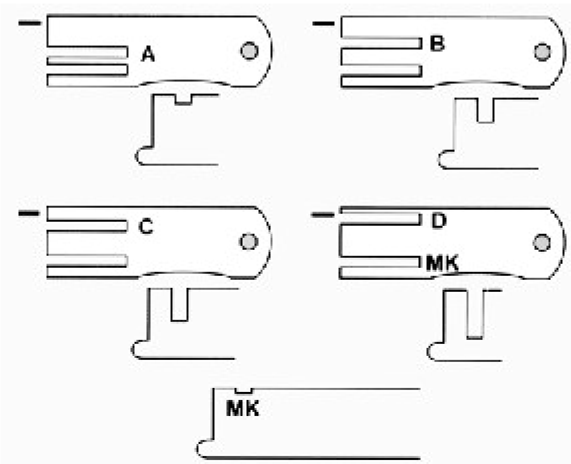
14_2.3 Master Keying Systems

Although still quite popular in Europe and many other parts of the world, lever locks have not gained wide acceptance in the United States other than for use in banks. They are not suitable for large facilities where master keying is required. There have been several schemes developed over the years to allow multiple keys to fit one lock, but none has been widely accepted. The main problem is the inability to provide for more than one extra level of keying.

Master keying of a lever lock does not markedly decrease its security against picking. Depending upon the technique, cross-keying can become an issue. This subject is more fully discussed in **Chapter 11**. Several options have been developed. These include:

- **Two sets of levers;**
- **Two sets of gates in one lever;**
- **Wide gating;**
- **Two keyholes;**
- **Two points on which the keys make contact with a set of levers (compound levers);**
- **Two plugs in one lock;**
- **Butter's system.**

Butter developed a variation of the lever lock that utilized a modified lever and allowed master keying. He determined that the vertical movement of the flat levers by the correct key allowed a toe-and-crank mechanism to release the bolt.



14_3.0 Security Enhancements

Lever locks are subject to surreptitious opening by picking, decoding, and impressioning techniques. Many of these methods, as well as countermeasures, were initially developed over 150 years ago by such lock masters as A. C. Hobbs, J. M. Hart, George Price, Tucker, Reeves, Tann, Chubb, and many others. **Chapter 29** provides detailed information regarding the development of anti-picking features incorporated within lever locks. Only brief mention of these will be made here.

Since its early development, the lever has undergone many changes to frustrate picking, wax casting, and impressioning. There have been several important advances to combat surreptitious opening, decoding, and production of keys. In 1989, for example, Hirvi in Sweden patented a lock (**4836000(150)**) to frustrate the reading of bellies to determine their position. Two critical design enhancements made the early lever locks difficult to pick or otherwise compromise: the stump was made to project from the bolt rather than the lever, and extra notches were cut into the levers.

Once multiple levers were utilized, the use of wax to read the mechanism became extremely difficult, at least for awhile. Then the lock pickers made more variations of false keys, finding that virtually any bit would fit through the talon to lift the levers.

Slots, rather than **notches**, were then cut into the levers. These came to be known as **gates** and added precision and greater tolerance to the "double-action" lock, forcing the lock picker to produce an exact key. Sawtooth cuts were added to the edge of the levers to provide even more security against picking. These teeth, now found primarily in safe- deposit and high-security levers locks, are very effective in frustrating picking and are discussed in detail in **Chapter 29**.

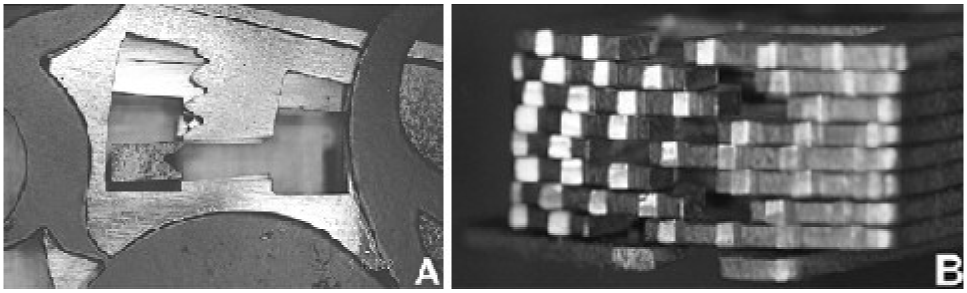
Certain special design features can be incorporated within the lever lock to increase its resistance to picking and other forms of surreptitious entry. Unfortunately, its inherent design places limits on such options in comparison to the pin tumbler lock. While the pin tumbler locks physical security can be enhanced through the use of anti-drill pins, mushroom tumblers, rotating tumblers, pin depths, and other techniques, few of those are available to the lever lock manufacturer.

Five critical parameters can be modified to affect internal security of the lever lock:

- **Design of the gate area;**
- **Interaction of the lever with the fence;**
- **Access to the levers during actuation of the bolt;**
- **Positioning of the levers during operation of the lock;**
- **Heavy, high-strength materials may also be used for most lock parts.**

14_3.1 Interaction of the Lever to the Fence

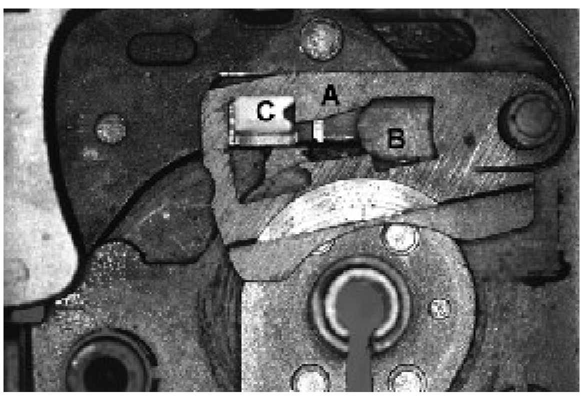
In order to provide greater security, sawtooth cuts are added to the edge of the lever tumblers. These encounter the fence during the tentative method of picking. The teeth are very effective and are discussed in more detail in **Chapter 29.** Randomly placed false gates on the edge face of the lever will also increase the difficulty of picking the lock. False gates are shallow notches near the true gate that will mask the location of the operative gate.



Exploded view of false gates.

14_3.2 Design of the Gate Area

Resistance to picking is enhanced by high tolerance between fence and gate, in combination with "H" combination gating. "H" combination gating provides higher tolerances between fence and gate and performs the same function as a mushroom tumbler in the pin tumbler lock.



This form of gating requires more precision in the positioning of the lever tumbler with respect to the stump or fence and hence more security. "H" gating will make picking more difficult because false indications may be received as to tumbler position. Two stages of picking are then required in order to place the stump into the correct position.

14_3.3 Access to the Levers during Actuation of the Bolt

First developed by Chubb, the curtain and rotating barrel can prevent access to the levers during picking attempts. A metal cover surrounds the trunnion to block the entrance of picking tools, wires, feelers, and other devices. The curtain inhibits

viewing or manipulation of the levers. Baffle plates are also sandwiched between adjacent pairs of levers, making picking even more difficult.

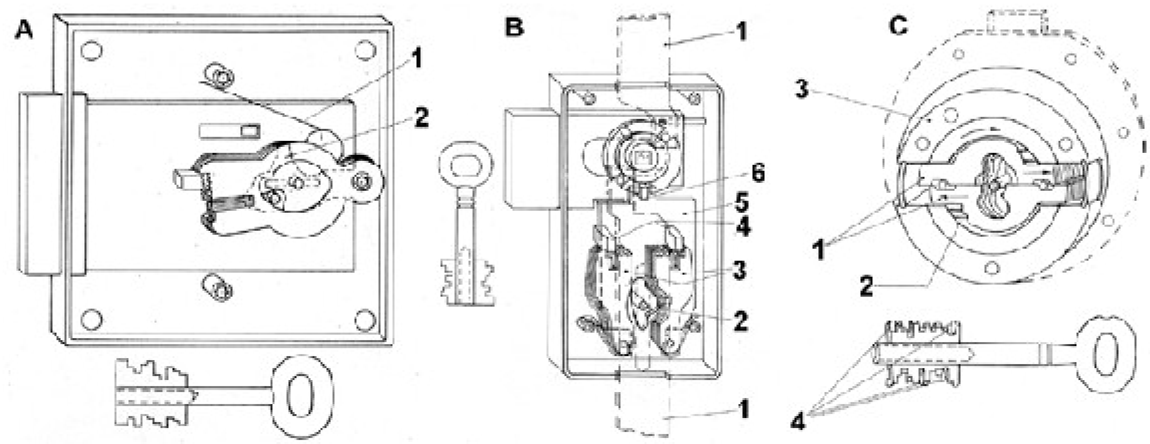
14_3.4 Positioning of the Levers during Operation of the Lock

Western Electric (WE) received patent protection for many unique security enhancements to lever locks used in coin telephones. The WE lock is especially difficult to pick due to the implementation of a spring-bias system that provides and affects tension to all levers simultaneously. This technique will remove tension from any particular lever if lifted individually with a pick. The inventors also changed the center of curvature for the top edge radius of the lever. By doing so, the "feel" for the position of each lever, acquired during picking, is destroyed.

The lock was also designed with a special plug-camming surface that rides against the leg of each lever. Plug rotation causes all levers, including those picked to the unlocked position, to return to the locked position. Also incorporated was a floating cam feature, greatly increasing the skill required for picking. A complete description of this lock appears in **Chapter 23**.

14_4.1 Special Applications

Lever locks have been designed for many uses, including United States Post Office boxes, safe-deposit boxes, telephones, and jails. Lever locks are also quite popular for use in safes and vaults, especially outside the United States. See **Chapters 17-23**, for detailed descriptions of lever locks used in special applications.

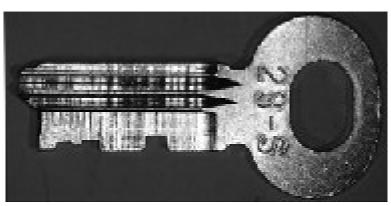


14_4.1.1 Post Office Locks

All United States Post Office collection boxes have one standardized eight-lever lock and key. Likewise, all mailboxes within post offices utilize a proprietary reversed Yale-8 keyway. It is a federal offense to possess or duplicate unauthorized keys to mailboxes. See the extensive discussion of postal locks in **Chapter 23.**

14_4.1.2 Coin Telephones

Telephone companies in the U.S. and Canada have employed special lever locks for at least fifty years. These offer a high degree of security and are covered by several patents held by Western Electric and other companies. The blanks for all telephone locks are similar, restricted, and very distinctive.




Exploded view of keys 1, 2. 3, 4.

Each coin box is keyed individually rather than master keyed. Investigators should be alert to these unique blanks if found in the possession of suspects. There have been many instances of organized gangs burglarizing coin telephones throughout the country. Since the deregulation of the Bell System, surplus coin telephones can be purchased with keys that can be used to produce keys to other Bell System telephones. Thus, although the blanks

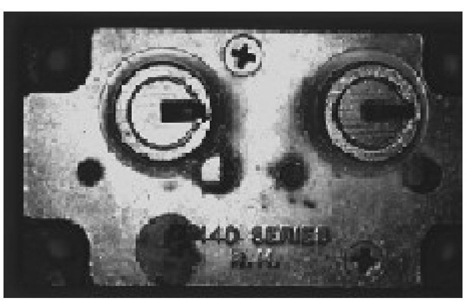
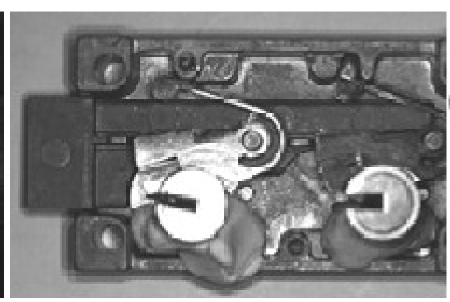
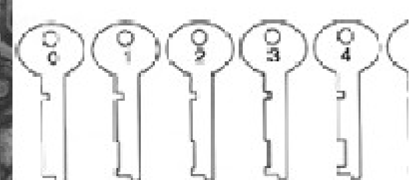
are restricted, they are available in the U.S. and from Asia.

There are generally two locks per telephone: one to release the top housing and one for the coin box. Bell System blanks are typically stamped as follows for coin boxes: 30B (WE), 10L (AE), and NE222QA (NE). Top housing keys are identified as 10G (WE), 29S (AE), and 21B (NE). In some older telephones, tubular Chicago locks were also used. Coin telephone lever locks are very pick resistant. Their security is augmented by "key keepers" that retain an unauthorized key, once inserted. Alarm systems have also been incorporated into many telephones.

14_4.1.3 Safe-Deposit Boxes

A major application of the lever lock is in safe-deposit boxes. Usually, two locks are operated in tandem. This requires a change key to be carried by the customer and the guard key that is kept by the bank. Both must be actuated at the same time.

The guard or control key usually fits all locks in the safe-deposit vault, while each customer has a unique renter's key. A novel safe-deposit access system is in use in Europe, having only one lock for each box. Bank personnel allow individual customer access with the use of the renter's key, and a remotely activated solenoid. Each box is alarmed to advise of improper access or openings.

14_4.1.4 Jail and Prison Locks

Lever locks have been used for more than a century in jails and prisons. They have been designed to provide physical protection against both surreptitious and forced-entry, and are described in detail in **Chapter 23**.

14_4.2 High Security Lever Locks for Safes and Vaults

There are many high security lever locks that are utilized in safes and vaults, especially in Europe. There are specialized decoding tools for many of these locks. These are shown in **chapter 31**. A sample of some of the most prevalent lever mechanisms are shown below. Note the complex gear drives, gate and fence designs, and security enhancements. These locks typically contain nine or more levers and maintain extremely high tolerances.

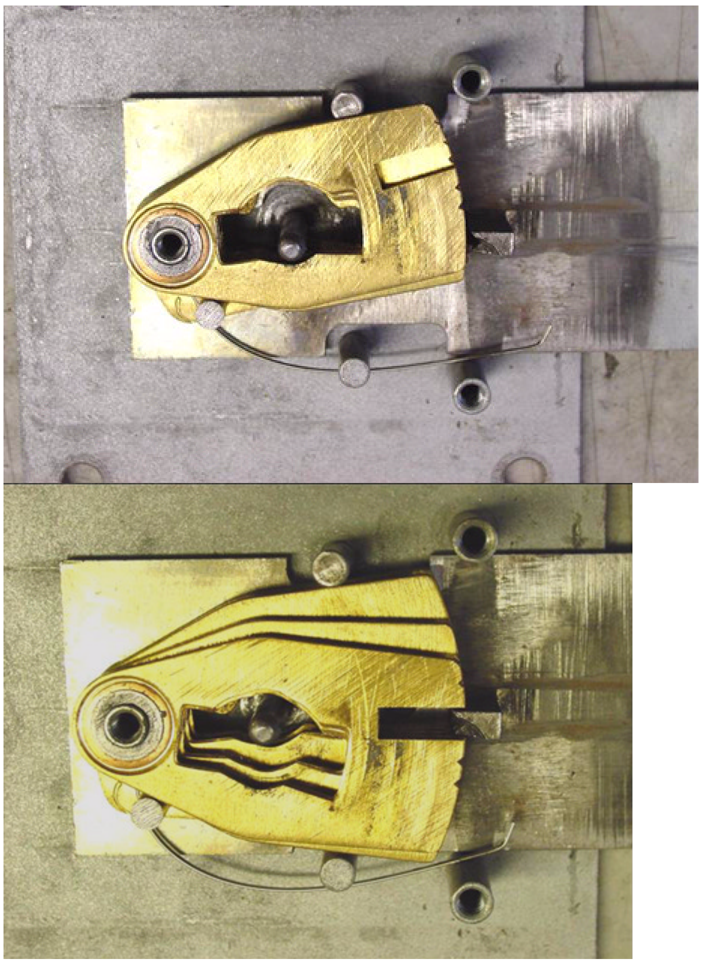


Figure LSS+1414 Kromer Novum lever lock, courtesy of Owe Bengtsson.

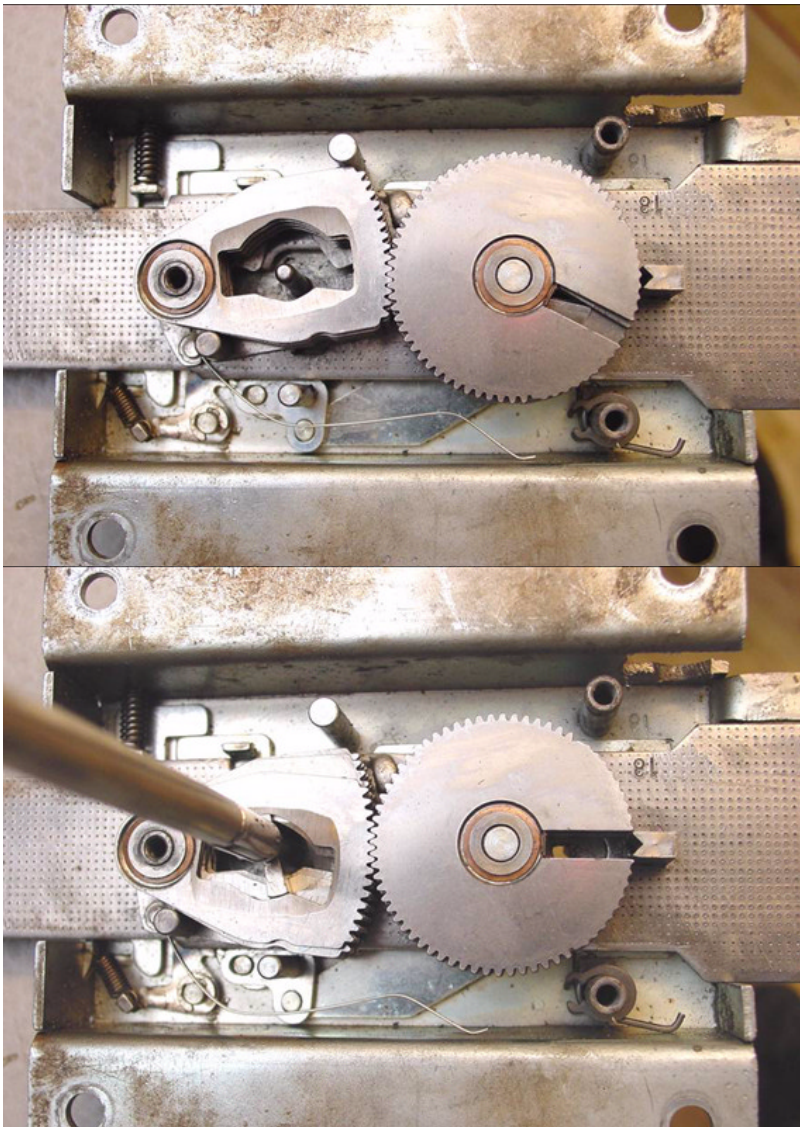


Figure LSS+1415 Kromer Convar, courtesy of Owe Bengtsson.

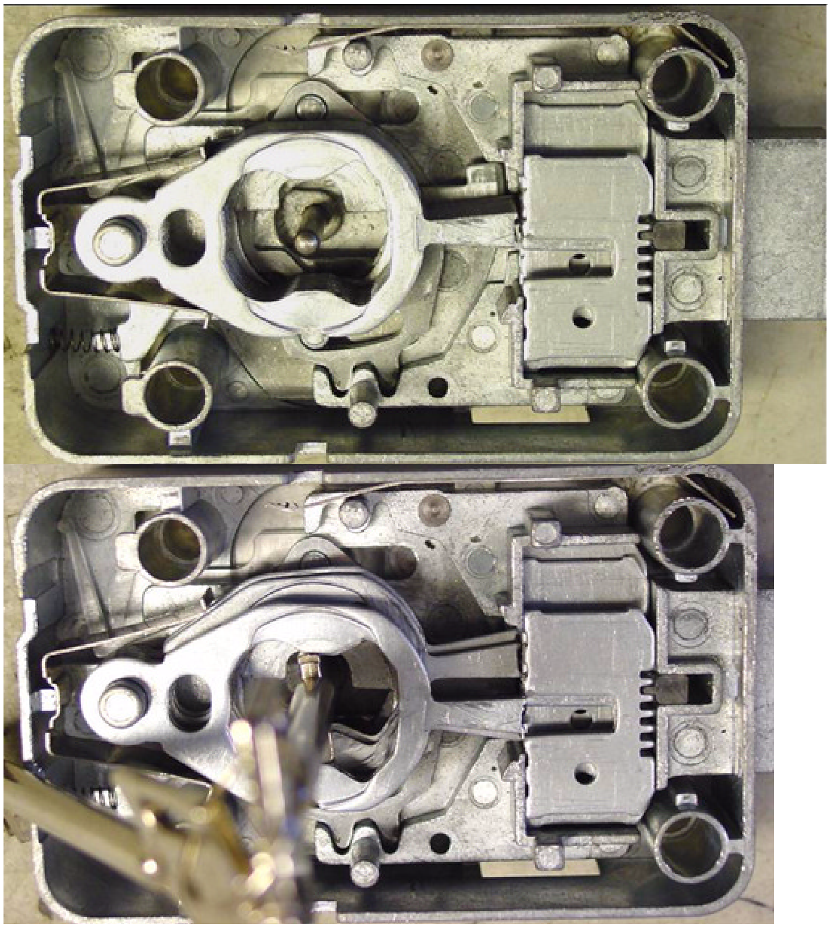
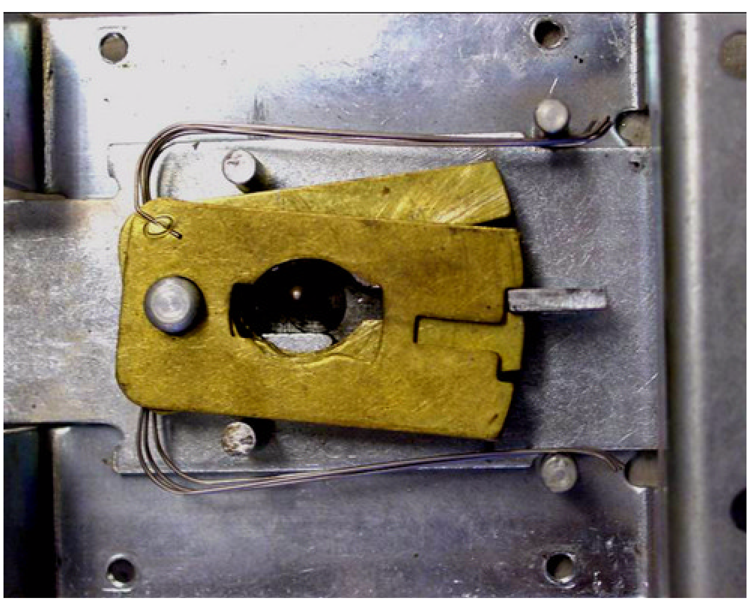


Figure LSS+1416 Mauer 70091, courtesy of Owe Bengtsson.



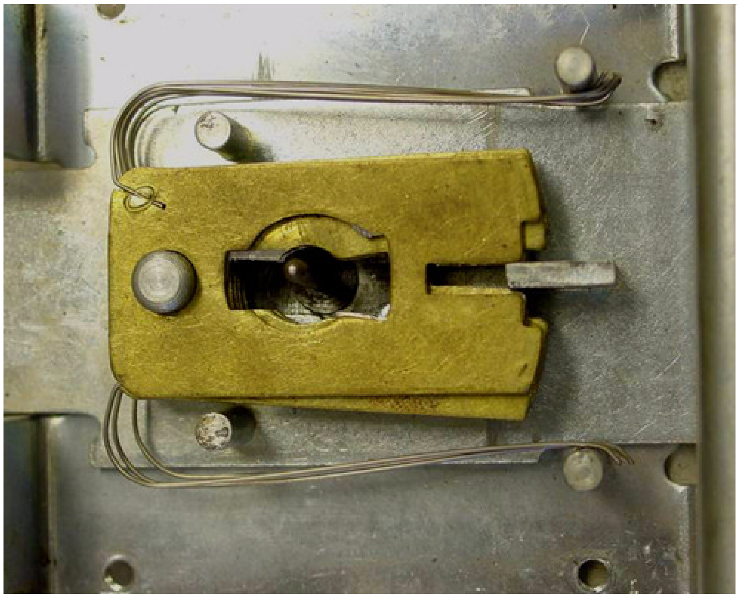


Figure LSS+1417 Ostmarks 1919, 1925 m.fl. Courtesy of Owe Bengtsson.

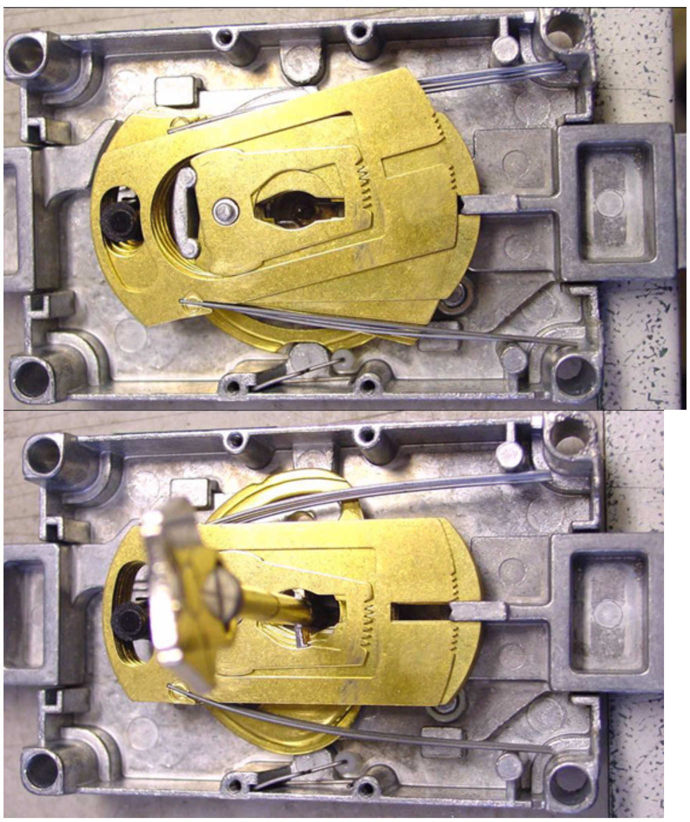


Figure LSS+1418 Rosengrens ABN, courtesy of Owe Bengtsson.

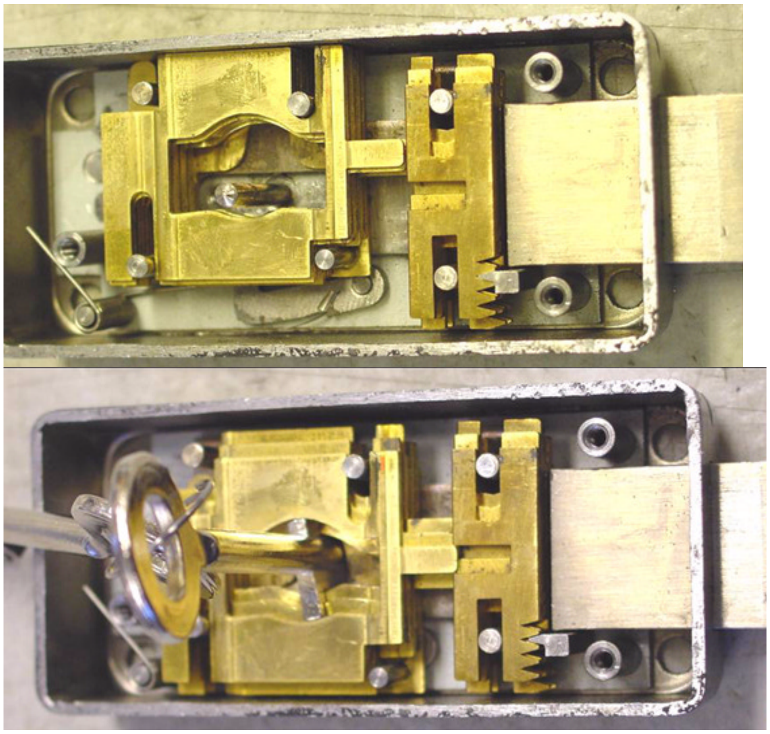


Figure LSS+1419 Stuv (Steinbach & Vollman Gmbh), courtesy of Owe Bengtsson.

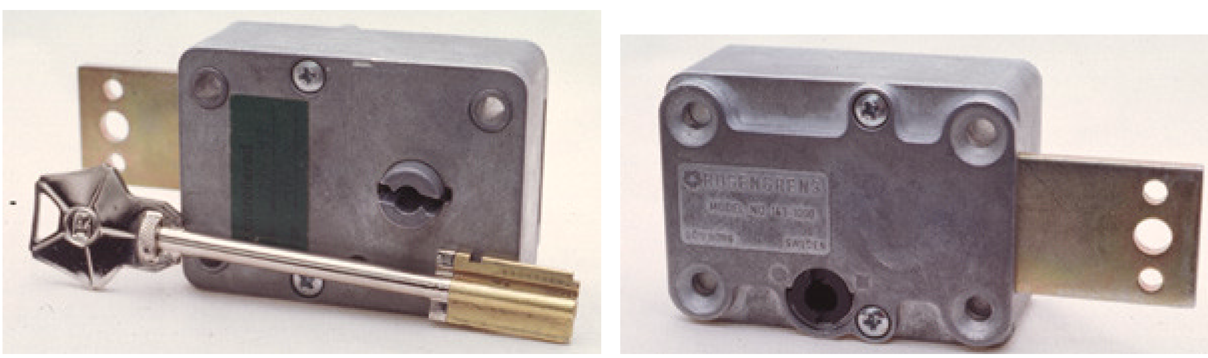
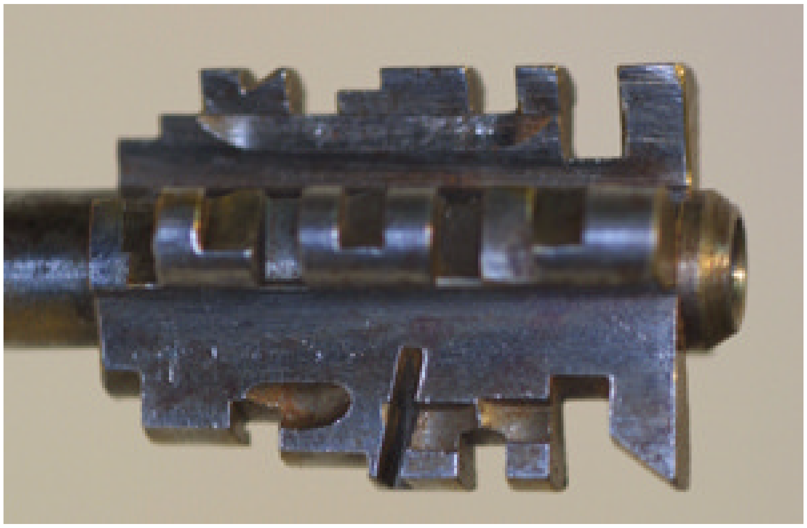


Figure LSS+1420 Rosengrens RKL 10, courtesy of Mark Bates.

The Rosengrens RKL10 is an extremely complex lever lock that is very popular on high security safes. A detailed **assembly protocol** has been provided as a courtesy of Owe Bengtsson in

LSS203: Rosengrens RKL10.

An interesting example of a high security multiple-bitted lever lock is shown in the photograph below. The key was utilized on a World War II German submarine.



14_5.0 Definitions and Identification of Parts

There are many components found within the lever mechanism, some with special application in safe-deposit locks. These parts are defined below. See also **Chapter 30**, for supplemental information regarding certain components.

Barrel and Curtain: This is a security device employed in some lever locks to block access to the keyway once a key or pick is inserted and turned. The curtain was developed by Jeremiah Chubb to prevent bypass by picking.

Belly of Lever: The edge, generally curved, with which the key comes into contact at the base of the lever.

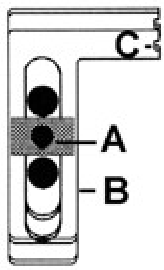
Bond Box: The removable box in which valuables are stored within the safe-deposit vault.

Butter's System: A century ago, Butter developed a modified lever that allowed limited master keying.

Change Tool: A device that is used to change the combination of the gate position without disassembly of the lock.

Changeable Fence: A multisegment fence can be made to align each of its individual components, to each corresponding gate. The combination is arranged by moving each segment.

Changeable Lever: A lever consisting of two parts whose relationship can be altered to affect the position of the gate, and the corresponding bitting of the key.

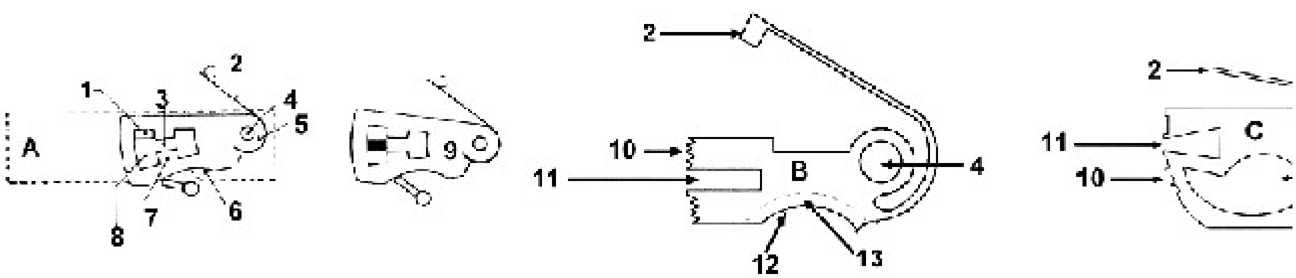


Chubb: The name of a famous English lock maker who founded a company in 1818 and which still exists today. The name Chubb is identified with many revolutionary patents, including the Detector lock. See **Chapters 1** and **34**.

Compound Levers: Certain levers have two bellies at different radii, utilized for master keying.

Detent: That portion of a changeable lever containing the gate, which can be separated from the sweep lever in order to alter the distance between the sweep and the gate.

Double-Acting Lever: A lever that must be lifted to a precise level: not too high, nor too low, to enable the stump to pass through the gate.



Dummy Lever: A special lever used for master keying, which, when raised, causes other levers to be lifted.

False Notches: Serrated notches are placed on the lever edges and on the bolt stump to improve security against picking.

Fixed Lever: A lever for which the position of the gate cannot be changed.

Flush Bellies of Levers: When all levers are at rest and in a locked position, the lower radii or edges of the bellies are at the same level. Theoretically, the reason for flush bellies is so that no indication may be deduced as to the amount of lifting required to align the gates. In practice, as will be explained in **Chapter 31**, the relative position of the gates can be determined from an analysis of the bellies.

Gating: Square slot in a lever through which the stump of the bolt passes.

High-Lift Lever: A type of lever that must be lifted as high as possible to pass the stump. Another variation of this is a high middle lift lever, which can be over-lifted to block passage of the stump.

Lever Tumbler: A form of catch that normally holds the bolt immovable until raised by the key. It is the American name for the pivoting part in the lever tumbler lock. The term appeared in Parsons' patent in 1832 in England.

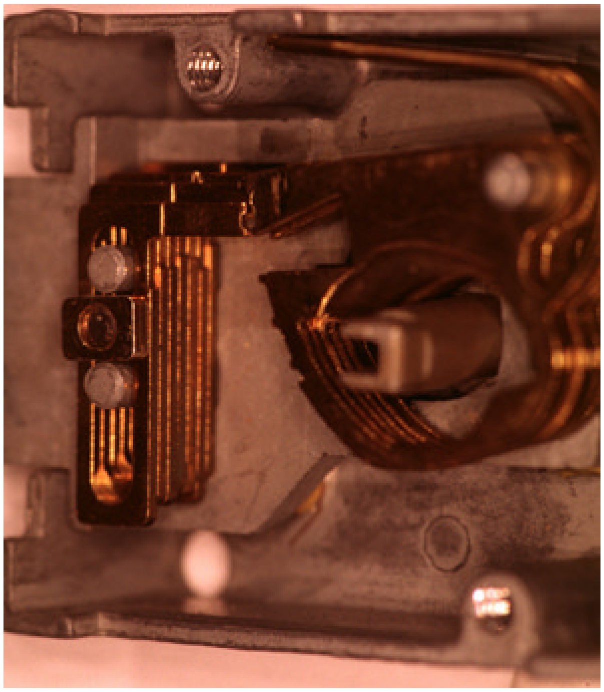
Low-Lift Lever: The lowest possible lift of the lever by the key, while maintaining some portion of the lever above the gating, to block movement of the stump.

Lever Cuts: Another term for the steps or variations of the bitting of a key.

Lever Spring: The purpose of the spring is to force the lever to its lowest position. Usually the spring is made of fine wire, fitted into a slit cut in the end of the lever. The lever and spring may be combined and made from one piece of brass.

Pocket: That portion of space within the gating of each lever tumbler that allows the stump to rise and fall within the lever.

Programmable Lever Lock: A lever lock may be programmable, in order to allow the bitting pattern to be altered by changing the fence-gate relationship. In the photograph below, the relative position of the fence and gate can be adjusted by moving the individual fence pieces on the left. All of the bellies within the levers are identical. The bitting is changed by lifting the individual levers to different heights, matched by the corresponding fence. When the setscrew is loosened, the vertical pieces are free to move to any desired height.



Serrations: Shallow notches are cut in the fence and along the gate opening edge of the levers to frustrate picking.

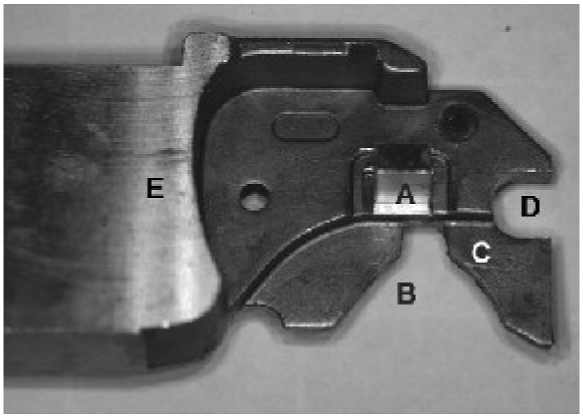
Setup Key: A key with identical bittings. Changeable safe-deposit locks are factory set to this bitting combination.

Sweep: The portion of the lever contacted by the bitting of the key. It is generally radiused.

Talon: The gap in the bolt, curved to the radius of a key, which has some resemblance in shape to the talon or claw of a bird of prey. A **Fly Talon** allows a small key to give a long throw to the bolt.

Tee Piece or Slider: A scheme utilized by S&G allowing the lock to be easily keyed to different combinations or lever tumbler depths.

Trap Lever: A special lever, placed in a changeable lever lock, which will prevent the insertion or removal of a change tool until the lock is set properly.



Exploded view.

CHAPTER FIFTEEN: THE WAFER

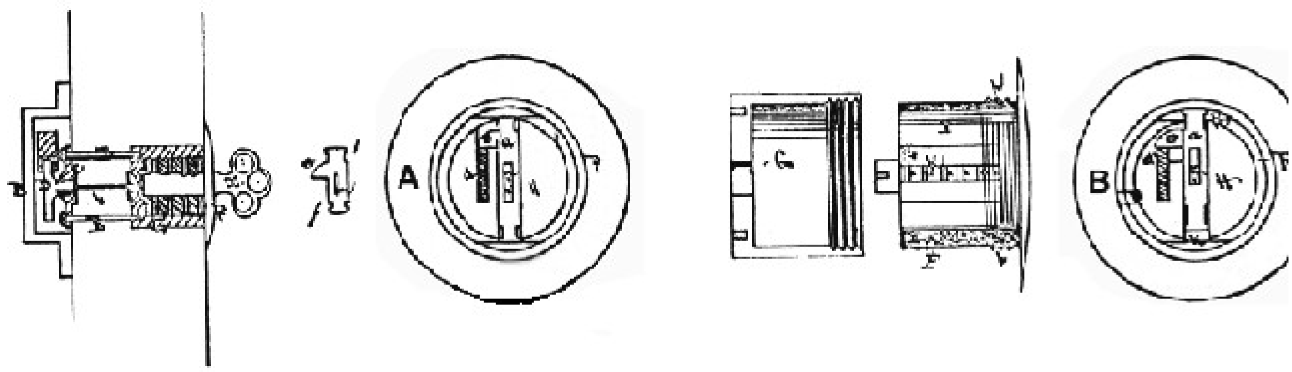
Wafer Locks

Master Exhibit Summary

15_1.0 Introduction

The wafer or disc lock, developed during the latter part of the nineteenth century, is a low to medium security device that is versatile, simple to install, and an inexpensive substitute for the pin tumbler mechanism. It is easy to identify by looking into the keyway. The prototype was developed by Hiram S. Shepardson, and in 1870, a patent was issued for the design (**99013(151)**). The inventor had worked for Yale prior to conceiving of the lock. He formed the United States Lock Company in Massachusetts that was later purchased by Yale. The wafer lock did not gain popularity, however, until the 1930s when Chicago

Lock and Briggs and Stratton (STRATTEC) introduced the famous die-cast sidebar mechanism.



Wafer locks are used in many applications. These include: luggage, cash registers, showcases, desks, motor vehicles, electric switch and alarm controls, elevators, file cabinets, padlocks, coin boxes, money bags, mobile radios, and vending machines. The lock is known by various terms: disc, wafer, plate, blade, or flat tumbler. Detailed information with respect to picking, decoding, and impressioning can be found in **Chapters 29-30-31.** Special applications of wafer and disc locks are presented in **Chapter 23.**

15_1.1 Development of the Wafer Lock

Worldwide, the wafer or disc lock has become the most popular low-cost security mechanism. It far surpasses even the pin tumbler, due to its versatility and simplicity. There are many variations and improvements to the original wafer concept. The most significant of these are sidebar and laser-track locks used in many automobiles, and the plate wafer lock found in a majority of vending machines.

Wafer locks support single, double, and triple-bitted key designs. Cam locks, probably the most popular low-cost configuration, usually have wafers rather than pin tumblers. Double-bitted mechanisms can be found in hundreds of applications, ranging from bulletin case locks to elevator controls. Double bitting means that there are spring-biased wafers active at both the top and bottom of the rotating plug. Generally, double-bitted locks contain more wafers than do single bitted. Triple-bitted locks are utilized in applications requiring higher security. They are common in access control, motor vehicles, and storage lockers. They generally are a

modified double-bitted mechanism with a third set of tumblers riding on a superimposed ridge running parallel to bitting on one side of the key.

The sidebar lock is a variation and hybrid of both the wafer and lever design. It was developed in the 1930s, specifically for the automobile market, and was introduced by Briggs and Stratton. It is still the predominant motor vehicle lock. The mechanism is extremely pick resistant and is discussed in **Chapter 23**.

The plate wafer is another popular variation of the original design. Up to thirteen wafers are contained within a pack, held together by a spring wire. Essentially, the lock is a high tolerance, double-bitted mechanism. One embodiment of the plate wafer mechanism was described in the Christoph patent (**1287882(152)**).

15_2.0 Principles of Operation

15_2.1 Introduction

The wafer design is based upon the double-detainer locking principle and can be viewed as a modification of the lever lock concept. It was developed in response to the increased requirement for flexibility in the way that the bolt was to be used for locking.

Originally, lever locks, and to a limited extent pin tumbler locks, were produced for doors and other applications where a straight bolt was utilized. The design of the lever precluded the use of any actuating mechanism other than a straight sliding bolt, driven by the rotating action of the correct key. It would not allow use of a rotating locking cam, screw, or any other form of latch; just the sliding bolt. The wafer provided different options and alternatives for bolt activation.

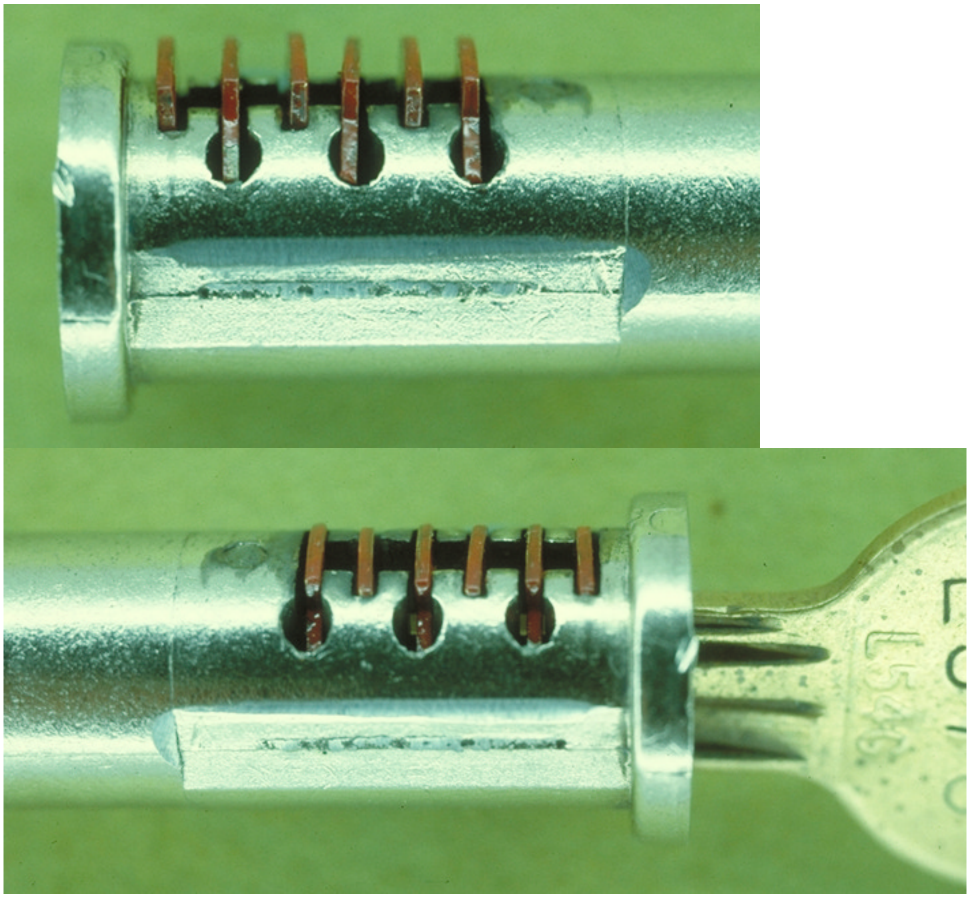


Figure LSS+1501. A six-wafer mechanism in the locked and unlocked state. The plug on the right can be turned within the shell because there are no obstructions to rotation. Courtesy of the Illinois State Police, Bill Sherlock.

15_2.2 Component Description and Identification

The basic design of all wafer locks is the same: making manufacturing, keying, rekeying, picking, and service easy. The mechanism consists of the outer shell, the plug or core, the wafer tumblers, and associated springs. The locks are usually constructed of die-cast metal. The specific function of each component is described below.

Bitting: Wafer locks are generically defined by their bitting levels. Thus, a single- bitted lock has one set of wafers, all of which make contact with the key bitting on one surface. Keys with bitting on two opposite surfaces fit double-bitted locks. If the key has bitting on three surfaces, then the lock is triple bitted.



Figure LSS+1502, example of a double bitted wafer lock in the locked and unlocked state. Courtesy of Illinois State Police, Bill Sherlock.

Cam: The cam or tailpiece is connected to the end of the plug and is used to control or cause a locking or unlocking condition. Its other function is to secure the plug within the shell.

Discs or Wafers: Disc tumbler, wafer tumbler, plate tumbler, and flat tumbler are used interchangeably. They refer to the active

locking components. Wafers are made of flat brass, are spring biased, and are individually moved by the bitting surface of the key to a precise position called shear line.

Master Pins: Special wafers used for master keying have two different stepped portions. Each meets the bitting of either the change key or master key.

Plug: The plug forms a perfectly round core containing all wafers and springs. It rotates within the shell to allow actuation of a cam, bolt, or other locking control.

Shear Line: This term denotes the level to which all wafers must be raised in order for the plug to rotate.

Shell: The shell contains all moving parts of the lock.

Shell Slots: These are the empty channels formed above and below the plug. They allow the tops and bottoms of the wafers to enter when in a locked condition.

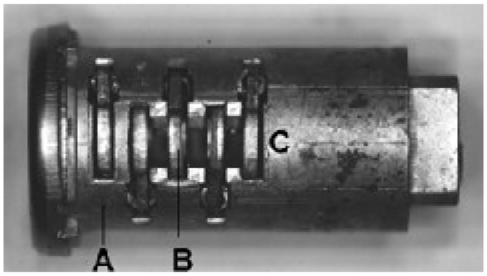
Springs: Springs are much smaller than in the pin tumbler lock and are generally made of steel or bronze. Their function is to bias the individual wafers above or below shear line. They are held in place by the arm of the wafer.

15_2.3 Mechanical Operation of the Lock

All wafer locks contain three active locking components: the plug, shell, and tumblers. A key, with bitting that corresponds to each wafer, is utilized to move each tumbler to shear line, so that the plug is free to rotate.

15_2.3.1 Plug

The plug forms a perfectly round core containing all wafers and springs that rotates within the shell to allow actuation of a cam, bolt, or other locking control. The front of the plug has an opening called the **keyway** that guides the key once inserted through the center of each wafer. There is also a set of vertical tracks or channels cut into the plug for each wafer and associated spring. These align each wafer and allow their vertical travel as the key moves across the keyway.



The plug is held in position by an arc ring, screw-locked cam, inset pin, or by an extra disc tumbler that protrudes from the inside of the lock. When a spring-loaded disc is utilized, it can be depressed and released with a pick or stiff wire. Inset locking pins generally must be drilled to be released.

15_2.3.1.1 A Comparison: Wafer and Pin Tumbler Plugs

In comparison to the pin tumbler lock, the wafer **plug** is a great deal more complex. Whereas the plug and shell can be said to be of equal importance in the pin tumbler mechanism that is not the case with the wafer lock. Because the plug contains all moving parts, it can be completely removed with all internal parts intact. Within the pin tumbler device, there are always pins in both the plug and shell: they work interactively. That is not the case with wafers. Thus, no follower is required to take the wafer lock apart.

15_2.3.2 Shell

The shell contains all moving parts and provides the surfaces (upper and lower shell slot) upon which the rotating plug and wafers can act to create a locked or unlocked condition. If the lock is single bitted, then **either** the top or bottom shell slot will be occupied in the locked position with no key inserted. If the lock is double-bitted, then tumblers will enter **both** shell slots.

15_2.3.3 Wafers

The plug is fixed in one position by the wafers until they are brought to shear line. The wafer is the critical locking component, and performs the same function as the pin tumbler. Wafers are, however, markedly different in their design and function.

Locks generally contain four to thirteen flat stamped, rectangular metal wafers, each having a slot cut in their center. This inner space allows the key to pass through the middle of each wafer. Corresponding parallel vertical channels are provided for each wafer within the shell.

15_2.3.3.1 Wafers: How they secure the Plug

Wafers are spring biased and positioned so that they protrude into the top or bottom recessed areas of the shell. The counterforce to this spring bias is provided by the action of the key and the bitting corresponding to the position of the wafer. If the spring forces the disc to a position above the keyway, then the bitting for this same tumbler must cause the wafer to be moved **downward** to shear line. The plug will continue to be held fast until all of the wafers are brought even with its diameter (the shear line). Once all the wafers are at shear line, the plug is free to rotate, thereby turning and actuating the desired mechanism.

In the single-bitted lock, all wafers are forced to the top **or** the bottom of the plug. In the double-bitted configuration, the position of the wafers is **alternated** between positive and negative shear lines. Each wafer can occupy one of three positions within the shell: **above** the positive shear line, **below** the negative shear line, or **precisely aligned** with both shear lines. When all tumblers are at shear line, each wafer is completely contained within the plug and the plug is thus free to rotate.

As the key passes through the center of each wafer, the bitting moves each to shear line, above or below it. The relative vertical position of the internal slot relates directly to the bitting level of the key. Each wafer has an arm that extends from its body. The function is to hold a corresponding spring within a chamber. When wafers are moved to their correct respective positions by the action of the proper key, they will all be exactly contained within the plug: no portion of any wafer will extend past its diameter. The principle of operation is the same in the double-bitted lock; all wafers must be moved to the proper level in order for the plug to rotate.

15_2.3.3.2 Size and Design

All wafers have the following physical characteristics:

- **Each is rectangular;**
- **Each has exactly the same length as the diameter of the plug;**
- **Their width will be slightly more than the thickness of the key;**
- **All wafers will be the same length;**
- **The ends of the wafers will either be square cut or rounded;**
- **Each wafer has an internal rectangular slot to allow the key to move through its center.**

15_2.3.3.3 Modified Wafer Designs

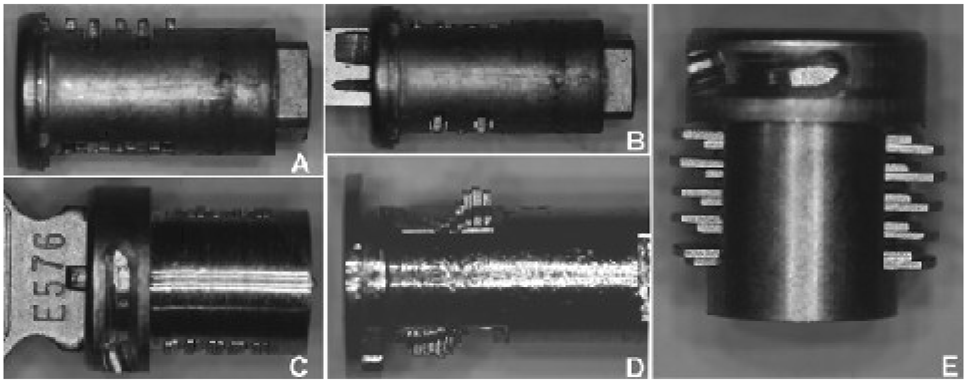
Wafers have been developed for specialized applications. **Datsun,** for example, introduced a wafer with a notch in the top to prevent removal when rotated 180°. They were not popular due to wear, jamming, and collapse. Likewise, **Mercedes** developed the split or half wafer, allowing each side of the tumbler to work at a different depth. This utilized the same space in the lock to increase security and double the number of possible combinations. The scheme allows an eight-wafer lock to have sixteen permutations. **Winfield** made a split wafer that allows reprogramming of the bitting position to change the combination of the lock externally. See **Chapter 23**.

The **Schlage** Company produced an extremely popular and unique medium-security wafer lock that was primarily for residences and apartment complexes. The lock has been used for the past fifty years, and can still be found on millions of doors, although it has not been manufactured for many years. The 922 series was quite popular because of ease in keying, rekeying, and setting up and changing master key systems. They are easily picked and have a limited number of key combinations. A detailed examination of this lock was presented in **Chapter 7** of the first edition of this text.

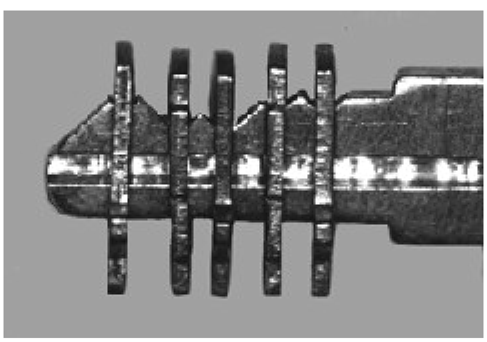
15_2.3.4 Shear Line

The shear line is a physical barrier to plug rotation that changes its shape and characteristics to correspond to the bitting of an inserted key. When all of the tumblers move to their correct position, then the shear line becomes imaginary.

Its function is to allow or block turning of the plug, depending upon the relative position of each wafer or disc. At least two shear lines will always be created in the wafer lock. In this text, these are referred to as **positive** and **negative**.



A positive shear line means that the wafers "break" or are brought even with the diameter at the top of the plug (positioned at the top of the keyway or bitting of the key). Conversely, the negative shear line is formed at the bottom of the plug where the wafers drop **below** or opposite to the bitting of the key. If the bitting is not deep enough, then a particular wafer will be over-lifted and thus protrude above the shear line. If the bitting is too deep, then the wafer will extend from the plug in the opposite direction, also blocking rotation.



15_3.0 Keys and Key Systems

The function of the correct key is to force the individual tumblers to shear line. A tolerance of at least .01” must be maintained when cutting the wafer key. Bitting level and position will correspond with the number of wafers and their orientation. Thus, in single-bitted locks, plugs may be configured so that the bitting makes contact with only one set of wafers, all in the

same vertical orientation.

The double-bitted wafer lock will provide for the bittings to appear on two vertical surfaces of the key, generally the top and bottom. In this configuration, alternately oriented wafers are used. For example, the first wafer will be raised by the top bitting of the key; the next wafer will be biased in the opposite direction and moved by the bitting on the opposite side of the key.

Triple and quad-bitted keys may also be found in certain high-security control locks and in some foreign cars. Mercedes, Volvo, and other manufacturers utilize what is known as a laser cut key. Actually, these may have a third and sometimes a fourth set of bittings that are overlaid on the primary bittings. They simply lift secondary wafers at different contact points.

Depending upon the design of the lock, the fact that a key has bitting on two, three, or four sides may not mean that there are actually different corresponding tumbler sets. Some double-bitted keys are actually made for a single-bitted lock and simply mirror the bitting pattern on the top and bottom. Ford does so for the convenience of the car owner, so that the key may be inserted using either vertical orientation.

In true double-bitted locks, the cuts will be of a different pattern on each surface of the key. This is because different tumblers with different depths are being moved. Note that if the top bitting for a particular tumbler is high, for example, then the non-active position for that tumbler on the opposite bitting surface of the key will be a mirror image. This is because there is only so much clearance within the interior portion of the disc through which the key passes.

15_3.1 Producing Keys for Wafer Locks

Keys for wafer locks are easily produced by direct duplication, by hand, by code, by visual decoding, impressioning, and by taking the lock apart. Most key machines are capable of duplicating both single and double-bitted patterns. Making keys by impressioning is discussed in **Chapter 30**.

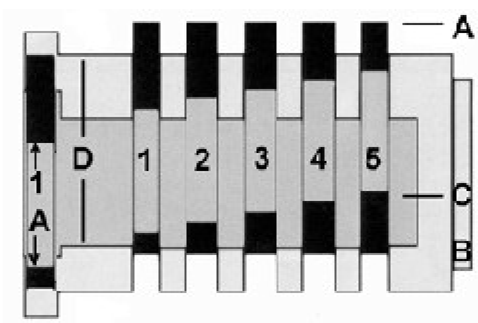
If the lock is to be disassembled, the plug is first removed. The correct blank is selected and inserted. Pressure may then be applied to the surface of each tumbler to cause the blank to mark, defining their positions. Filing is done with a small

rat-tail; the key is then reinserted into the plug to check the level of the tumblers. The key is repeatedly removed and filed until the tumblers are all at shear line. After the key is completely cut, the plug is reinserted into the shell and secured.

15_3.1.1 Decoding Wafer Locks and Producing Keys by Code

Reading wafer locks, courtesy of Harry Sher.

Wafer locks may be visually decoded simply by looking into the keyway. The direct code for each wafer can be determined, thereby allowing the production of a key. The underlying theory is simple: all wafers come to rest at the same position. The bitting pattern mirrors the key, but the position of the wafer pack is shifted because of the spring tension. All tumblers are in perfect alignment just not at shear line. Thus, the **relative** position of the bitting surface of each tumbler may be observed.



In practice, all but the last tumbler is raised, so that the relative position of the first wafer is determined. Each tumbler in succession, is similarly read. If master pins are employed, the same side of each tumbler must be examined and decoded. A borescope or magnifying otoscope, wafer depressor and reading tool, spring door retaining tool, slip coder, depth and space keys, and a code cutter are the tools which will enable the lock to be read easily. **Chapter 31** presents a thorough discussion of techniques for decoding wafer locks.

15_3.1.2 Key Codes

Generally, keys for wafer locks are coded by the manufacturer and may be duplicated by such direct or indirect codes. Numbers denoting the depth-cut will generally be stamped on each wafer.

A two-digit code on a master pin will indicate the bitting depths for the change and master keys, for right and left bitting.

15_3.2 Changing Combinations

Changing the combination may be accomplished quickly and easily in single and double-bitted locks. This may be done by either varying the order of the individual wafers, or by filing them. It is preferred, however, that tumblers be switched rather than filed. It is important to understand that the combination cannot be changed by filing the **tops** of the wafers but only by modifying the internal slot.

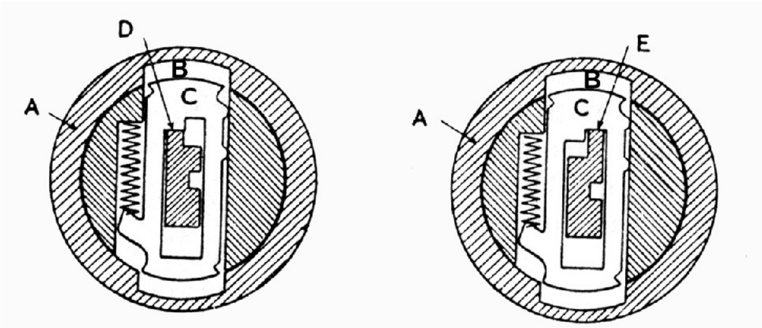
Due to the type of construction in the **plate wafer** lock, all the individual tumblers come in a "pack." This tumbler pack may be entirely removed from the plug and replaced with another, having a different combination of depths. Individual tumblers are not changed.

15_3.3 Differs

Due to the limited number of tumblers and possible depth cuts, relatively few differs or key combinations are available for most wafer locks. The number of permutations may vary from a few hundred to several thousand. The Chicago Lock Company, which is possibly the largest manufacturer of double-bitted wafer locks, will have an average of six hundred key changes per keyway on any double-bitted mechanism. Differs may be determined by taking the number of depths, raised to the power of the total number of tumblers. Thus, a lock having four depth differences using five wafers would theoretically produce 4^5 or 1,024 different key changes.

15_3.4 Master Keying

Wafer locks may be master keyed using special tumblers having two stepped areas or contact points. The change key lifts the left side of the wafer, while the master key raises the right side. No cross-keying occurs in a mastered wafer system, because different blanks are required for the master and change key. A thorough discussion of master keying is presented in **Chapter 11**.



CHAPTER SIXTEEN: THE PIN TUMBLER

Pin Tumbler Locks

Master Exhibit Summary

LSS101: Ikon factory, Berlin, Germany: How locks are made.

The use of a pin tray or setup tray is required for forensic disassembly of a lock. Courtesy of Hans Mejlshede.

Producing pins for cylinders. Courtesy of Hans Mejlshede.

Forensic issues regarding the bypass of security and mushroom tumblers. Courtesy of Hans Mejlshede.

Decoding the Best removable core lock for the control key, courtesy of Harry Sher.

LSS204: Brian Chan on positive and negative locking.

LSS204: Brian Chan discussing balanced drivers

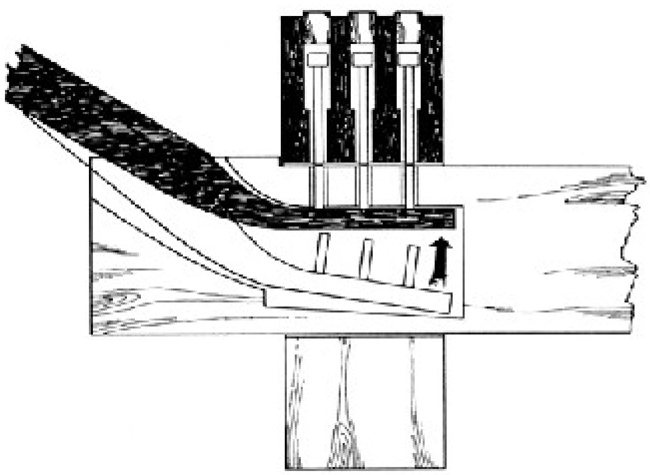
16_1.0 History and Development of the Pin Tumbler Lock

There is evidence that the first use of a moveable pin within a lock occurred about four thousand years ago in Egypt. The initial pin tumbler mechanisms, as described in **Chapter 1**, consisted of moveable pegs which held a sliding bolt in position until the proper key was inserted. The lock provided a measure

of security that was previously unknown. What can be referred to as "picking" was made difficult because of the length of the key- up to three feet.

The design was both simple and ingenious. The original lock housing was made entirely from a block of teak or other hardwood. The locking mechanism was within the bolt itself, isolated by up to three feet from the staples securing the assembly to the timbers of the door.

Inside the locking mechanism were from three to seven square slots in an uneven pattern. Within each of these slots or chambers would be a wooden pin or tumbler, free to move vertically. Although there were no springs, the mere weight of the pins would force them downward into the bolt, resting on a shoulder so as not to fall out of the lock. The key was fashioned of wood, with metal pins protruding from the active end that was inserted into the entire length of the bolt. This actually formed the keyway.



It is almost certain that whoever conceived of the original Egyptian mechanism did not recognize that the double-detainer locking principle had been invented. Although it would take another four thousand years for the concept to mature into practical locking devices, nonetheless, the genesis of the idea was brilliant. It set the stage for the evolution in design upon which all modern locks would be based.

The Egyptian design established two rudimentary concepts:

- **The use of a moveable detainer (pin) whose physical**

position would cause a locked or unlocked condition to occur within the housing;

- **Creation of a "shear line" and corresponding physical barrier to movement of the bolt until the detainer was placed in the correct position.**

In the Egyptian lock, there was only one set of pins (drivers). The bolt did not rotate; it was slid to a locked or unlocked state. When thrown into the jamb or placed in a locked position, the pins projecting from the fixed staple would enter corresponding holes in the bolt and prevent any movement.

The purpose of the key was to raise each of the pegs within the lock casing so that they would not interfere with the movement of the bolt. The location of pins on the key would precisely match the position of the corresponding pegs within the lock that protruded from the upper housing. The key could be likened to the end of a toothbrush: the pattern of "brushes" would be different for each lock. Once the key was fully inserted, it was lifted straight up. The pegs on the end of the key would pass through holes on the upper surface of the bolt. These would raise the projecting pins to a point where all of them would be resting above the bolt. When this occurred, the bolt and key could then be pulled back to the unlocked position. The reverse procedure was followed to secure the bolt. The security of the lock was based upon the location and number of upper pins. The "shear line" was created by simply lifting all pins above the bolt, rather than to a precise point in relation to its surface.

The Egyptian lock makers realized that their "pin tumbler" devices suffered from serious problems: each took a great deal of time to construct because of the craftsmanship involved, and locks could be picked or wax impressioned. For no known reason, the Egyptian pin tumbler lock faded into history and was essentially forgotten for forty centuries until rediscovered by Linus Yale, Sr. The principle established by the Egyptians appeared in locks all over the world. In fact, India, Japan, Scotland, and the Faeroe Islands all produced similar designs. Even the Romans adopted the use of pins, until wards were invented. It is interesting to note that the Scottish, around the eighteenth century, used square rather than round pins in their locks.

16_1.1 The Yale Lock

Linus Yale Sr. was born in Middletown, Connecticut in 1797. He

was a talented inventor and successful manufacturer of bank locks, who, in 1844, developed the first practical pin tumbler cylinder lock. His son, Linus, Jr. was born in 1821. He began his career as an artist. Although never in partnership with his father, Linus Jr. soon followed in the elder's footsteps, designing and making locks in his own factory. He is credited with the introduction of the grooved keyway and mass production of the Yale cylinder.

Linus Yale, Jr. improved the pin tumbler lock between 1860-1865, based upon the original Egyptian principles and the work of his father. In 1868, Yale, Jr. began working with Henry R. Towne, a young engineer who had been employed in the Port Richmond Ironworks during the Civil War and later had studied at the Sorbonne in Paris. In 1883, the Yale Lock Manufacturing Company became the Yale and Towne Manufacturing Company and is now Eaton, Towne, and Yale.

16_1.2 The Egyptian and Yale Designs: A Comparison

The Yale invention bore little resemblance to the original Egyptian lock, but Yale clearly based his design upon the initial concept. Within the Egyptian lock, the pins kept the bolt from sliding; Yale adopted the idea to a rotating plug within a stationary shell. In both cases, the pins would hold the actuating component fast until raised to a proper level. Yale improved upon the ancient design and made it practical by taking the pegs that were affixed to the end of the key and making them part of the internal mechanism. Thus, the Yale lock would have **two** sets of moveable tumblers: **upper pins**, which were in the Egyptian design, and **lower pins**, which were originally part of the three-foot key.

In order to make the locking system functional, Yale also had to conceive of the rotating plug as the actuating device to control the bolt. This required that a shear line be created; hence the use of two pins per chamber. Once Yale made the fundamental alteration to the original Egyptian design, he was able to produce a lock having a small key (not three feet in length) that was capable of a great number of different combinations. The final Yale cylinder had several sets of spring-biased pin tumblers, each split in two segments and aligned in a straight line, corresponding with the bitting of the key. Yale required that a moveable pin be lifted to a precise position to allow free

rotation of a concentric internal plug. When the Yale key was inserted, its upper edge would raise each pin to the correct height so that the inner plug could be turned. In his lock, a difference of .02" in pin length was sufficient to prevent rotation.

16_1.3 The Modern Pin Tumbler Lock

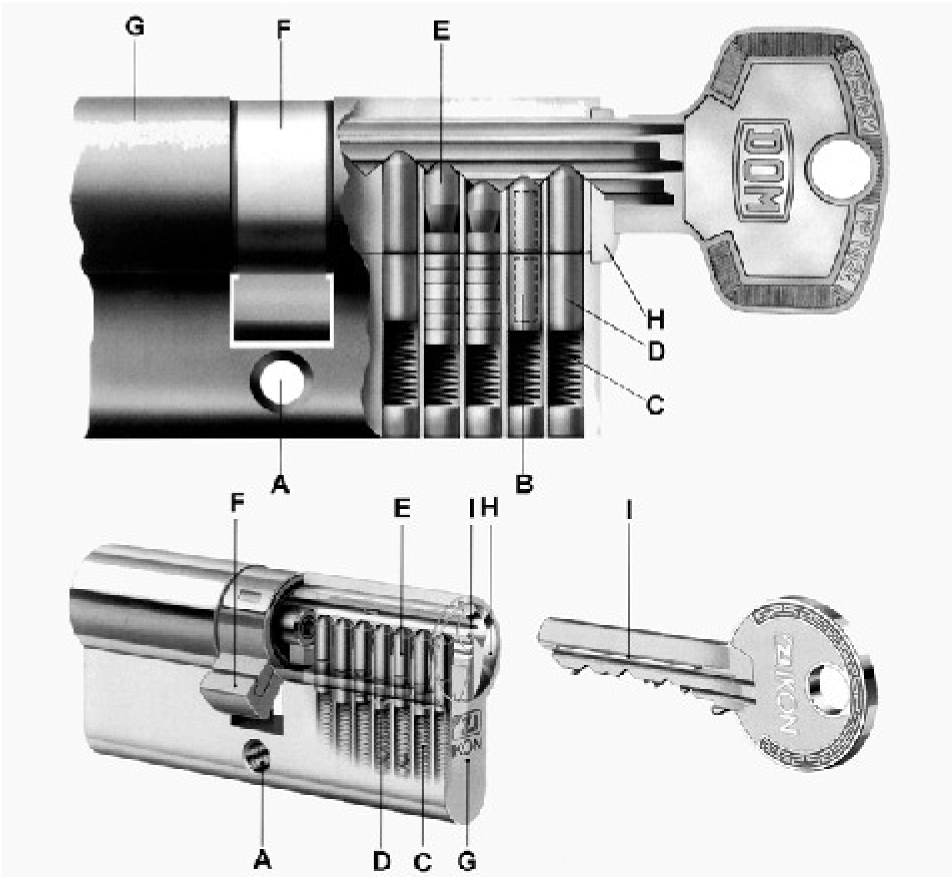
The pin tumbler design appears in many configurations and applications, from bank vaults to padlocks. Any sort of bolt or locking cam may be controlled, adding to the locks versatility. There is inherent security because of the tolerances required for functionality and the use of the double-detainer principle.

The number of tumblers, keyway configurations, pin chamber design, and tolerances may be altered to increase security. Most modern cylinders contain five to seven pin sets. The term **"pin tumbler"** is generic: it does not denote size, quality, security or pattern of the key. It simply indicates the use of moveable pins to block rotation of the plug.

There is a vast difference in the quality of locks. As will be detailed in this chapter, those differences are based upon many complex factors. Today's mechanism is a small, secure, virtually trouble-free and inexpensive device. It is found in every part of the world and is heavily relied upon by all societies to provide security.

16_2.0 Lock Part Identification, Definition, and Characteristics

Cylinders are available in many different configurations and levels of security. All conventional pin tumbler locks have ten basic parts: shell, plug, keyway, key, pin tumblers, pin chambers, springs, chamber seal, cam, its retaining mechanism, and actuation link, and lock face. In addition, there are terms generic to this mechanism relating to disassembly and maintenance. This section shall describe each part and define relevant terms.



Bottom Pins: The bottom or lower pins make direct contact with the bitting surface of the key, and create one portion of the shear line, when combined with the top pins or drivers.

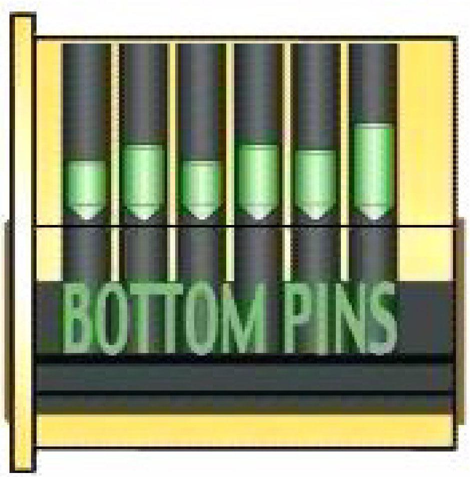


Figure LSS+1601 The bottom pins and top pins form the pin stack within each chamber. Courtesy of HPC Interactive Learning Series.

Broaching: The process of cutting, forming, and shaping the keyway in a brass plug during the manufacturing process.



Figure LSS+1602 A broach for creating a keyway profile.

Bumping or rapping: A method of opening a pin tumbler mechanism by using shock and vibration applied to the shell. The technique utilizes a wooden or rubber mallet, or requires rapping the lock against a hard rubber or wood work surface.

Cam: The cam is attached to the back of the plug. Its primary purpose is to transmit the action of rotation to the bolt or other locking device. The cam-retaining mechanism, usually held by screws or a spring loaded screw-cap, has two functions: (1) it maintains a precise alignment between the upper and lower chambers and (2) keeps the plug from being removed when the correct key is inserted.

Cylinder Lock: A pin tumbler lock having its mechanism contained within a cylinder. A bicentric cylinder contains two plugs and pin sets and allows separate operations by change keys and master keys. See Chapter 23 for a description of the Winfield lock.

Cylinder Ring: A collar or washer applied under the head of a cylinder, often to increase security.

Driver Pins (top pins): The upper set of pins that project downward into the plug. They are also known as roller pins.

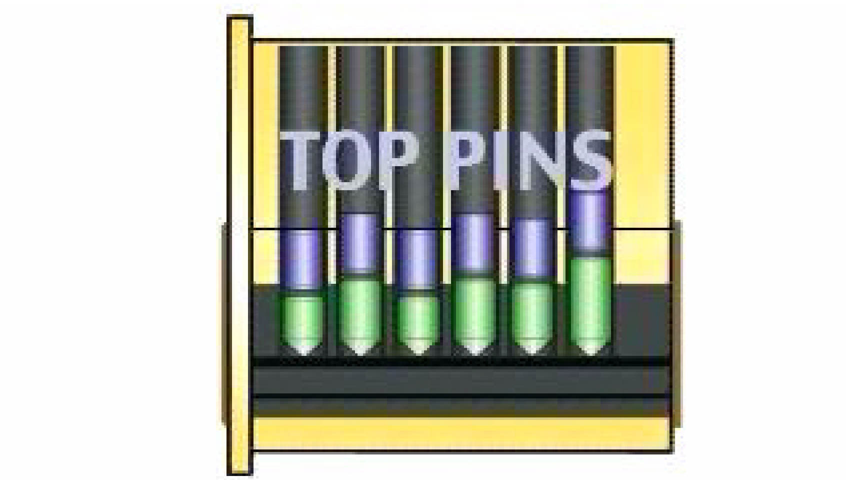
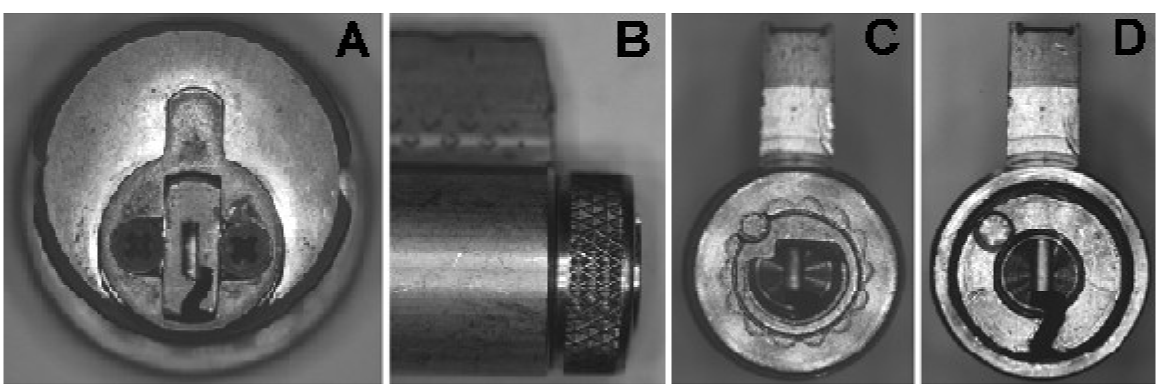


Figure LSS+1603 The top pins or drivers allow for the creation of a shear line. The drivers place downward pressure or bias on the bottom pins and create the pin stack. Courtesy of HPC Interactive Learning Series.

Following Tool: A round, dowel-shaped tool having the same diameter as the plug. It is used to disassemble a pin tumbler lock. Its purpose is to follow and fill the space left when the plug is withdrawn. The follower keeps the drivers and springs within their chambers.

Keys, Design Parameters: A number of terms are used to describe design components involving keys: **Center of Cut, Root, Slope, Valley.** These are discussed in Chapter 6.

Keyway: The keyway limits the number of keys that can enter the lock and thereby increases security. They can also make picking difficult. By varying the design, sophisticated keying systems are made possible. Keyways can be infinitely varied and are created through broaching.



If all locks had but one keyway, key control would become impossible. Manufacturers would very quickly run out of combinations because keys intended for one lock would fit numerous others. There are thousands of different keyways in use today. Each is copyrighted and unique to one manufacturer. The purpose of the keyway is to guide the key through the plug, and position it in order that the bitting may precisely lift the pins. Many vendors offer special system keyways. These are for use in large complexes where complicated master keying is required. Each area or section can be given a unique keyway that prevents the use of keys from other areas. Master keys can be designed to fit all of the different keyways of the system.

Lock Face: The face acts as a protective shield to the internal parts, allows the lock to be mounted on a hard surface, and offers a stop for the shoulder of the key.

Master Key: A key designed to operate two or more locks having different change keys.

Master Pins: The tumblers used specifically for master keying. They are generally sandwiched between the driver and bottom pins in order to create additional shear lines.

Paracentric Keyway: A keyway that has wards or obstructions protruding from either side, past the vertical centerline. A flat piece of metal is prevented from entering, without matching grooves corresponding to the obstructing wards.

Pin Chambers: Each pin tumbler and associated spring (pin-stack) is contained within a bored chamber located in the shell (for drivers) and the plug (for lower pins). The upper chambers are generally drilled completely through the shell; lower chambers are only drilled partially through the plug and into the keyway. The upper and lower chambers are in perfect vertical alignment to allow the pins to freely move above and below shear line. The pin chambers are at the heart of the double-detainer locking principle. Without them, the lower tumblers could not be raised into the shell, nor could the driver pins enter the plug. See the discussion below regarding tumbler classifications, below.

Plug or Core: This is the active, rotating component of the pin tumbler lock. The plug contains all lower pins, held within chambers that are bored to correspond with the precise position of the top pin chambers. The plug or core is the part which, when all of the pin tumblers are in perfect alignment, can be turned

with the key to actuate a bolt mechanism.

Security Tumblers: Security is enhanced by the use of special tumblers that make picking more difficult. These are generally referred to as spool, serrated, and mushroom pins. See the discussion below.

Shear Line: The level to which all pins must be raised in order for the plug to rotate.

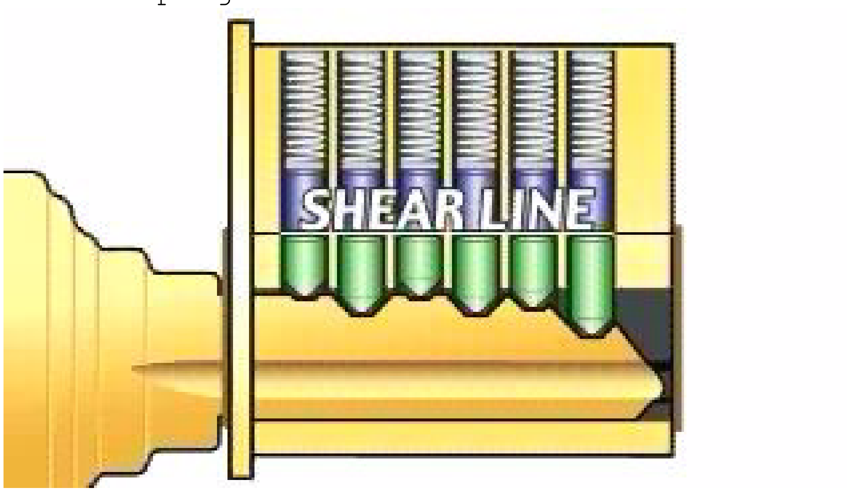
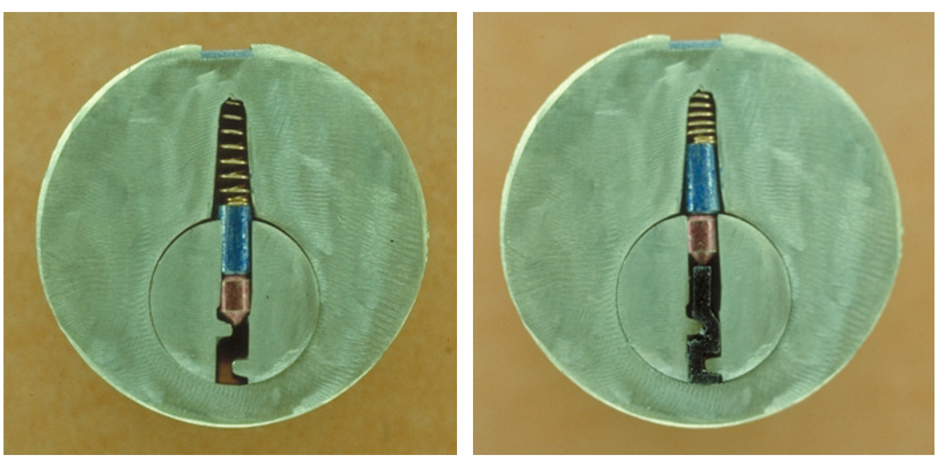


Figure LSS+1604 the shear line is the break point between bottom and top pins. Courtesy HPC Interactive Learning Series.



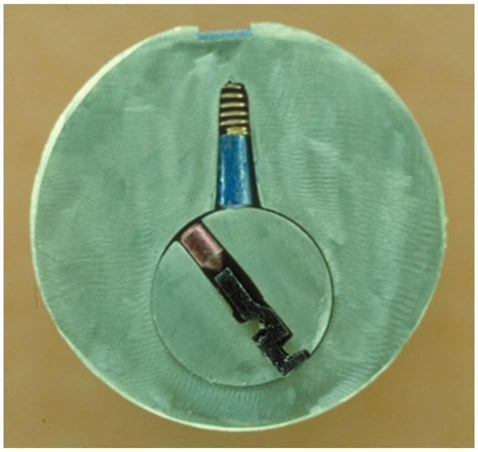


Figure LSS+1613. These photographs show the driver and lower pins in their three states.
(Left), driver is blocking the rotation of the plug, (center) driver and lower pin are
split at shear line, and (right) plug can rotate. Courtesy of Bill Sherlock, Illinois State Police.

Shell: The shell contains all of the internal components: the upper and lower sets of pins, the springs, and the plug.

Springs: Springs provide the bias to force each tumbler-set into the plug and to maintain the integrity of the pin-stack while the key is inserted and removed. Proper functioning springs are very important: they insure reliable and continued operation and security against surreptitious methods of attack. For every driver there must be a spring, if jamming of tumblers and unreliable operation is to be avoided. Without them, dust and dirt will build-up in the lock, eventually freezing the tumblers in one position. The correct springs must be used: if too short, too long, or incorrect tension is produced, operational difficulties will occur.

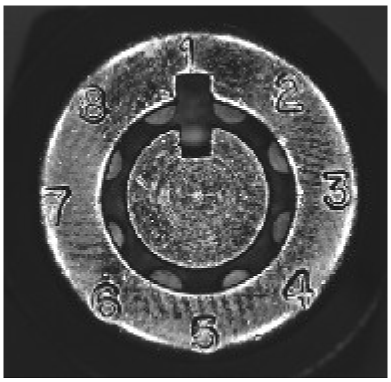
16_2.1 Mechanical Configurations

The double-detainer pin tumbler system of locking has been modified for a number of different mechanical configurations, for specialized applications. Regardless of the design, however, the basic operating theory is identical. Any lock that utilizes a split pin to create a shear line will block the rotation or movement of a plug, unless all of the tumblers are in alignment. Whether the pins are arranged in a straight line, axially, or in several planes around a circle, the theory is identical.

16_2.1.1 Conventional Design: Vertical or Horizontal Orientation

Locks utilizing the pin tumbler principle are produced in conventional form, aligned in one vertical or horizontal plane. All chambers or bores are co-located along one axis within a rotating plug.

16_2.1.2 Axial



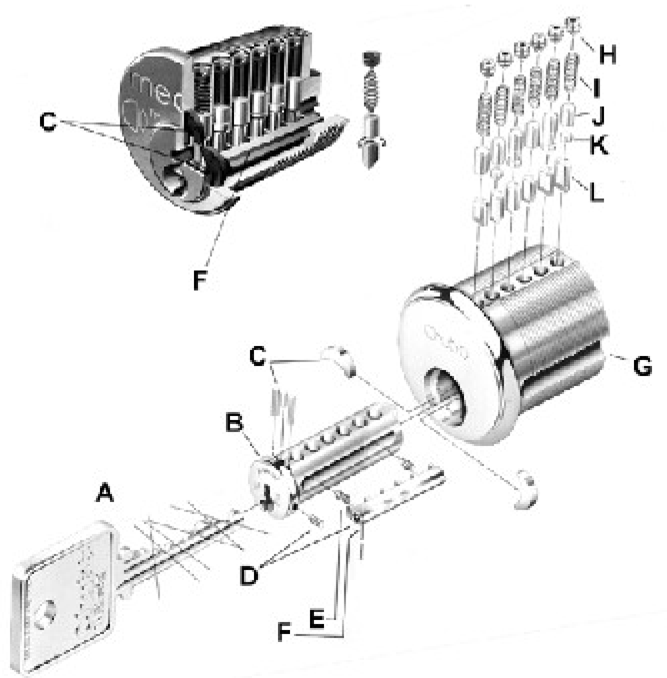
Locks are produced in an axial configuration, where up to eleven pins are organized around the circumference of a plug. The operation of the lock is identical to the conventional design; only the placement of the pins is different. Certain variations of the axial pin tumbler mechanism are described in **Chapters 17** and **23**.

There have been many significant patents issued for rotary pin locks and security enhancements thereto. Relevant cites are included here. Picking and decoding tools for axial locks are described in **Chapters 29-30-31**. Kerr was granted three patents for a tamperproof lock (3267706, 3541819, **3813906(153)**). Buschi (3604231) invented a lock with sliding tumblers that controlled access by the key to a locking pin. Szova produced a lock based upon the same theory in 1977 (4006615).

16_2.1.3 Sidebar

A sidebar pin tumbler lock utilizes conventional pins in combination with a secondary locking arrangement. In the best-known example, Medeco utilizes vertically oriented pins that must also be rotated to one of three or six angles in order for a secondary sidebar to engage. See Spain (**3499302(154)**,

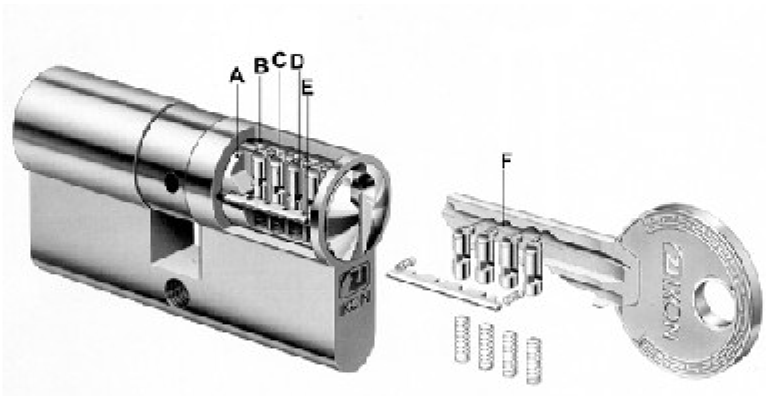
3499303(155)) and Oliver (**4723427(156)**) for a description of the original Medeco designs.



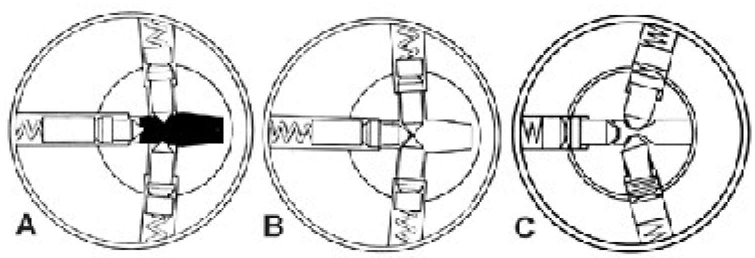
Some hybrid locks combine pin tumblers with other sidebar locking techniques; magnetic discs are probably the most popular. See **Chapters 17-23** for information on specialized applications.

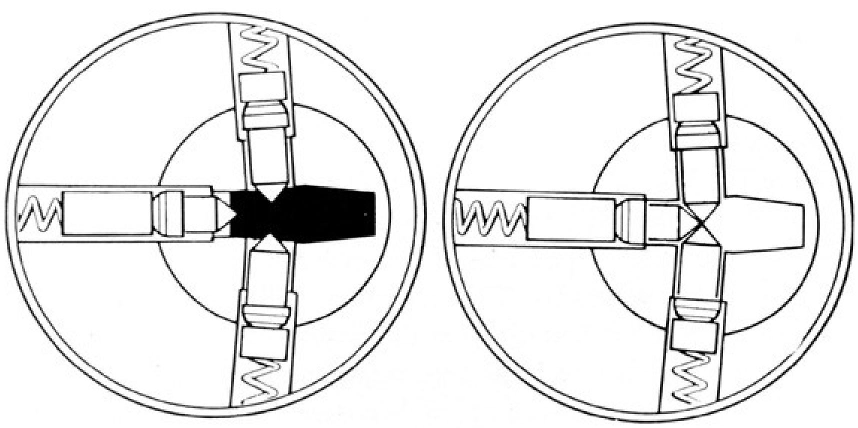
Lopez, in 1973, was granted a patent (**3837197(157)**) for a sidebar lock that utilized dual- locking tumblers with detents. Likewise, in 1992, Folger Adam Company was assigned a patent from Stefanek for a high-security pin tumbler lock with a second set of angled pins (**5079936(158)**). Other patents have been granted for using auxiliary tumblers in different radial directions to prevent picking and impressioning. See Prunbauer (4434636), Hofmann (4343166), Gerlach (3802234), Crepinsek (3393542), and Bauer (3181320).

Other relevant patents for sidebar design include Oliver (39,910), Taylor (758026), Fitzgerald (1965889), Crepinsek (3393542), Besseches (3455130), Surko (3667264, 3713310, 4208894)), Gartner (3857263), Genakis (**4078406(159)**), Pechner (4185480), Vorob (4194604), Widen (4356713, 4393673, 4453432), Wolter (4377082), Reder (4380163), Hennessy (4404824, 4524593), Litvin (4429554), Prunbauer (4434636, 4250725), and Fits Gerald (1965336).

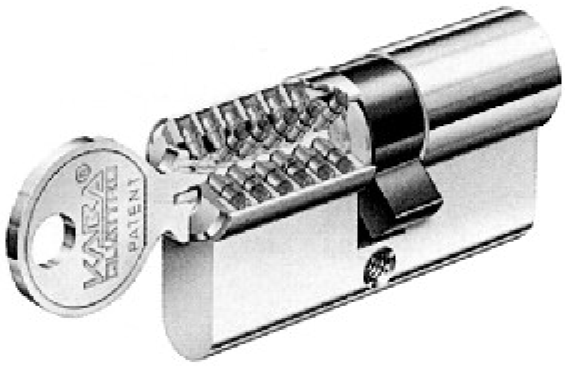


16_2.1.4 Multiple Interlaced Tumblers (Dimple Locks)





Keso, in 1968, introduced the dimple concept for high-security locks. Today, many manufacturers produce mechanisms that employ one or more rows of interleaved pin sets that encounter multiple bitting surfaces. Keso, DOM, Ikon, Evva, and Mul-T-Lock are the most popular in the industry. These locks are discussed in **Chapter 17**. Crepinsek (**3413831(160)**) was granted a patent in 1968 for a rotary cylinder lock that was the forerunner to more sophisticated devices in production today.





16_2.2 Tumblers

All pins have certain design characteristics relating to length, diameter, chamfer, and curvature. Security tumblers are a sub-class of the top pin and have variations in the number, location, and size of indents. Each manufacturer specifies pin chamber diameter and overall length for each lock they produce. This determination will control the number of depths that are available. This, in turn, allows calculation of differs.

The ends of the bottom pins that encounter the key may be **rounded**, **pointed**, or **square-cut** with a chamfer or bezel. For higher tolerance between the pin and valley of the cut, the surface may be flat-bottomed. Driver or top pins are generally square cut on both ends, with chamfering. There are three primary tumbler classifications: upper pins, called **drivers**, **lower pins**, and **master pins**.

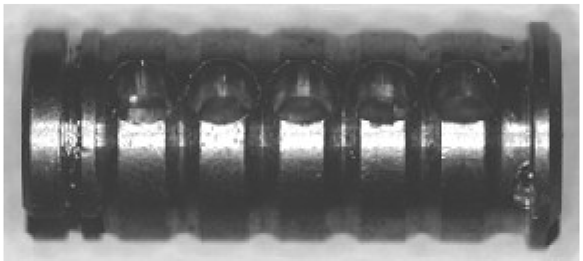
16_2.2.1 Driver Pins

While the lower pins make contact with the bittings of the key, the driver pins (or upper pins) press down on the lower set of pins and actually provide the locking function. The drivers are constantly biased by the springs directly above each chamber. There are four basic types of driver pins: **standard driver**, **mushroom**, **serrated**, **and spool tumbler**.

16_2.2.1.1 Standard Driver

The normal top pin is simply a flat-topped and flat-bottomed tumbler. Its function is to project into the plug or withdraw

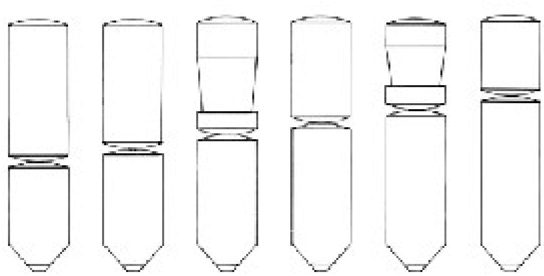
into the shell and create a shear line in combination with the bottom pin when raised to the proper level. For the lock to operate smoothly, drivers must be perfectly flat-bottomed, or convex, depending upon the design of the plug-shell interface. In high-security locks, the plug is perfectly rounded; the tumblers will correspond in shape.



A lower pin with flat-bottom down may also be used as a driver. If driver pins are worn from use or old pins are reused when changing combinations, the plug may rotate roughly, catching edges of the tumblers at shear line. This is especially true if pins have been hand-filed or have worn at an angle. In such case, the lock may operate smoothly when turning the plug in one direction only.

Drivers are normally provided in three standard lengths, depending upon the space displaced by the lower pins in the plug. In a properly designed keying system, the drivers are said to be **balanced.** This means that the length of the pin-stack is **constant**, regardless of the length of the bottom pin. This parameter becomes important in preventing the use of a comb to pick a lock, discussed in **Chapter 29**.

LSS204: Brian Chan discussing balanced drivers



16_2.2.2 Lower Tumblers

The lower tumblers are those pins that are in direct contact with the bittings of the key. They are usually rounded on the bottom and flat on top and come in a variety of lengths and diameters. They are generally color-coded as to length. Tumbler size is based upon the diameter of the plug, the dimensions of the keyway, and the number of depths chosen for use by the lock maker.

Certain bottom tumblers resemble drivers in that both ends are flat. In such cases, the keys are cut specially with flat rather than rounded valleys. The Best Lock Company uses flat-bottomed tumblers to attain a closer tolerance between the bitting and pin. A flat-cut tumbler is not used with a rounded valley. A number of manufacturers insert steel balls below one or more lower pins. These have the effect of prolonging the life of the tumbler and allowing for smooth operation of the key.

16_2.2.3 Master Pins

Master pins are miniature drivers, sandwiched between lower and upper pins to create additional shear lines. They can vary in thickness from one depth-cut to many, depending upon the complexity of the master key system. Medeco patented a unique master key system in 1973, based upon their twisting tumbler sidebar design (**3722240(161)**). This approach to a multilevel keying system virtually eliminated the potential for cross-keying.

16_2.2.4 Security Tumblers: Mushroom, Spool, Serrated

Forensic issues regarding the bypass of security and mushroom tumblers. Courtesy of Hans Mejlshede.

Security tumblers are installed in order to make picking more difficult. They are interchangeable with standard drivers and are used by many manufacturers, especially in more expensive locks. Security tumblers can be picked, but special procedures are required. As a rule, a five-pin lock will have up to three security tumblers; a seven-pin lock, up to four tumblers. It is not possible to fill every chamber with these special pins because the lock would not function properly.

Although there are many different tumbler designs, the function of all security tumblers is the same: **to create a false**

indication of shear line. Ironically, while these pins can make picking very difficult, certain security tumblers, such as serrated, may make impressioning easier. A discussion regarding picking and impressioning of these tumblers is presented in **Chapters 29-30-31.**

Although their use is standard in most high-security locks, the installation of security tumblers to replace driver pins has become common in the less expensive cylinders, also. Whether mushroom, spool, serrated, “S” design, or a combination of variations, their dimensions will always include indented gaps, ridges or notches that will “catch” between the shell and plug.

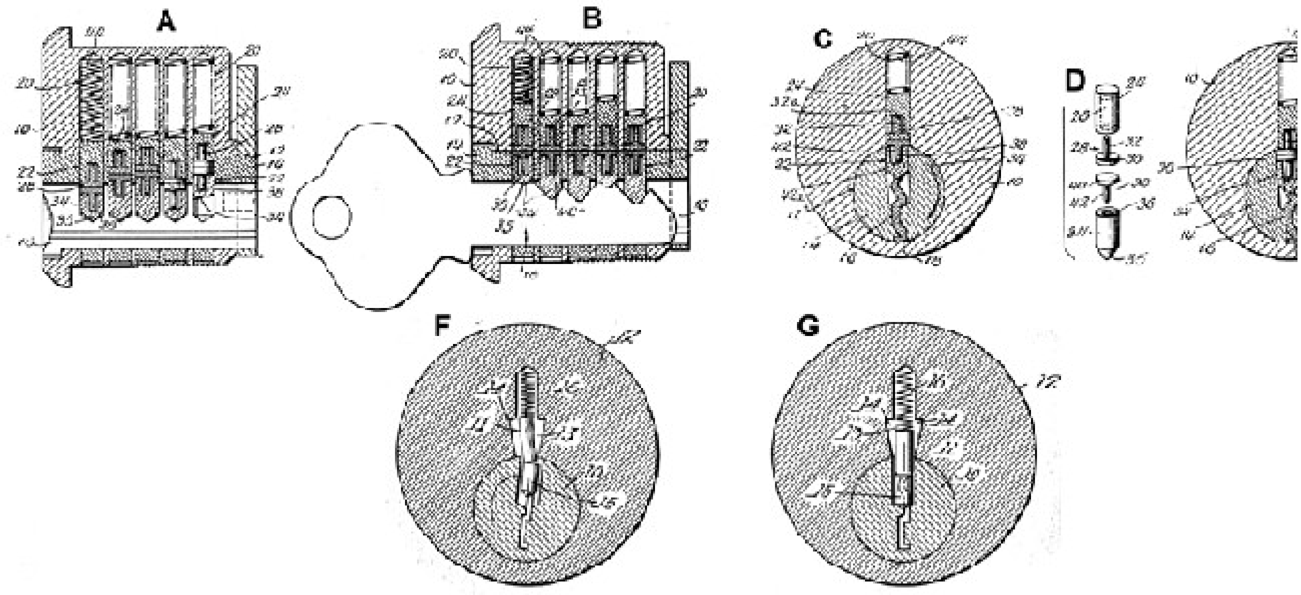
There have been many attempts to deter picking, impressioning, and decoding through the alteration of pins and their chambers. Many significant U.S. patents have been granted for such designs. It appears that the first U.S. patent to issue for a security tumbler was in 1865. Several other patents have been granted for variations upon the original concept, but the security tumbler, regardless of form, always has the same purpose.

A number of patents have been issued for modifications to pin tumbler locks to prevent picking. The following patent cites relate to the alteration of pins and bores in order to trap tumblers that are the subject of pressure or torque caused by picking: Hainline (1739964), Thompson (2043205), Fremon (2194469), Rauh (**2281714(162)**), Crousore (2283489), Spiegler (2565531), Pastor (2596720), Mendelsohn (**2629249(163)**), Crepinsek (3393542), Wolter (3731507), Neale (3824818), Genakis (4068508, 4068509), Raskevicius (4098103), Schlage (4107966), Voight (2149959), Taylor (457753), Maxwell (**2059129(164)**), Voight (**2194959(165)**).

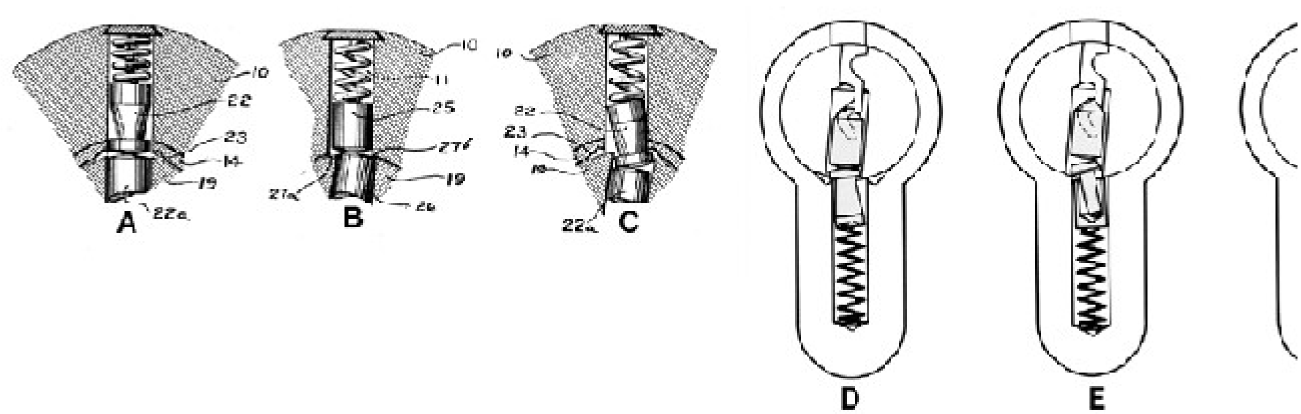
In 1989, Johnson invented a high-security axial lock for the Fort Lock Corporation (**4802354(166)**) that included notches in the driver tumblers.

16_2.2.4.1 Specific Parameters for Pins

All pin designs are based upon the fundamental technique of lock-picking: the application of turning pressure on the plug in order to bind pins above the shear line. Whether pins individually are forced into the upper chamber with the pick or are initially moved there, then released to fall back to the plug, all security tumblers will essentially perform the same function.



In order to enhance pick resistance, the size, shape, diameter, and striations of the lower and upper tumblers as well as their bores have been altered.



Exploded view 1, 2.

16_2.2.4.1.1 Cylinder Bores

Many structures have been patented based upon serration or grooving of the cylinder bores, the plug bores, the driver pins, and the lower pins. Where transverse grooves are provided in the pins and bores, the pins cannot move freely during the picking process. The diameters of the upper and lower chambers have been altered in some locks so that the upper bores are slightly

larger. In other designs, the bores and pins have been threaded and provided with sufficient tolerance that when torque is applied to the plug, the top pin will be caught in the threads.

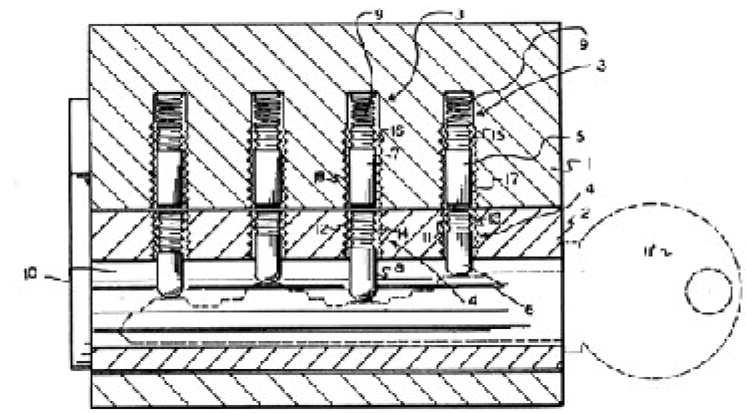
In the Genakis patent (**4078406(167)**), bores are modified to trap tumblers when upward pressure and torque are applied simultaneously. Eizen, in his 1989 patent (**4856309(168)**), describes a system of grooves within the plug to prevent picking. This invention was incorporated into the Mul-T-Lock and is further described in Chapter 17. Embry, in 1990 (4977768), incorporated specially designed pins and bores in an axial lock to defeat picking attempts. In 1932, Gutman altered the size of the upper chambers to make picking more difficult (**1860712(169)**). In 1938, he devised a multisegment pin with shoulders to prevent decoding, vibrating, and picking (**2158501(170)**). Then Liss, in 1934, patented a type of serrated pin (**2070233(171)**) for securing the plug against picking. Crusore, in 1942, developed a tumbler that was grooved and would cooperate with recesses in the bores to make picking very difficult (2283489). Hucknall, in 1973 (**3762193(172)**), developed a pick resistant lock utilizing special pins and milled bores, and Mendelsohn patented a lock with grooved pins and bores (**2629249(173)**) that frustrated picking.

16_2.2.4.1.2 Indents, Grooves, Ridges, and Serrations

The number, spacing, depth, and diameter of the grooves have been changed, both with respect to the pins and their chambers. Telescoping pins have also been employed to create false indications of shear line.

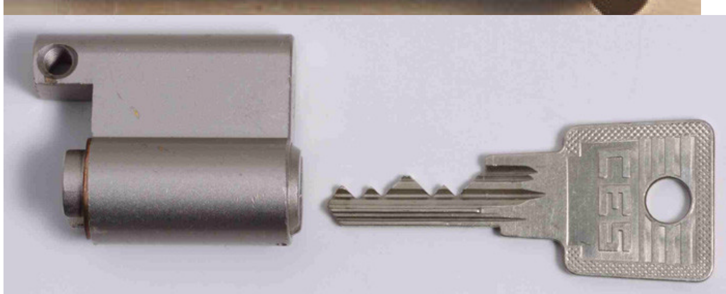
False ridges, shoulders, and serration patterns have been employed within the bores to freeze the movement of pins, except under prescribed conditions. This would occur when their dividing line is coincident to the shear line between the cylinder and plug. The materials used for the production of pins have even been changed to allow shearing or flexure, depending upon design.

In 1990, Embry was granted a patent (4977768) for a specially designed pin to be incorporated in an axial lock in order to frustrate picking. This tumbler was a modified spool that would catch whenever pressure was applied to it.



An interesting approach was taken by CES by creating a special pin in the third bore of this plug that requires a correspondingly high cut on the key. This makes picking extremely difficult.





16_2.2.4.1.3 Spring Bias

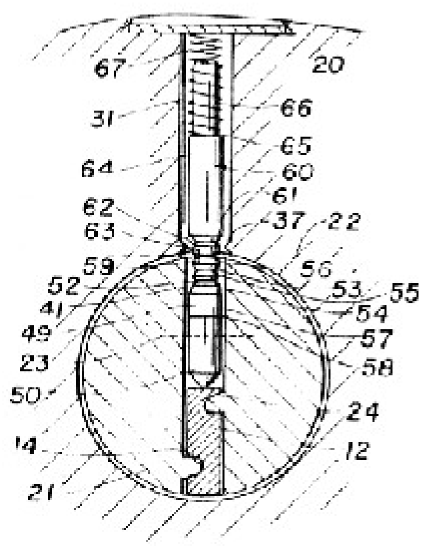
Kerr received a patent in 1966 for an invention to defeat pick tools specifically designed for axial pin tumbler locks (3270538). He describes the incorporation of springs with varying tensions within a lock in order to frustrate picking and decoding.

16_2.2.4.1.4 Secondary Locking Pins

Secondary locking pins have been utilized to block access to primary tumblers in an effort to prevent picking. In 1975, Steinbach was granted a patent (**3916657(174)**) for an axial lock that allowed pins to be rotated to a secondary position.

16_2.2.4.1.5 Mushroom and Spool Tumblers

The design of mushroom and spool tumblers is quite similar. Unfortunately, they cannot be used to replace all of the driver pins in the lock. This would cause the plug to rest in an off-center position with respect to the shell, creating a misalignment between upper and lower pin chambers and making key insertion difficult. In contrast, "S" pins may be used in all chambers. Often, they may be detected by looking into the keyway.



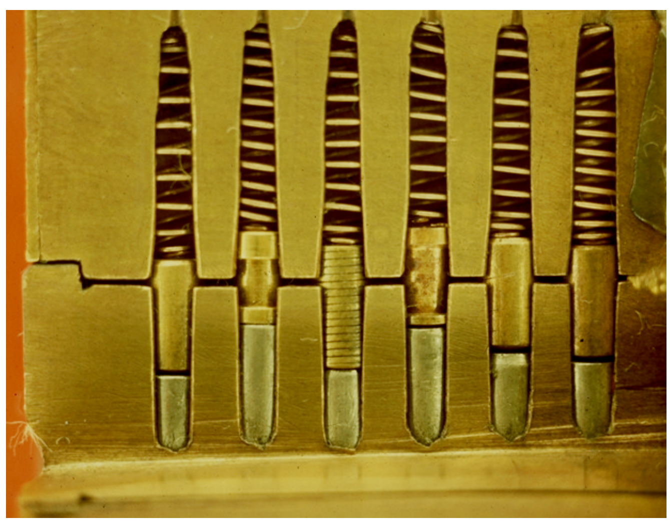
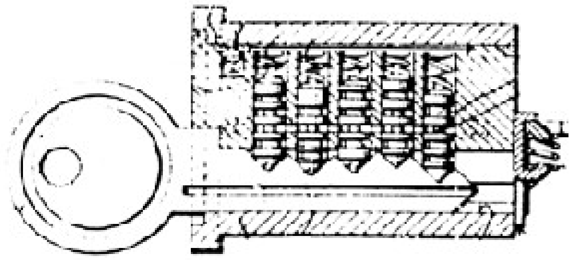


Figure LSS+1614 This sectional view graphically illustrates the location and function of the mushroom tumblers in positions two and four. Courtesy of Illinois State Police, Bill Sherlock.

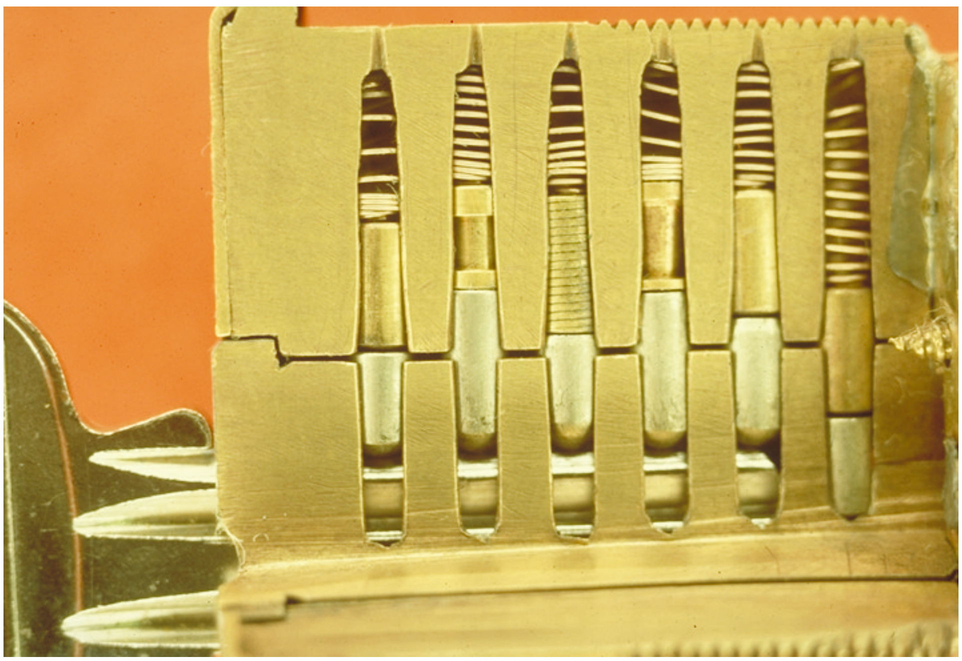
16_2.2.4.1.6 Serrated Tumblers

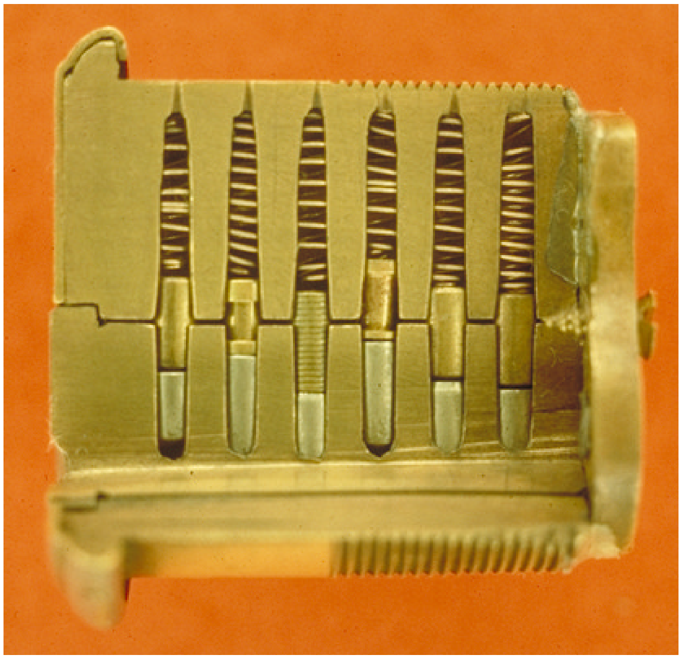
Serrated tumblers actually contain many segments common to the mushroom or spool. Generally, serrated tumblers have a series of ridges on the tops, bottoms, and sides. Pin chambers may also be serrated. Master pins are never serrated.



16_3.0 The Pin Tumbler Mechanism: Principles of Operation

This section describes the theory and principles of the pin tumbler mechanism.





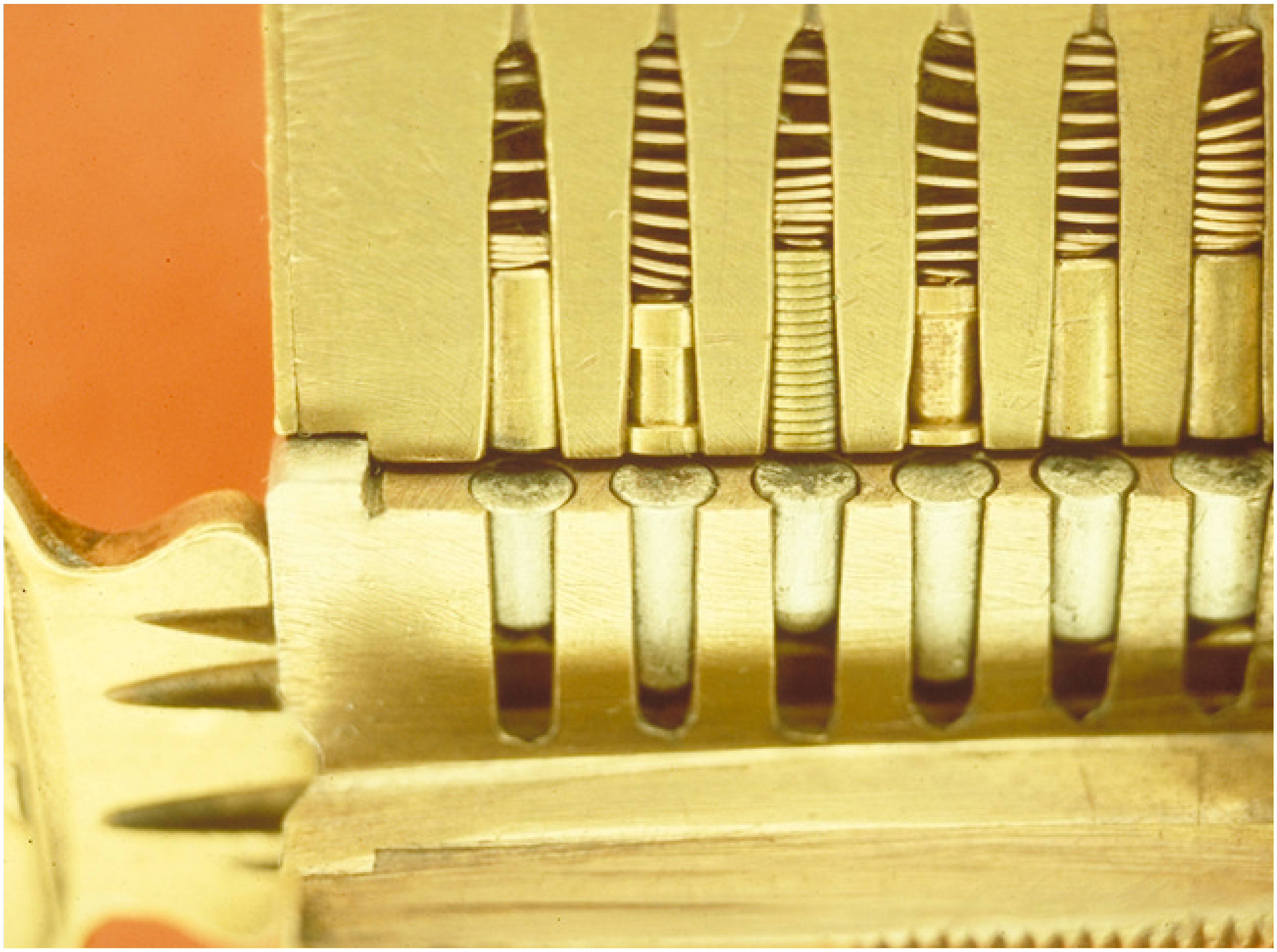


Figure LSS+1615 Sectional photographs showing the status of driver and bottom pins in the locked and plug rotating unlocked position. Courtesy of Illinois State Police, Bill Sherlock.

16_3.1 Introduction

Every lock has relied upon some mechanical means to keep a specific part (bolt) from moving (opening or locking) until the correct device, code, or combination is inserted or applied to the mechanism. The pin tumbler design probably offers the most inherent security and flexibility of all the different mechanical locks presented in this text. Its operating principle is based upon the double detainer theory of locking which is actually quite straightforward.

Let us begin our discussion by examining the pin tumbler cylinder in terms of its mechanical operation and security, from the

perspective of a design engineer such as Linus Yale of 150 years ago. Yale set out to construct a lock that utilized split pins as the basis of its security. He knew that 4,000 years earlier, the Egyptians had invented a lock which also used pins but in quite a different configuration. Once he conceived of the shear line, the other design requirements were obvious. Based upon the underlying theory of operation, its evolution and required mechanical components become logical and easy to understand.

16_3.1.1 The Simple Mechanism that only controls a Bolt

At one extreme, a lock could be constructed which simply controlled the operation of a bolt or latch without regard to security. At the other extreme, a high-security device could be built that maintained close tolerances and required a precision key to allow actuation of the bolt.

In the first instance, all that is needed is a housing (shell) that contains a rotating member (plug) connected to an actuating mechanism (cam) which transmits action (rotation) to a bolt. This "lock" in its simplest form would consist of a housing with a hole drilled through it. A solid plug with a slot in the front would be inserted into this hole and attached to the bolt. Turning the plug, with a screwdriver, flat piece of metal, or key would transfer the motion to the cam and thus the bolt.

There would be no security in this lock; any blade could rotate the plug. It would simply be a matter of communicating a turning motion to the bolt via the plug. The important mechanical consideration in our most simple lock is the interaction of the plug with the shell in allowing a turning motion. **The plug rotates within the shell; the shell provides a bearing surface and stability.**

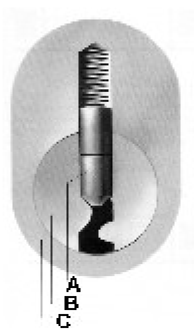
The mechanism just described will perform one function: it will allow anyone with the proper tool to turn the plug, thereby extending or retracting a bolt. What if we now want to add **security** to this lock? Enter Linus Yale.

16_3.1.2 A Lock that provides Security

Now, we must provide the mechanics to accomplish several tasks, depending upon **how much security** we desire. The critical action that must be controlled is the movement of the plug, because it is directly linked to the bolt. In the final analysis, the

purpose of every component within the lock is to actuate the bolt. That is where we shall concentrate our efforts regarding security.

Security in every lock is a function of access to the bolt by the authorized user. The level of restrictions that can be placed on access provides an index of security. We must create a method to stop or block rotation of the plug until a defined event occurs. That event is the insertion of the correct key, code, or combination. With this in mind, we shall now add components to create our modern pin tumbler lock, first conceived 4,000 years ago and made practical by Yale.

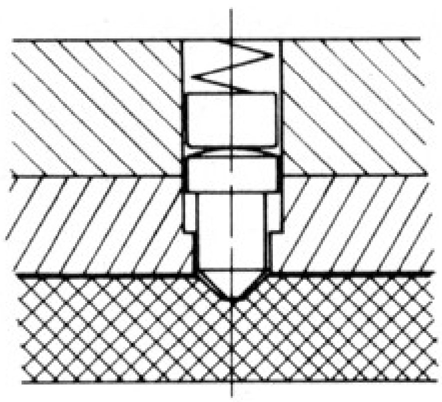


Once Linus Yale determined that he needed to rotate a plug within a shell to control a bolt, the Egyptian design provided the basis upon which to block that rotation: the **split pin tumbler.** Yale thought that if a moveable piston or pin was allowed to travel vertically within chambers or bores between the shell and plug, then he had a means to control plug rotation. The position of each pin could independently control whether the plug could rotate. When multiple pins were utilized, then the security of the lock increased dramatically.

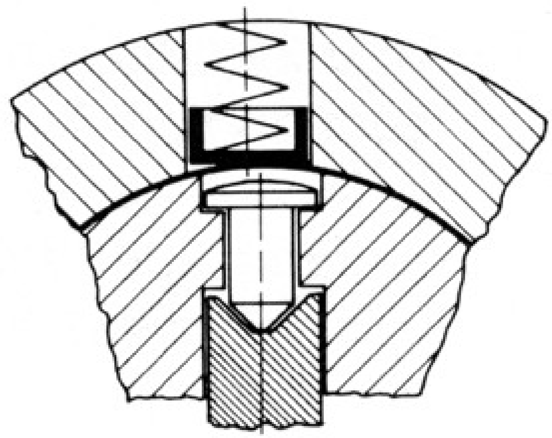
The Egyptian lock used several moveable **solid** pins that were lifted above the plug to allow rotation. The means to raise each of the pins was provided by placing corresponding pegs on the end of the key. Yale modified the ancient design by incorporating a **split pin** within the lock housing, creating an upper (driver) and lower pin. Yale then drilled vertical holes through the shell and plug and placed a pin and spring in each hole or chamber. The pin segments would be separated at the place where the plug **met** the shell. This would be called the **shear line**.

These channels would allow the pins to travel together within each pin chamber. The moment the pin was inserted into the

shell, each of the top pins (drivers) would be forced partially into the plug because of the spring bias applied to the top of the driver. The system is said to be one of **positive locking.** That is, the plug is frozen in position at all times, except when the correct key is inserted. In contrast, a **negative locking** system would provide that when any but the correct key was inserted, the plug would be prevented from moving because the pins would be forced out of alignment. The distinction is subtle but important.



Positive Locking



Negative Locking

LSS204: Brian Chan on positive and negative locking.

It can be seen that once a pin occupies space in **both the shell and plug at the same time,** the plug is not free to move until the pin is lifted to a point where blockage does not occur. That point is called shear line. It is defined as the place where the lower pin is precisely level with the diameter of the plug. When the lower pin is lifted to shear line, there is no longer an obstruction to rotation. This is because the driver is fully contained within the shell and the lower pin is completely within the plug; no part of either pin is protruding. The upper and lower pins are "split" at the exact point where a gap occurs between plug and shell.

If we add a **keyway** to limit what can enter the plug, we have a modern pin tumbler lock. Once the key clears the wards within the keyway, the bitting will physically raise each of the lower pins to shear line. The bitting replaced the pegs in the Egyptian key.

All of the modern modifications to the Yale lock are but refinements of the simple principle of blocking rotation of the plug. Thus, the rotating tumbler (Medeco); dimple (Keso, DOM, and Ikon); magnetic rotating tumbler (Ikon, Evva, Chubb); axial (Chicago Lock); and other designs are all based upon the use of the split tumbler to stop rotation until all pins are lifted to one or more shear lines.

16_3.1.3 Operation of the Modern Pin Tumbler Lock

In operation, the key is inserted into the keyway: only the proper blank is allowed to enter. If correct, the bittings will raise the lower tumblers to the same level as the outer diameter or top of the plug. The lower tumblers must be raised just to the top of the plug and no further. If the bitting is cut too high, causing the lower tumblers to be raised **above** shear line, then they will be forced up into the shell. Conversely, if the bitting is too low, the drivers will fall **below** shear line, also resulting in a locked plug.

Because of the close tolerances achieved in manufacturing, the tumblers must be precisely leveled at shear line. If they protrude or are recessed > ±.002", the plug will not turn. This tolerance depends upon the quality of the lock.

16_3.2 Security of the Pin Tumbler Lock

The rating of a lock is affected by many factors. The mere fact that the mechanism is a pin tumbler does not guarantee any measure of security. Protection against forced and surreptitious entry depends upon the following factors:

- **Manufacturing tolerances;**
- **Materials utilized and their metal content;**
- **Number and type of pins;**
- **Differs;**
- **Keyway design;**
- **Use of security tumblers;**
- **Master keying levels;**
- **Anti-drill pins;**
- **Special variations of the lock design (as with Medeco, for example);**

- **Other enhancements to increase security.**

Perhaps the most important criteria in the analysis of the security of any cylinder is manufacturing tolerance between plug and shell, the design of the keyway, and the use of security tumblers.

16_3.3 Keyway Design

There are hundreds of thousands of different keyways in use worldwide. Keyways provide security by limiting the global number of keys that can enter the lock. The keyway is the first limiting criteria to restrict access to the internal mechanism. Keyways can be designed through a combination of square, rounded, curved and angled bullets or fixed wards, to make entry by all but the correct blank very difficult. Thus, the paracentric keyway will contain obstructions that cross the vertical centerline of the entrance to the plug. Such designs make the insertion of a pick tool difficult.

16_3.4 Depth Segments and Differs

The manufacturer will decide how many different depths shall be available for a given key bitting. That will define how many "segments" the lower pin can be divided into and, thus, its overall length.

0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9

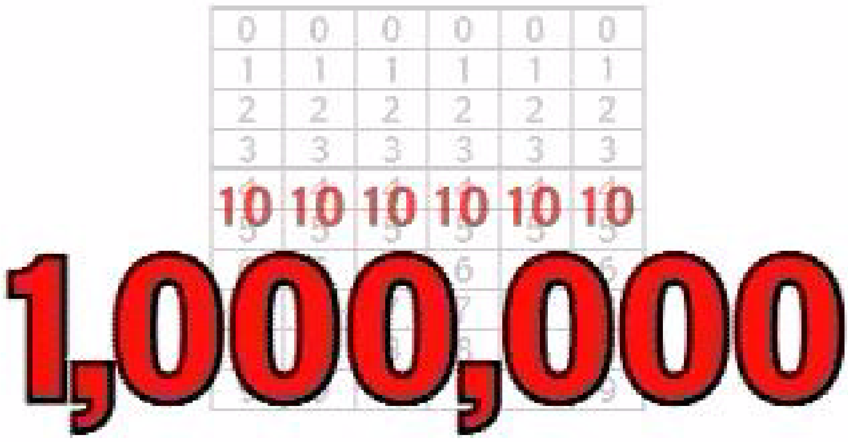
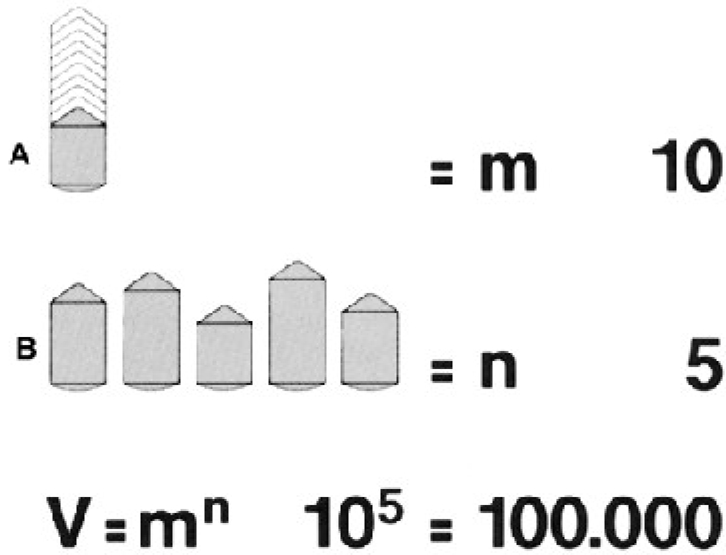


Figure LSS+1605 In a six pin tumbler lock with ten depth segments per chamber, there are a total theoretical number of combinations of 1,000,000. However, this number will actually be far less, depending upon tolerance and master keying levels. Courtesy of HPC Interactive Learning Series.

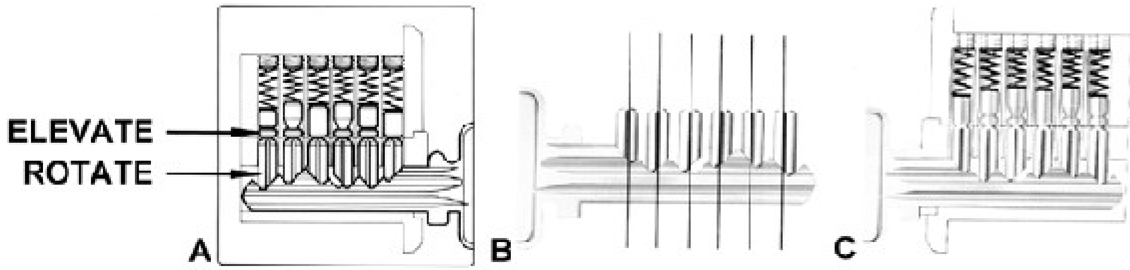
It can be seen that the greater the number of increments or segments into which the lower pins are divided reduces the distance between segments. Plug-shell tolerance must be such that the smallest pin segment must be at least twice or three times the plug-shell gap in order to prevent the pin from becoming caught between moving surfaces.

Shell-plug tolerance relates directly to differing, or the number of theoretical different key combinations available to the manufacturer. A greater precision between moving parts allows a larger number of bitting depths to be utilized. The gap between plug and shell must be factored into the distance that the lower pin is allowed to travel.



A five-tumbler lock, for example, allowing for ten different depth cuts, will offer $\mathbf{10^5}$ or 100,000 different combinations. When using six tumblers with ten depth cuts, we will have 1,000,000, or $\mathbf{10^6}$ different combinations. A thorough discussion of manufacturing tolerances is presented later in this chapter and is critical to an understanding of picking and impressioning. Rarely are pin segments less than .023". This relates to the tolerance of most locks, the potential for cross-keying, and the fact that master pins would be too thin to operate reliably. Note that the number of theoretical combinations will be different in master key systems, and will in part depend upon whether the rotating constant or total position progression method is utilized. The number of differs with master key systems will also relate to whether one or two-step progression is chosen. A thorough discussion of this subject is presented in **chapter 11**.

The decision as to the distance between pin chambers depends upon a number of factors. Because each lower pin must rest in the center of the valley (root) of each key cut and not on the slopes, the key will take on certain design constraints. There must be enough spacing between cuts to allow proper seating and smooth operation in tumbler movement. Thus, a specified minimum spacing is required between cuts. This will dictate inter-chamber distance and the number of chambers for a given plug. Medeco, in their Biaxial lock, has utilized this principle to increase the number of possible combinations by controlling **where** the bottom tumbler rests on the bitting surface.



The length of the top pin for a given chamber will be dependent upon the length of the lower pin. If a deep cut is present requiring a long lower pin, then the corresponding driver will have to be relatively short. This will prevent the spring from being compressed in the upper chamber. Standard pinning kits are available for all lock manufacturers. HPC, for example, contains color-coded pins for all lengths used in driver, master pin, and bottom pins. This kit is highly recommended when any cylinder work is to be performed.

16_4.0 Keys for Pin Tumbler Locks

There are three basic profiles used in pin tumbler locks: **regular bitting**, **dimple**, and **laser track**. Each type of key must meet stringent design parameters to function properly in a given cylinder. Angle of cut, ramps, valleys, spacing between pins, difference between depths, and other factors all must be considered. A unique patent was issued in 1994 to Escribens (**5355702(175)**) for s security key that will open several different locks by adjusting moveable sliders to simulate the proper tumbler combination.

Cutting tolerance must be maintained between .0075"-.003" for correct key duplication. A .005" variance per copy is acceptable. The tolerance in making blanks should be held to .001"-.003." Key machines should be capable of maintaining tolerance for ten generations in the duplication process.

16_4.1 Changing Combinations

Depending upon the complexity of keying within the lock, changing combinations can be simple or complicated and generally requires that the lock first be disassembled. There are, however, certain mechanisms in which the tumbler combination can be altered externally. See **Chapter 22** for a discussion of Instant rekey locks. The plug can be removed by a variety of techniques.

Depending upon what is to be accomplished, only the lower pins may be changed, or all pins may be exchanged by emptying each chamber of the spring, driver, lower pin, and any master pins.

If the lock is not master keyed, the lower pins can be switched or new tumblers inserted. Generally, the new key will be cut by code prior to taking the lock apart, so all that is required is to insert the new tumblers. If change keys are altered within a master key system, then new master pins as well as lower pins will be substituted within the pin-stack.

16_4.2 Procedures for Disassembly of Pin Tumbler Locks

There are many reasons to take apart a lock, including keying, rekeying, master keying, maintenance, decoding, and forensic examination. Methods of non-destructive disassembly include use of the correct key, shimming, rapping, "999" rapping, picking, impressioning, and removal of all pins through the pin chambers. A discussion of these methods, in the context of producing keys, is presented in **Chapter 9.** Specific procedures for disassembly to allow forensic analysis are presented in **Chapters 24-27.**

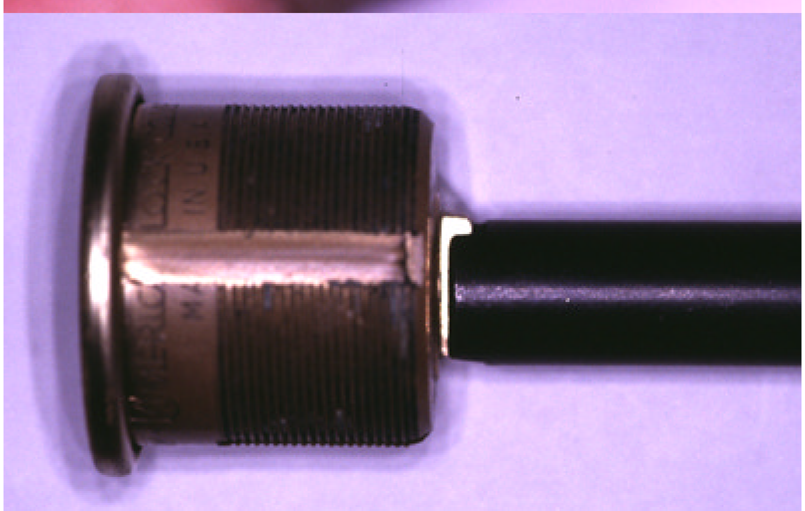
Certain precautions must be observed whenever a lock is disassembled, unless there is no concern for loss of components, and retention of the combination is not important.

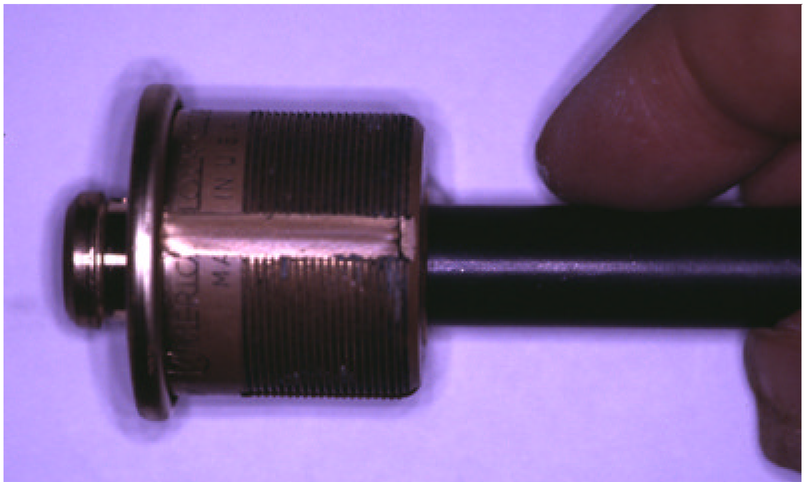
16_4.2.1 Use of a Following Tool

A follower must be utilized to fill the void left by the plug as it is withdrawn from the lock, unless pins are removed through the brass retaining strip at the top of the cylinder, shown below. If the tool is not utilized or it is used improperly, one or more springs, driver pins, or master pins can be ejected from their chambers.

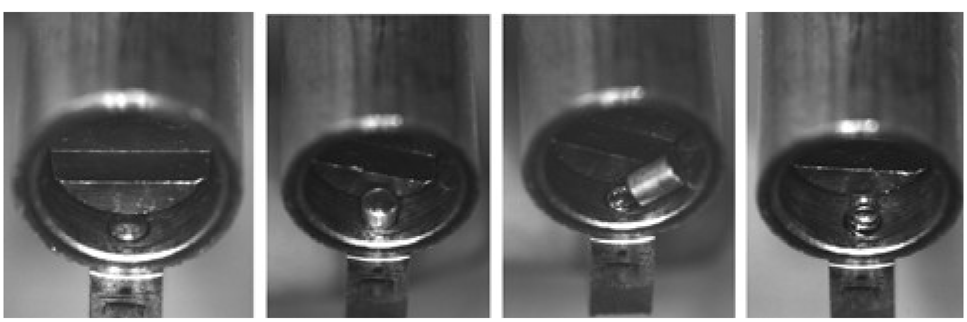
The series of photographs demonstrates the proper procedure for removing the plug from a cylinder without disturbing the driver pins, and for repinning a cylinder once all of the pins have been removed.











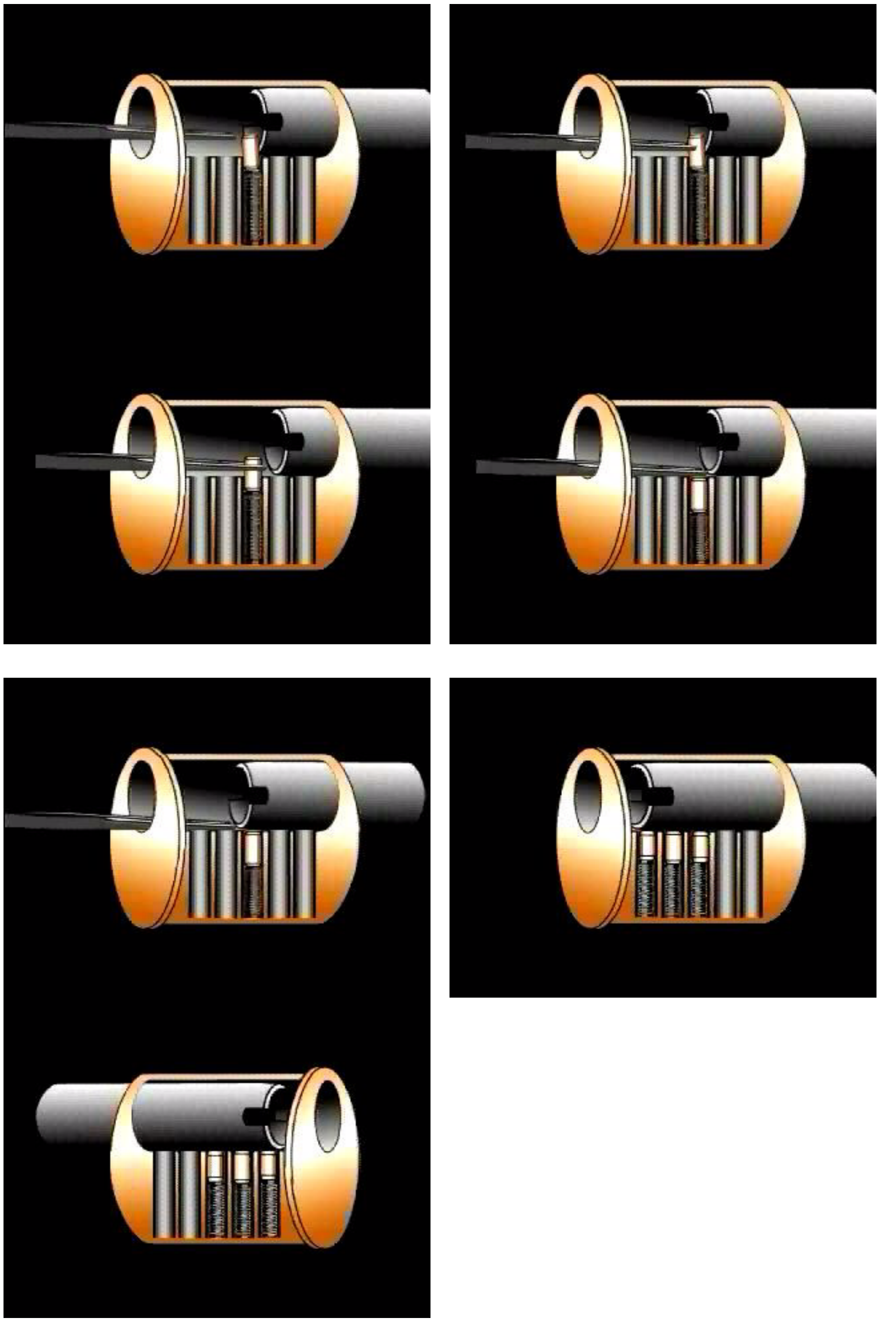


Figure LSS+1606 The repinning of the top pins requires the use of a follower tool, or removal of the spring retaining strip. In this series of photographs, the driver is inserted from one end of the cylinder and moved to the center chamber, which is loaded with a spring and top pin. It is depressed by a pick until the pin resides partially within the chamber. The follower is then abutted against the pin to freeze it into position. The pin is then depressed entirely within the chamber, and the follower then moved over the top of the pin, thereby retaining it in position. This process is then repeated for each

pin to either side of the center chamber, until all pins are loaded into their respective chambers. It can be seen that once three chambers are loaded (from center to the edge of the cylinder), the follower's direction is reversed and the remaining chambers are loaded. Courtesy of the HPC Interactive Learning Series.

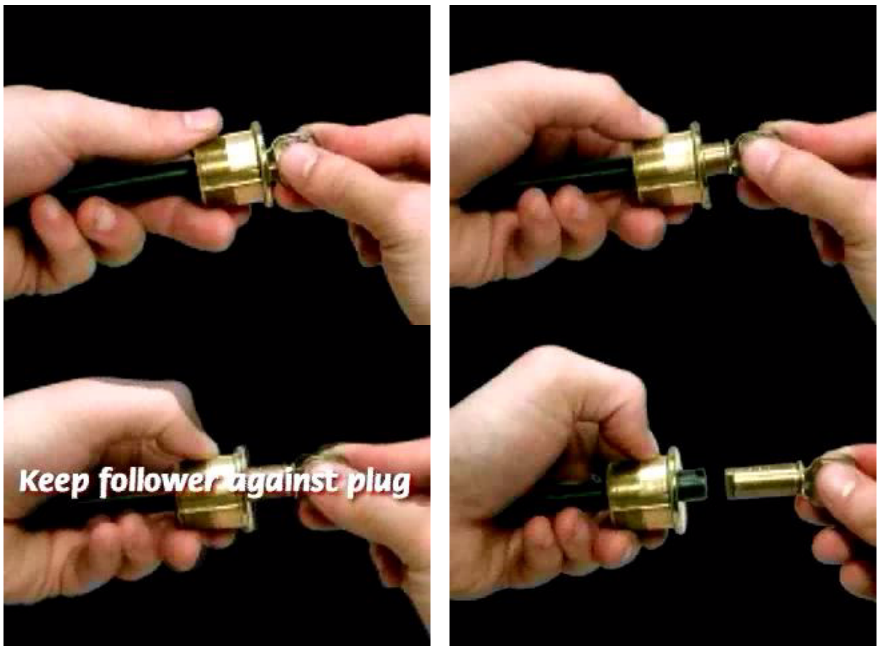
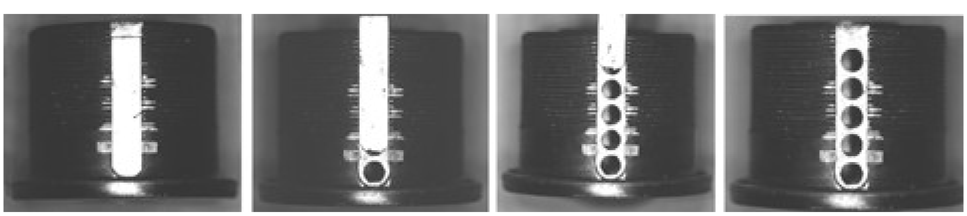
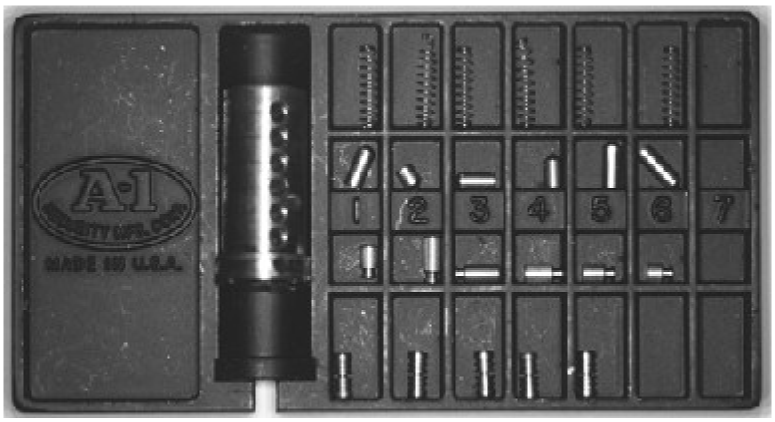


Figure LSS+1607 Once all of the top chambers have been loaded with driver pins, the plug containing the lower pins is inserted into the cylinder, and the following tool removed. The procedure to accomplish this requires that the plug and follower be placed against each other and inserted as one complete entity, as if the end of the plug and follower were connected to each other. In this way, none of the driver pins have the opportunity to eject from their chambers. The process is reversed during the disassembly of a cylinder, as shown in the above series of photographs. In such case, the follower is inserted at the rear of the cylinder and the plug is pushed forward as the follower takes its place. Take care not to allow a gap between the two, and that the rotation of the plug prior to removal is such that the pins within each of the bottom plug chambers can be controlled so that they do not fall out. Also, it is very important to insure that the plug be turned at least twenty degrees prior to removal to insure that drivers do not enter the lower chambers during removal. Courtesy of HPC Interactive Learning Series.



16_4.2.2 Use of Setup Tray

A setup tray provides an orderly means for preserving the position of all pins removed from the lock and thus allows for keying to be documented and reproduced. When the lock is disassembled, extreme caution should exercised as the driver pins are removed.



The use of a pin tray or setup tray is required for forensic disassembly of a lock. Courtesy of Hans Mejlshede.

If more than one pin is present in each of the top or bottom chambers, the lock is master keyed. Depending upon the level of master keying, there may be one or more master pins in one or more pin chambers.

16_4.2.3 Use of Pin Tweezers

Special pin tweezers referred to elsewhere in this chapter are recommended for pin removal and insertion. If a forensic examination is to be conducted, then wooden or nylon tongs should be employed rather than metal tweezers.

16_4.2.4 Removal and Insertion of Pins

When pins are to be removed or replaced, the proper procedure must be followed in order that the pin-stack order and combinations not be altered. As each pin is withdrawn, it is placed in its respective position in the setup tray. The lock can be decoded and repinned directly from the setup tray, if required. As each top pin is released from the shell, attention must be given to the possibility that one or more master pins may

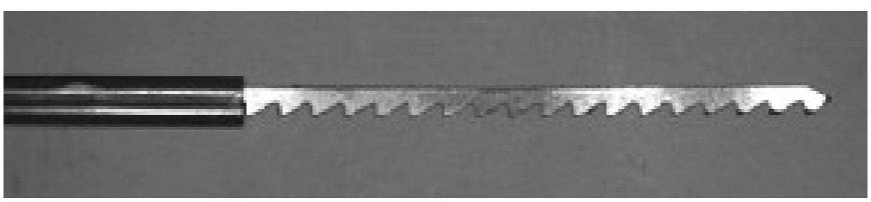
be present. Pressure is applied to the follower to control the ejection of each pin from each chamber. Once tumblers are removed, a micrometer may be utilized to read the length of each pin segment. The manufacturer specifications may then be consulted to determine the direct code for all permutations present in the lock.

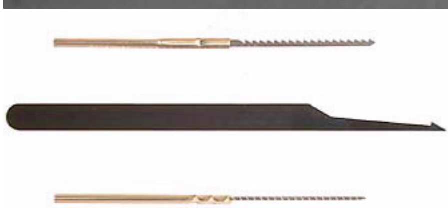
16_4.2.5 Lubrication

Ideally, a brass lock should be lubricated at least once a year. A lubricant such as oil that thickens or mixes with other materials cannot be used. In contrast, iron and steel parts must be lubricated regularly, especially in damp or moist climates, using grease or light oil. A dry lubricant such as graphite or WD-40 may be used for pin tumbler locks. The material is squirted into the lock, although the old way was to run a lead pencil over the key.

16_4.2.6 Broken Keys

A broken key lodged in the keyway can be removed by an extractor. This tool is either inserted to the side of the key or above it to catch the bittings. A straight or curved pick or a straightened fishhook can also be used. If the key was back cut, the tumblers must all be raised before the key can be withdrawn. See the Kimzey patent, granted in 2000, for a unique extractor design for removing inaccessible portions of a key from the keyway (**6052883(176)**).



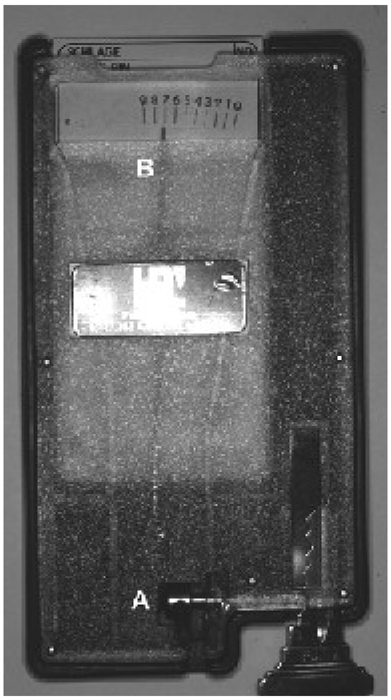


16_4.3 Keys by Code

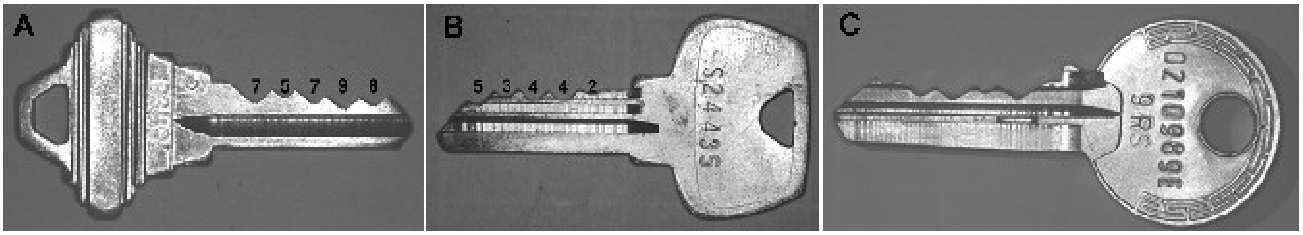
Keys are coded by the manufacturer during production and by the locksmith during the keying or rekeying process. The direct code

numbers from keys or equivalent derived information can be used to produce duplicates. A key can also be decoded using a micrometer, depth keys, or by visual estimation and experience.

Locks can be disassembled, the tumblers carefully removed, and then all of the possible combinations determined. In this instance, the pins are measured and correlated to specifications as set forth by the manufacturer for a particular lock.



Once a lock has been decoded, keys can be produced that will open that lock or others within a system. Thus, a master keyed cylinder can be taken apart, all combinations determined, and a key produced which will open every lock within the master key system or group. **Direct or indirect** coding is the method used by the manufacturer to differentiate tumbler depths for each key. Coding is required to facilitate multilevel keying, and to allow for orderly manufacturing, distribution, and maintenance of locks.



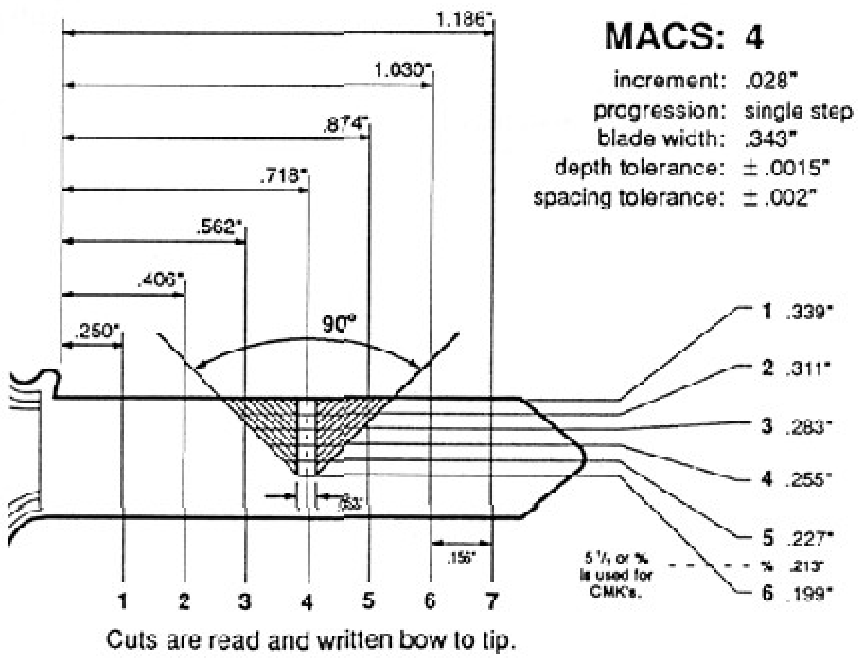
16_4.3.1 Manufacturer Depth and Spacing Specifications

Every manufacturer will set different bitting standards relating to spacing and depth assignment. The number of depths for a given key blade surface, their designation, the increment between consecutive depth cuts, and the inter-pin spacing must all be specified. This manufacturing data determines key coding and will provide the locksmith with the following required information:

- **Distance from the shoulder to the first pin chamber;**
- **Distance, center to center, between pin chambers;**
- **Total length for bottom and top pin chambers;**
- **Pin diameter.**

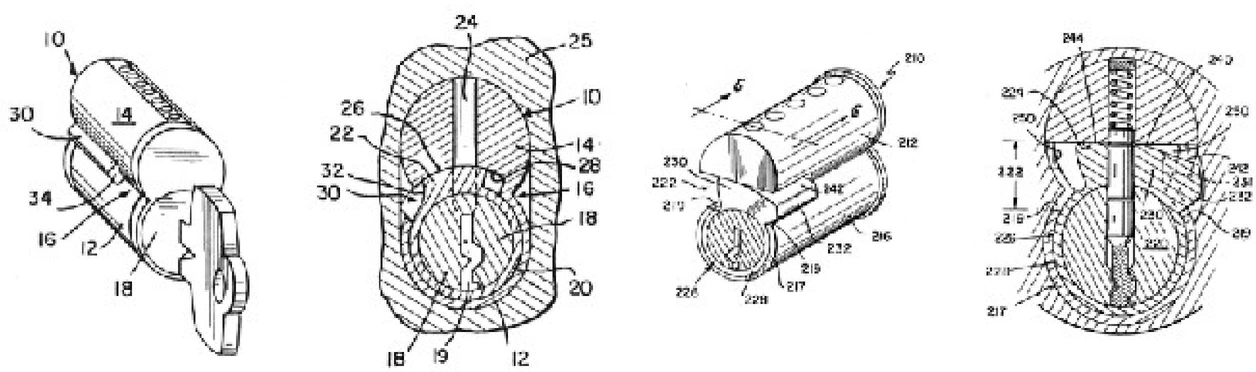
In any coding scheme, the bitting is divided horizontally into different levels, each separated by a defined space. For example, one manufacturer may divide a key into ten segments, and assign the following code depths for bitting levels: 1=.165” 2=.180 3=.190 4=.205 5=.220 6=.235, 7=.250 8=.260 9=.275 0=.290. The spacing between pins will also be designated. Failure of the locksmith to adhere to coding standards will result in reduced security, mechanical and operational problems, cross-keying, and even broken keys.

The manufacturer stamps many keys with code numbers. If the codes are direct, then they can be correlated to depth measurements and a key reproduced using a code-cutting machine, micrometer, or depth keys. If the codes are indirect, then a code list from the manufacturer must be consulted to first determine the direct reading code.



A more thorough discussion of coding and decoding can be found in **Chapter 31.**

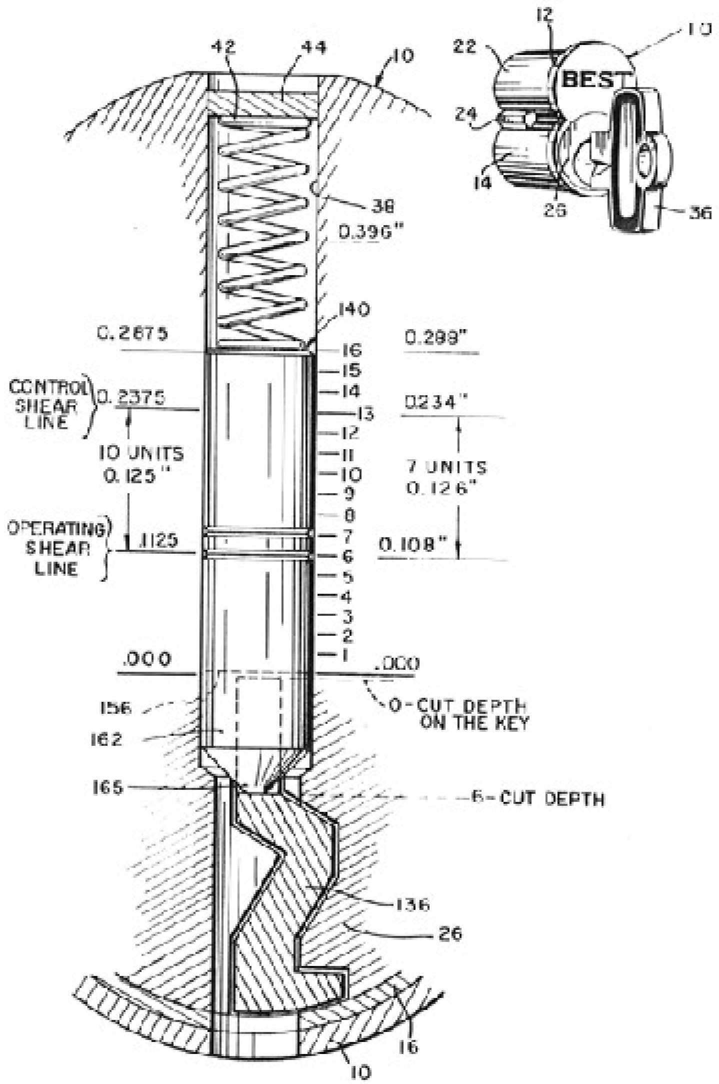
16_4.3.2 Decoding Master Key and Interchangeable Core Systems



Master key systems may be decoded to determine keying levels, cross-keying, and removable core control-key combinations. Decoding may be necessary for many reasons. These include:

- **Producing keys to locks;**
- **Matching specific locks with criminal suspects;**

- **Determining cross-key potential and the ability of a given key to open one or more locks;**
- **Assessing the pick resistance of a lock;**
- **Intelligence operations.**



If the system was designed properly and master keying rules were adhered to, then decoding can be a straightforward procedure. However, if a craftsman with limited knowledge implemented the system or basic rules were not followed, then the task can be somewhat more difficult. Special precautions must be observed in disassembly of master keyed cylinders in order to preserve the pin-stack order. These are discussed in Chapters 24-27, in the

context of forensic examinations.

16_4.3.2.1 Decoding Procedures for Standard Cylinder

Perhaps the simplest task is to decode the top master key. This can be a **GGMK** (great grand master key) to a simple **MK** (master key), depending upon the complexity of the system. The most straightforward method is to select a lock for which a change key is available and which is not cross-keyed or is a single lock keyed differently. The manufacturer must first be identified in order to learn if a one or two-step system is in use. In the case of Corbin, for example, a master ring is utilized which prevents cross-keying.

Generally, there will be one or two bottom pins and one top pin. In some cases, there can be additional master pins in certain chambers, depending upon the sophistication of the system. If, when the lock is disassembled, there are in fact two pins in each lower chamber, we can determine the top master key if the lock was keyed consistent with standard industry practice. In order to decode the master key, the individual change key bittings must first be ascertained.

In our first example, let us assume, after disassembly, that we find one bottom and two top pins in each chamber. This would indicate that the lock is master keyed and that there is one master pin for each cut. Once the lock manufacturer is identified, the depth for each cut will be known. In this example, it is assumed that we have a physical change key as our reference.

From the change key we can determine the actual length of each of the bottom pins through correlation with manufacturer data. The direct code and the physical pin lengths are required in order to compute the bitting for the master key. Once the pin-stack is determined for each chamber, the bitting depths will be known. For this cylinder, the following is learned:

CHANGE KEY BITTING	***1 2 1 5 3***
Cylinder Pinning:	
Master Pins:	***4 6 8 2 2***
Bottom Pins:	***1 2 1 3 1***

Master Key	***5 8 9 3 1***

If this lock has been pinned to standard industry practice, then the master key code can now be determined. It must be remembered that the introduction of each added master pin exponentially increases the possible differs, or key combinations. Thus, a five-tumbler cylinder will have the following number of permutations, depending upon the number of lower pins and master pins within each chamber:

1	***pin per chamber = 1 key***
2	***pins per chamber = 32 keys***
3	***pins per chamber = 243 keys***

Thus, a five-tumbler lock with one lower pin and one master pin in each of the chambers will have **32** different shear lines. As shown in Chapter 11, there would be 32 different keys that could open this lock. It can be seen that in our first decoding example, we have 32 possible master key combinations.

Based upon industry practice, no depth-cut used for the master key can be used in the same position for any change key. With this information, we know that the master key in our first example can be one of two combinations: 12131 or 58953. Applying our rule, the top master key must be **5 8 9 3 1**, because the other combination reuses pins in the change key.

Now let us say that we must decode a cylinder with two master pins in two of five chambers, one master pin in three of the chambers, and one bottom pin in all five chambers. This scenario could occur when a cylinder is intentionally cross-keyed. In this example, the pins are decoded as follows:

CHANGE KEY BITTING	***8 5 4 7 4***
Cylinder Pinning:	
Master Pins:	***- 2 - 2 -***
Master Pins:	***4 2 2 4 4***
Bottom Pins:	***4 1 2 1 0***

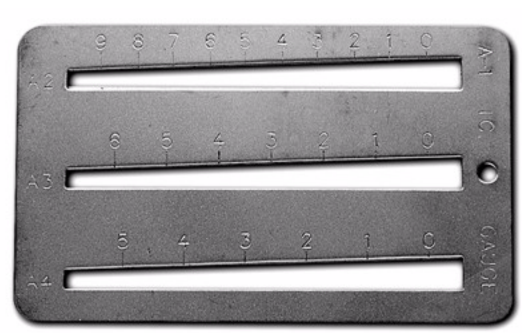
From a possible **72** different bitting combinations, we can reduce to 4 the number of possible master keys:

41210
43210
41250
43250

The only way to determine the actual master key is to try each key in several locks.

16_4.3.2.2 Removable and Interchangeable Core Locks

In the case of the Best-Falcon types of interchangeable core locks, a few comments are in order. There is no relationship between the top master key and the control key. Assuming there is a change key and one has an understanding of the physical construction of the lock, decoding is the same as for standard cylinders. There will always be three or four pins per chamber (bottom pin, master pin, build-up pin for control shearline, and top pin. In rare instances, there may be a master pin for the control key. In the Best lock, the top set of pins is used to decode the control key, because the pin stack for each chamber will always be a constant length. In the A2 series, the pin stack will always be a total of 23 depth increments. By measuring the top pin for each chamber, we can determine the bitting for the control key. There are a total of three series of Best locks: A2, A3, and A4. A simple depth decoder made by A-1 Security Manufacturing for the three Best series is shown below.

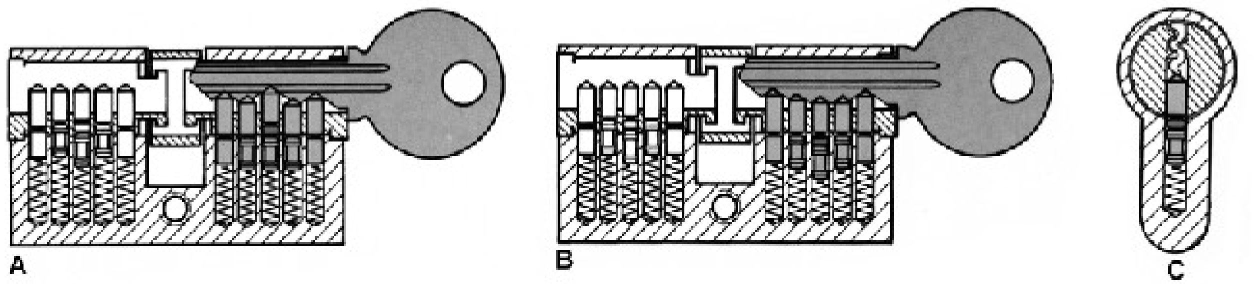


Decoding the Best removable core lock for the control key, courtesy of Harry Sher.

16_4.4 Master Key Systems

Master keying allows and defines access to one or more locks

within a system by one or more keys. Pin tumbler locks may be master keyed to many levels, depending upon individual requirements for each installation.

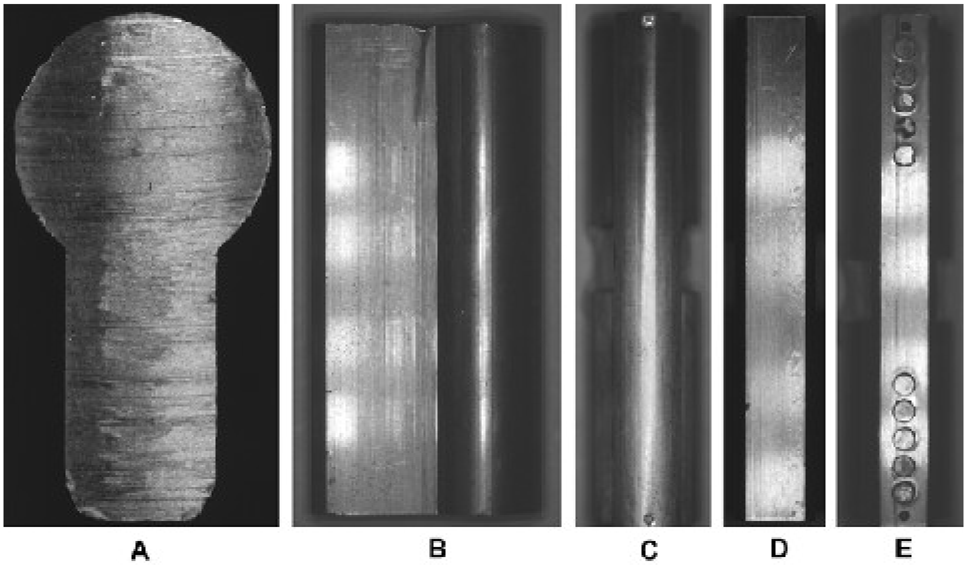


The underlying theory for all conventional master key systems is the same. It provides that more than one shear line is created within the pin-stack in order to allow different combinations of bitting to raise pins and master pins to a particular shear line. There are several techniques to accomplish secure master keying within conventional pin tumbler locks. The predominant schemes are referred to as Total Position Porgression (TPP) and Rotating Constant (RC). These are more fully discussed in **Chapter 11**.

There may be several defined shear lines for any given lock, dependent upon the complexity of the system. Tolerance errors can be a factor within a master key system, because up to 2000 or more effective shear lines may be created if the tolerance is poor between plug and shell. **Positional systems** rely upon the position of the pin, rather than its depth level, to define master keying levels. Sargent Keso was perhaps the first high-security pin tumbler lock to utilize this principle. Corkey, Showa, and other magnetic card lock vendors also use the scheme. **Chapter 11** describes master key systems for all types of locks.

16_5.0 Manufacturing Pin Tumbler Locks

The manufacturing steps for the production of pin tumbler cylinders involves many processes. These can affect the tolerance and commensurate security of the lock, the number of available differs, and pick resistance. The relationship between tolerance and the ability to pick the lock is vital to an understanding of surreptitious entry. The subject is covered in this chapter and in **Chapter 29**.



The modern cylinder is manufactured in an automated environment. The security rating of the lock determines the standard of tolerance maintained and thus the level of automation. Ikon produces its high-security locks in one of the most sophisticated factories in the world located in Berlin, Germany.

LSS101: Ikon factory, Berlin, Germany: How locks are made.

The entire procedure within the Ikon facility is automated, from the input of raw brass bar stock to the production of a finished, pinned lock. A brief description of that process is presented here.

In their high-security lock, Ikon maintains a plug-shell tolerance of between .016 mm-.07 mm, or a maximum gap of about .003."

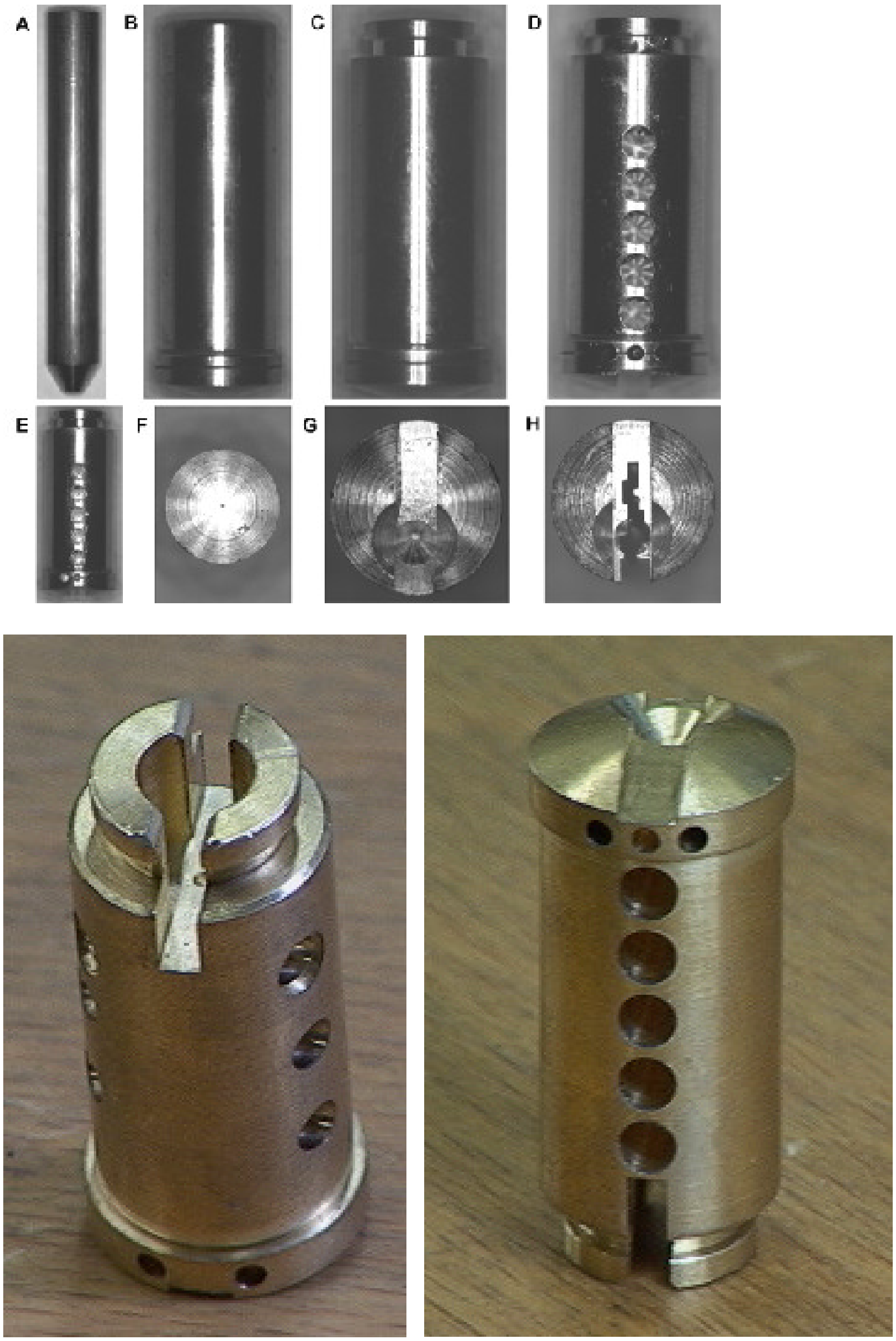


Figure LSS+1608 A plug is formed; drill resistant pins are inserted, then the individual chamber holes are drilled.

The process begins with unfinished brass bar stock. The stock is cut to the length of one lock, then the solid block of brass is

bored to the precise diameter of the plug. Chamber holes are then individually drilled from the top of the cylinder. It should be noted that some manufacturers, such as KABA, drill both the shell and plug simultaneously.

At the same time, round brass plugs are milled to very precise tolerance, from round bar stock. They are then drilled for lower chamber holes. Each hole is made individually with one bit, at 10,000 RPM. Broaching the plug then creates the keyway. The keyway is created within the plug by ramming it across the tool steel broach at high pressure. The die removes the metal as it is forced through the plug. The photographs show the sequence utilized at the Ikon factory in Berlin. Chamber holes are sealed in the shell with fixed pins, and the top of the cylinder is finished and rounded.

Pins are produced by cutting and chamfering brass wire to the proper length. The wire is produced in long rolls, and is fed into a machine that generates millions of pins. See the accompanying video for a detailed explanation.

Producing pins for cylinders. Courtesy of Hans Mejlshede.

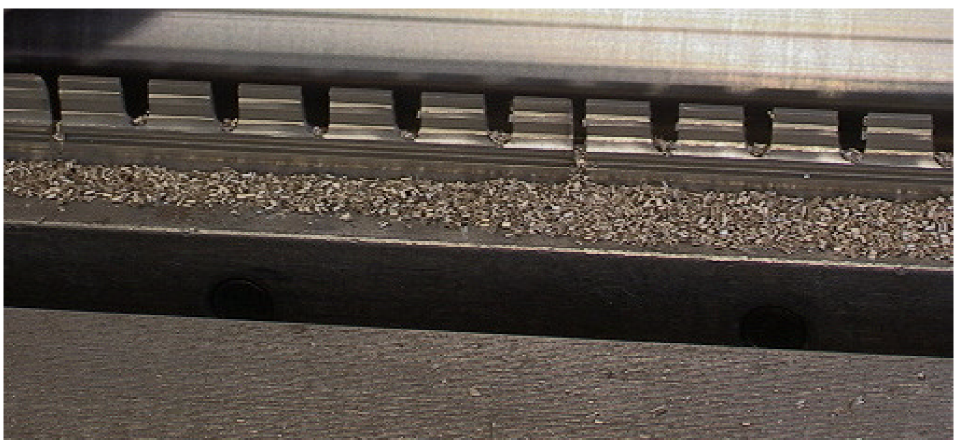


Figure LSS+1609 A broach is made of tool steel.

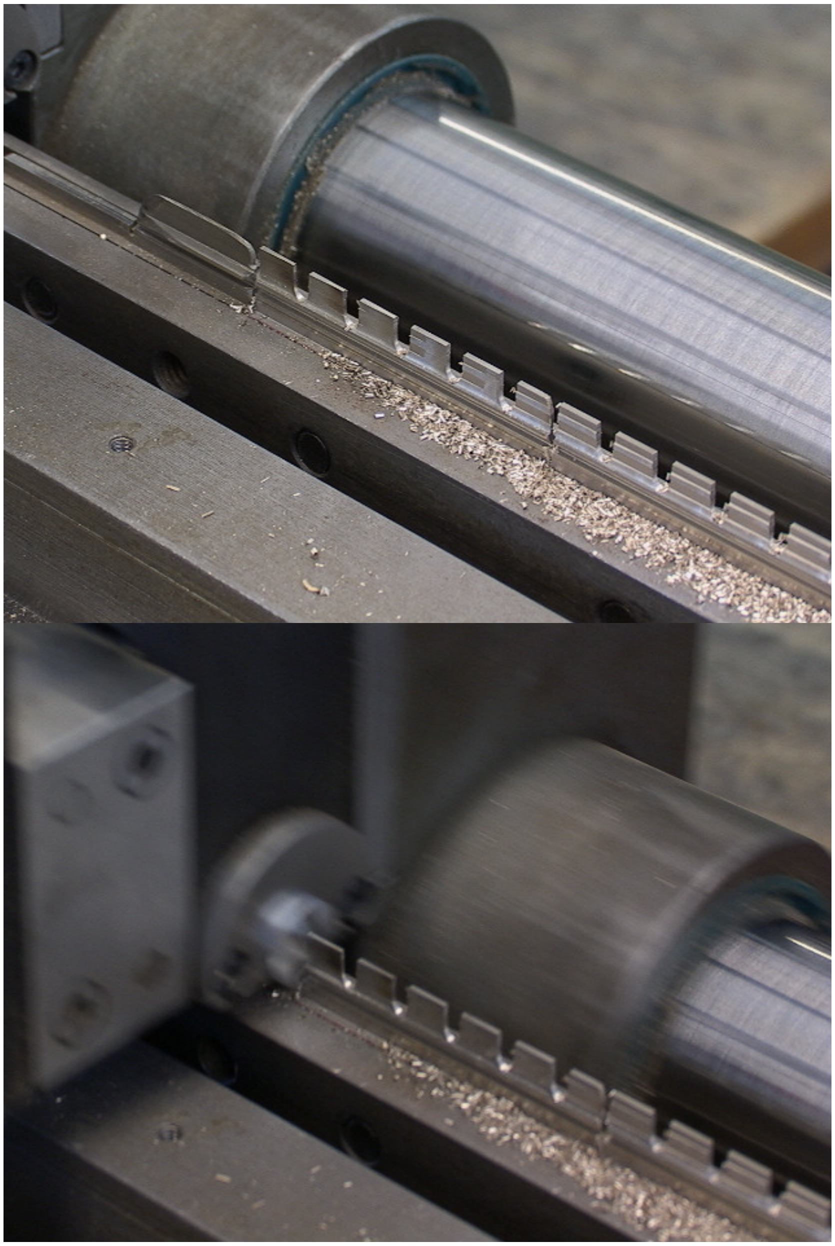


Figure LSS+1610 The broach is forced into the plug to form a keyway. The photograph on the right shows the plug being driven across the broach.

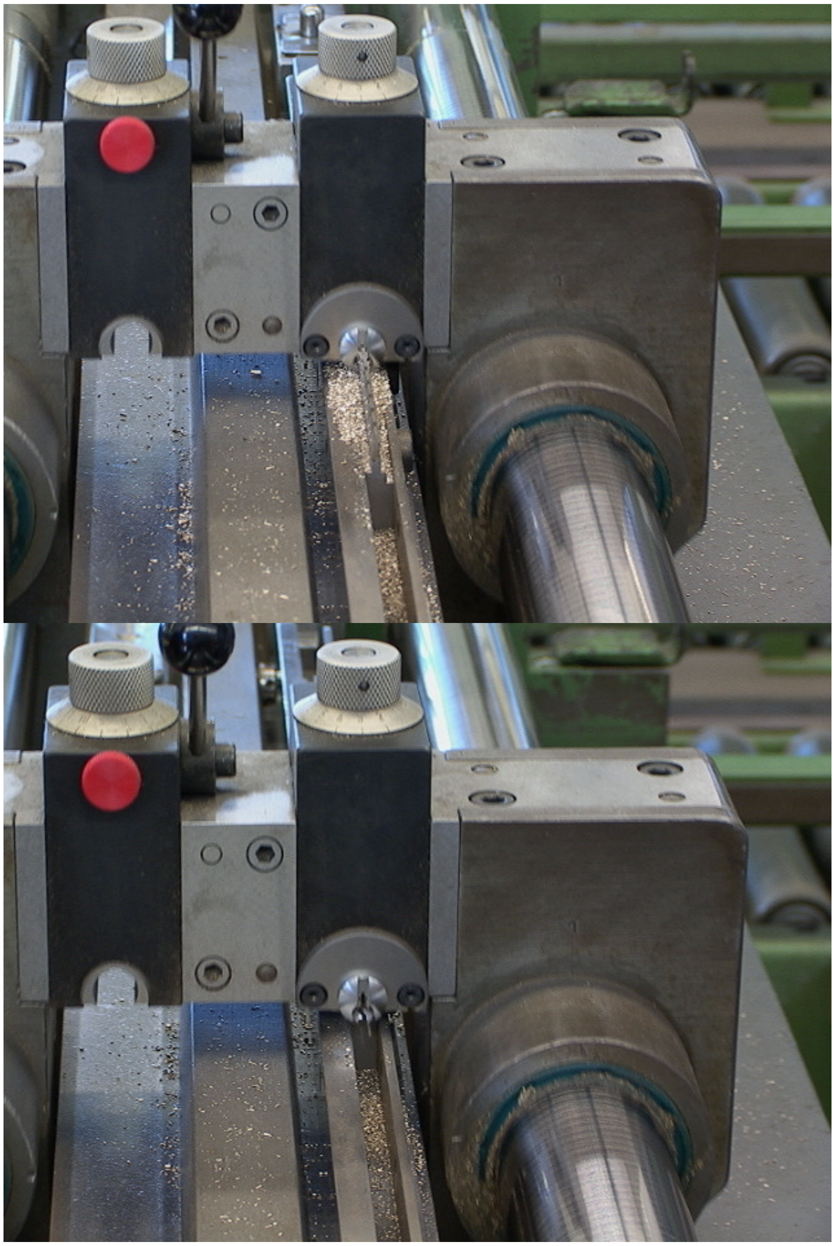


Figure LSS+1611 Photographs showing a plug partially and completely broached. Note how the hydraulic ram is designed.

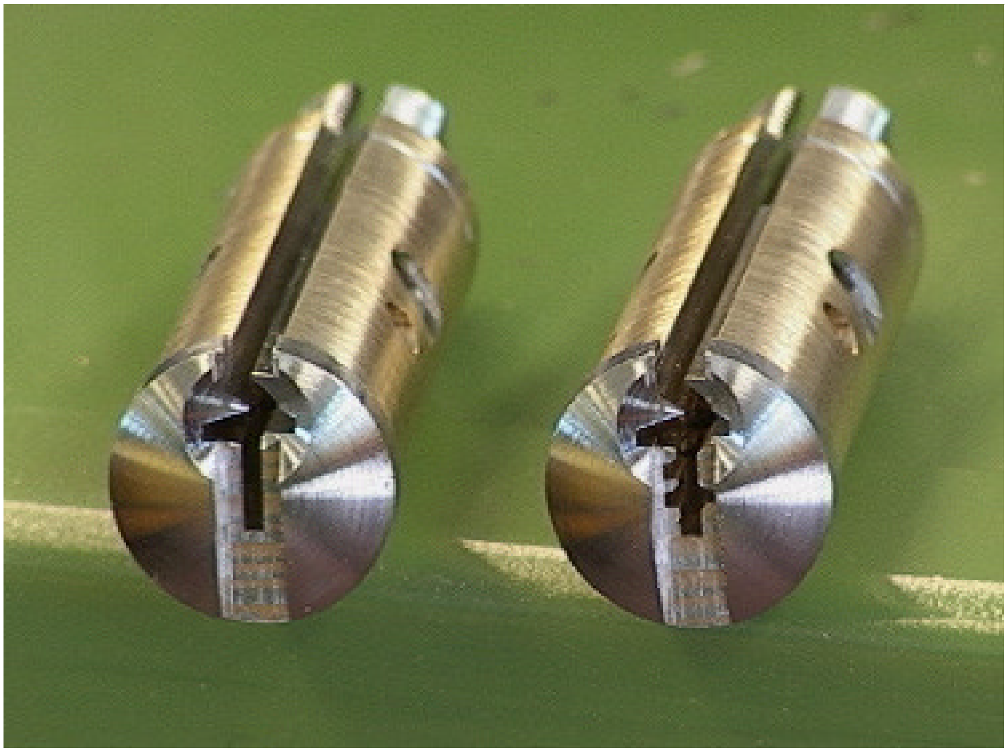


Figure LSS+1612 Ikon produces profile locks with over 3500 different keyways at its factory in Berlin. This photograph shows a basic keyway profile, and a special variety for a specific customer. Different sub-broaches are utilized for this process.

Finally, the plug and shell are married together, and the cylinder is pinned automatically to the correct combination. Pinning is accomplished by loading all upper tumblers and springs from the center of the shell. The plug is loaded in a separate operation, and inserted into the lock.

16_5.1 Tolerance

At every step of the manufacturing process, tolerance is a critical factor, because errors are **cumulative.** As tolerances diminish due to such errors, the security, pick resistance, and chance for cross-keying increase. There are four critical tolerances within the pin tumbler cylinder: **plug-shell, keyway, pin chamber, and key (cuttings and profile).**

16_5.1.1 Plug-Shell Tolerance

Plug-shell tolerance actually encompasses several issues:

- **Diameter and concentricity or roundness of the plug;**
- **Actual diameter of the plug;**
- **Diameter of the bore within the shell;**
- **Gap between the plug and the shell.**

There must be some difference in the clearance between the plug and the shell to allow unrestricted rotation. The minimum acceptable tolerance is .0025", which means an effective tolerance of .005". If the clearance is less, the plug will bind; if more, sloppy operation will result.

An optimum tolerance of .0025" could be maintained if the plug actually rested in the center of the shell. Unfortunately, this does not happen. The plug really rests slightly off-center at the bottom of the bore, leaving up to a .005" gap at the top of the plug. The gap between the plug and shell is actually somewhat less than .005". The closer the fit becomes between these two components, the greater the security of the lock. The tolerance is affected by the amount of metal removed from the bottom of the keyway in the broaching process, generally less than .0005". It is also influenced by the design of the top of the plug where the driver pins enter the lower chambers.

In most cylinders, the tolerance between the plug and shell is approximately one-third of one depth-cut. Thus, if the depth increment between cuts is .015", the tolerance would be between .005"-.010", although generally about .006"; just slightly more than one-third of a cut. This variance in tolerance is the reason why keys cut on inexpensive cutters will still open most locks.

In most cylinders, the surface of the plug is flattened across the shear line, because the top of the pin is flat. A slight gap is created at the point where driver and lower pins meet, making picking easier. Generally, the amount of metal removed at the top of the plug is between .005-.015." The amateur locksmith that files both tumbler and plug when fitting keys may also cause flattening of the top of the plug. In the true high-security lock, the entire plug is round; thus reducing the tolerance between plug and shell.

The **effective** diameter of the plug is thus different from the actual diameter. In the high-security lock, they are in fact almost identical. In the standard cylinder, the effective diameter takes into account the flat portion at the top of the

plug and will be less than the actual diameter. This affects the tolerance between plug and shell.

16_5.1.2 Pin-Chamber Tolerance

There are several considerations affecting pin-chamber tolerances:

- **Diameter of the pin;**
- **Diameter of the pin chamber;**
- **Linearity of the pin;**
- **How the chamber is chamfered;**
- **Alignment of the chambers.**

Drilling, either individually or all at one time creates pin chambers. The spacing and vertical positioning of the pin chambers is critical. The location of the holes drilled in the shell and in the plug must be precise and in perfect alignment. Some manufacturers bore holes in the shell and plug together for higher tolerance; in others, it is a separate operation. Gang drilling will produce results that are more varied. This is because of the use of different drill bits for each chamber and the varying replacement cycles for each drill.

The chambers and pins are chamfered with a reamer or drill bit in order to create a beveled or flared end. Unevenness in this process can result in a tolerance error. Chamfering and flattening the plug at shear line has the same affect; an error of from .005"-.015" can occur and can be likened to the difference between a flat versus rounded mating of plug and shell. Pin diameters may slightly vary, creating excessive play between pin and chamber walls. This will also reduce the pick resistance of the lock.

Depending upon the method of drilling, pin chambers may not all be the same diameter, nor have precise center-to-center alignment. Although the operation of the lock may not be affected, pick resistance can be markedly decreased. The concentricity or roundness of each chamber may also be affected by the drilling method. Each of these errors can have a significant impact upon:

- **Interaction and movement of the pin within each chamber;**
- **Relative position of each pin at shear**

line;

- **Position at which each pin binds between plug and shell when torque is applied during the picking process.**

As noted in **Chapter 29**, the significance of the foregoing discussion relates directly to the ability to pick a given lock. Picking is based on cumulative tolerance errors; if there were no errors, picking would be almost impossible. **The misalignment of moving components allows the lock to be opened by manipulation.**

16_5.1.3 Keyway Tolerance

Keyways are created through a process called broaching. A die having the exact mirror image of the keyway is forced into the plug lengthwise at high pressure. Metal will be displaced precisely equivalent to the shape of the die.

Depending upon a number of factors, broaching can be extremely accurate, or poor tolerances can be produced. In less sophisticated processes, a small amount of metal will be removed from the bottom of the keyway, adversely affecting the concentricity of the plug and the plug-shell tolerance. A consequence of the failure to maintain tolerances in the broaching process will be the improper alignment of grooves or wards, resulting in keys not indexing properly when inserted into the keyway. An error of up to .0005" can occur.

PART D: Locks and Keys

Specialized Locking Systems and Applications

Chapter 17, divided into seven sections, provides information regarding special locking systems that incorporate unique alterations to standard lever, wafer, and pin tumbler designs. In addition, combination locks, hybrid designs incorporating more than one technology, and high-security locks are covered. The many different types of locks that are discussed in the following sections have been selected based in part upon criteria defined below.

There are many variations in each design class; the most unique is described here. Each lock is illustrative of a different approach taken by their inventor to solve one or more security or mechanical concerns, evident in previous designs. Unique variations and applications of existing technology are presented in the following seven chapters. Each of the mechanisms has been selected by the author to represent specific design classifications for a particular group of locks. A brief description of each lock is presented that detail operating theory and uniqueness, together with illustrations showing functionality.

Locks have been included based upon the following criteria:

- **Unique and clever design;**
- **Security rating;**
- **Resistance to surreptitious, covert, and forced-entry;**
- **Commercial universal acceptance;**
- **Patent protection;**
- **Product life;**
- **Resolution of security issues raised in similar products.**

AUTHORIZED LAW ENFORCEMENT AND GOVERNMENT AGENCIES MAY CONTACT THE AUTHOR FOR DETAILED INFORMATION REGARDING BYPASS OF MANY OF THE LOCKS DESCRIBED IN CHAPTERS 17-23. IN CERTAIN CASES, REPORTS HAVE BEEN PREPARED REGARDING THE OPERATION OF A SPECIFIC LOCK, AND ARE AVAILABLE FROM WWW.SECURITY.ORG.

CHAPTER SEVENTEEN: GENERIC SYSTEMS

Traditional Mechanical Locking Systems

Master Exhibit Summary

Abloy master keying theory, Courtesy of Hans Mejlshede.

Forced entry of Abloy locks, and forensic indications, Courtesy of Hans Mejlshede.

The Peter Field (Medeco) patent for a security tumbler. Courtesy of Hans Mejlshede.

Forensic analysis of the Medeco cam lock. Courtesy of Hans Mejlshede.

Section 1: Lever Locks

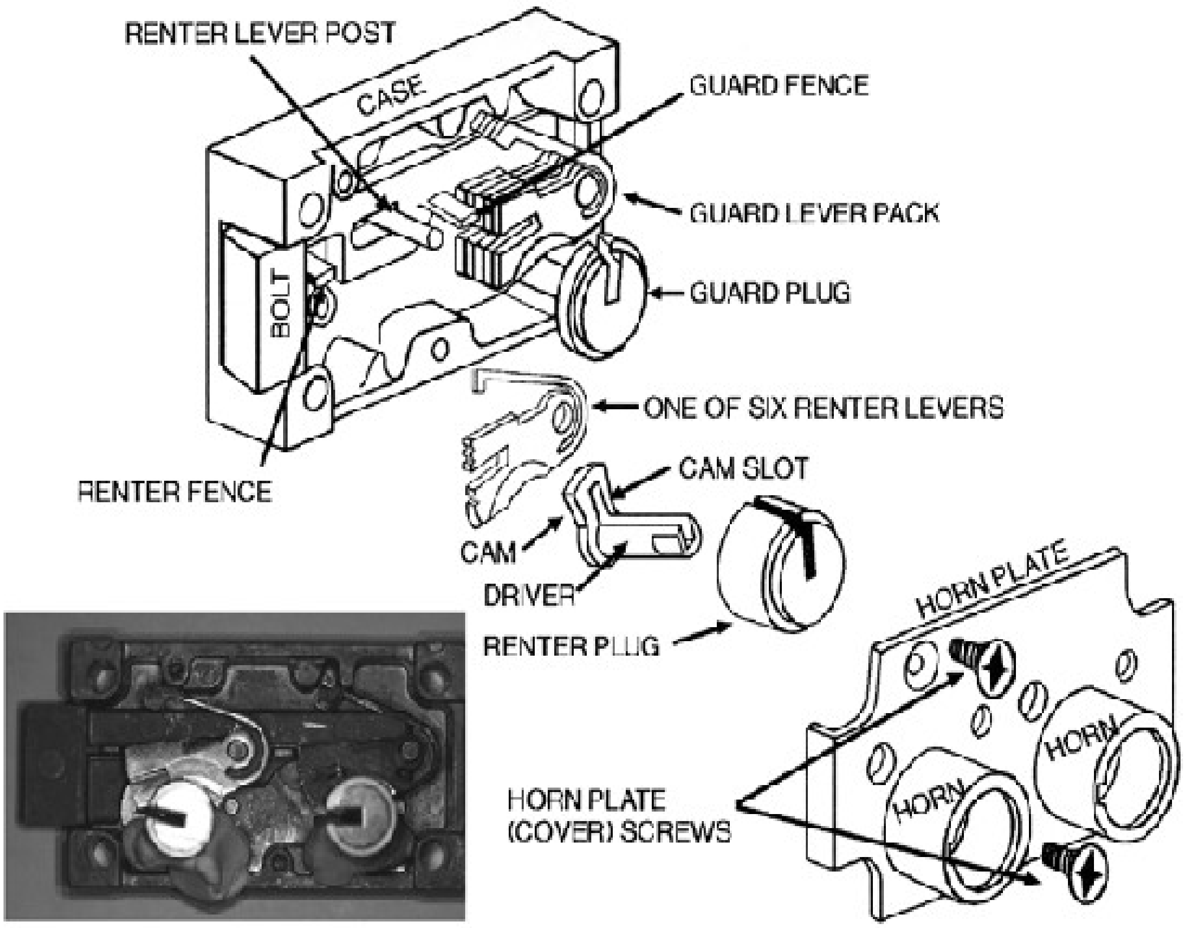
SAFE-DEPOSIT AND SECURITY CONTAINER

Information regarding basic lever locks can be found in **Chapter 14**. This section will describe three special applications: coin telephones, safe-deposit boxes, and prison locks. Lever locks can provide equivalent or greater security to that offered by a pin tumbler mechanism. They have found their way into many special applications, including post office boxes, safety-deposit boxes, coin telephones, and safes.

17_1.0 Safe-Deposit and Security Container Locks

Locks for safe-deposit boxes are generally lever mechanisms that contain security enhancements including pick resistance, dual control, and combination programmability. Sargent & Greenleaf dual-control designs are described here. See also **Section 4** regarding the **DOM** split-key approach to dual-key control. S&G manufacture a variety of safe-deposit locks that are used throughout the world. Models 4440 and 4110 are the industry standard for banks. Models 4110 and 6805 are changeable fence locks that allow the lever-fence relationship to be altered to fit any key. They are described in **Chapter 22**.

17_1.1 S&G 4440 Dual Control Lock



Exploded view.

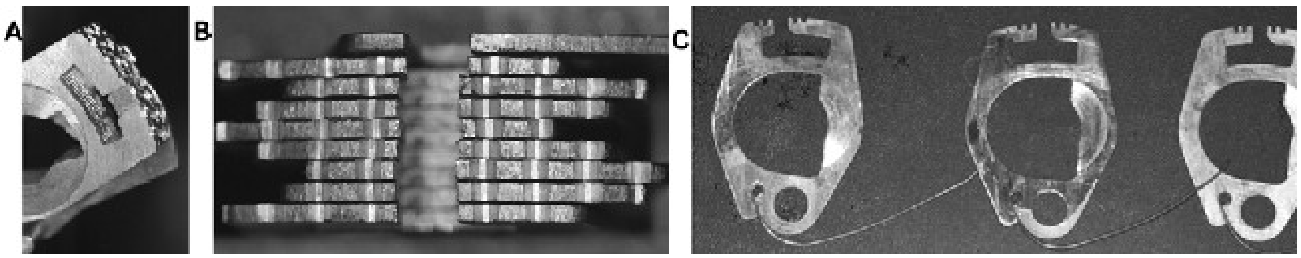
The S&G 4440 is a dual-horn five-guard lever plus six renter lever lock, that must be opened with two different keys. The guard and renter keys must lift the lever packs simultaneously. The lock is designed so that both of the gates are an integral part of the bolt upon which the lever packs rest.

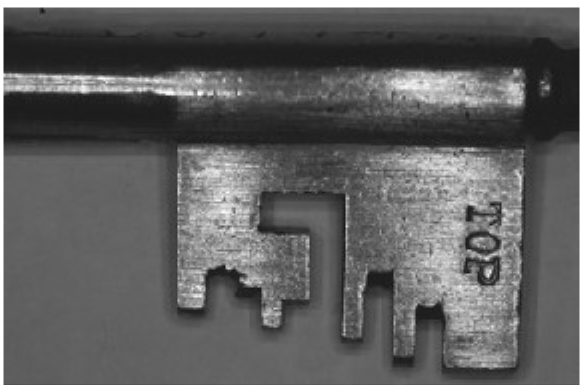
This is a **fixed lever** lock, meaning that each lever tumbler has a fixed sweep and gate position. There are six possible depths for each lever gate, or 46,656 differs for the renter's key and a similar number of differs for the guard key. Note that there are serrations around the gating of each lever to make picking difficult.

17_1.2 Safe and Vault Lever Locks

Lever locks used in safes and vaults utilize a number of

different designs to increase security, but all incorporate the basic gate and stump theory. Depending upon the lock, there will be more levers, higher tolerance gate designs, and often two separate packs of levers. In addition, serrations, traps, and false gates will be employed to frustrate bypass. One of the original Tann locks (made in England) utilized an ingenious guard lever to prevent all but the proper key from gaining access to the bellies.

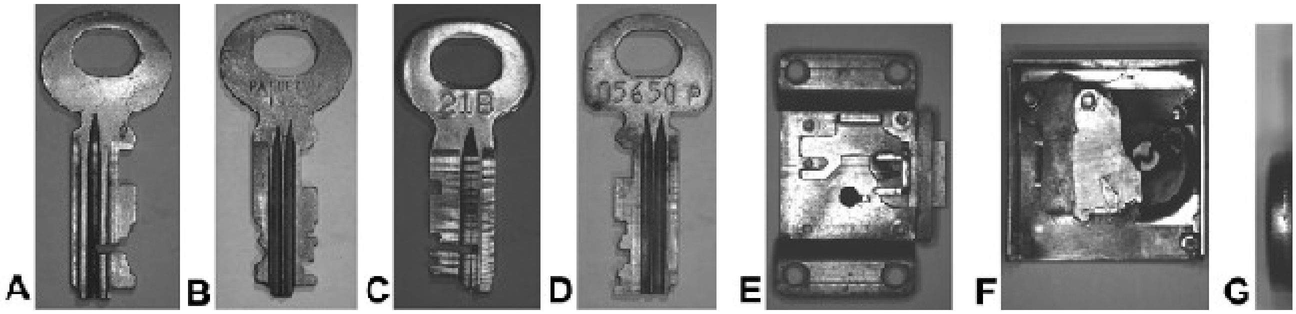


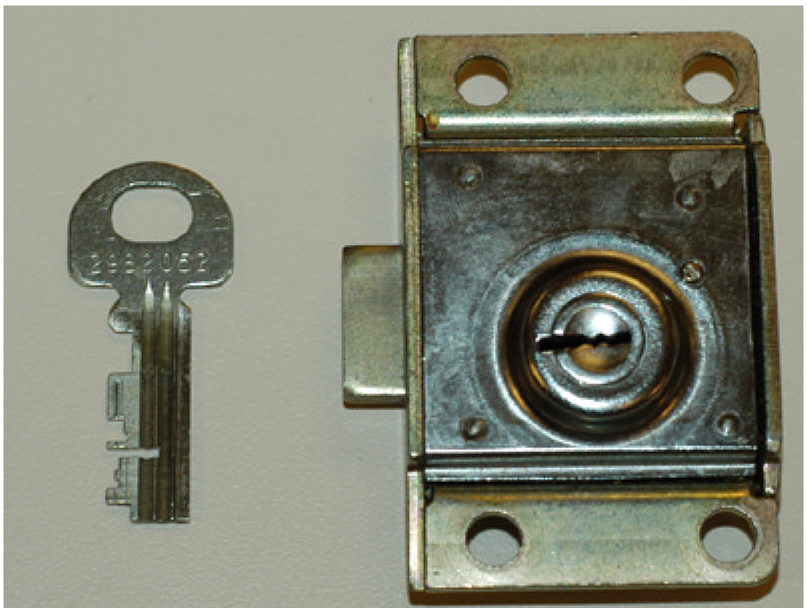


In perhaps the earliest design, Chubb patented his **protector** to double-lock the mechanism whenever picking was attempted.

17_1.3 Coin Telephone Locks

Coin telephones throughout North America have special security requirements. These have been met by the development of unique lever locks, developed and patented by Western Electric (WE), Automatic Electric (AE), and Northern Electric (NE)(3402581). Lever locks for coin telephones have evolved over the past fifty years to offer a high degree of security.


A
B
C
D
E
F
G



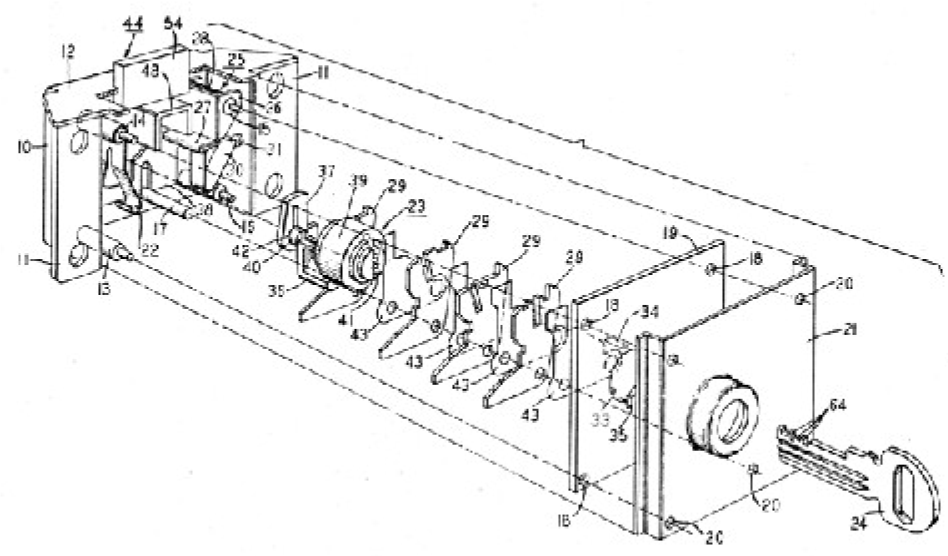


The locks used in coin telephones are extremely sophisticated in their design. They generally employ six levers and often have added pin tumblers (up to three) which contact the lower bitting of the key. The two photographs above show a 29B lock and key, a current model.

The Bell Labs patent describes a highly pick resistant mechanism with levers that pivot around a floating or unattached cam. The lock picker cannot gain any reliable sensory data from the application of tension on the levers as in traditional designs. The center of curvature of each of the radii of the levers has also been altered to make manipulation difficult. One common spring provides bias to all levers within this lock. This effectively destroys any feeling as to the position of an individual lever. Finally, an alarm switch will sense the movement of a single lever.

Locks used by **WE**, **AE**, and **NE** are very similar in their mechanical design and operation. Coin telephones require a dual-locking system to protect the upper housing and the coin vault. These separate compartments require controlled access by maintenance and collection personnel. The upper housing, which contains the electronic components and coin control devices, will have a lever lock keyed differently than the lower coin vault. The coin vault generally consists of a removable faceplate that covers the coin box. The lower vault is constructed of heavy-gauge steel and usually employs a four-point locking system to secure the vault cover. This makes penetration extremely difficult.

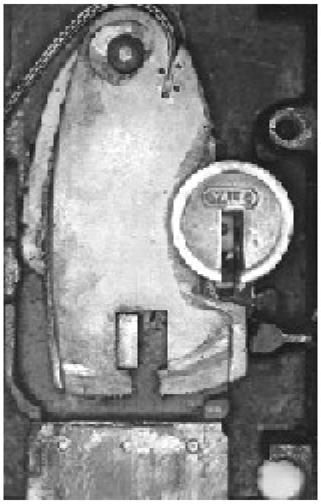
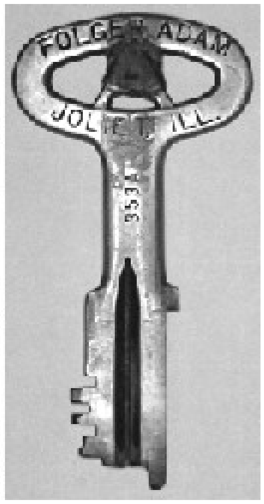
The keyway is limited in terms of access to the lever tumblers. Keys for these locks are quite distinctive. The design of the levers provides for pick resistance through a variety of patented features. There are three basic types of coin telephones in current use: the **Western Electric**, **GTE**, and **Intellicall** (privately owned) design. Although the lever locks described above are the most popular, Medeco, Abloy, Chicago, and other cam locks may also be encountered.



Possession of traditional WE, AE, and NE keys may indicate illegal activity, although the prevalence of private pay telephones has made these previously restricted locks and keys readily available.

17_1.4 Detention Locks

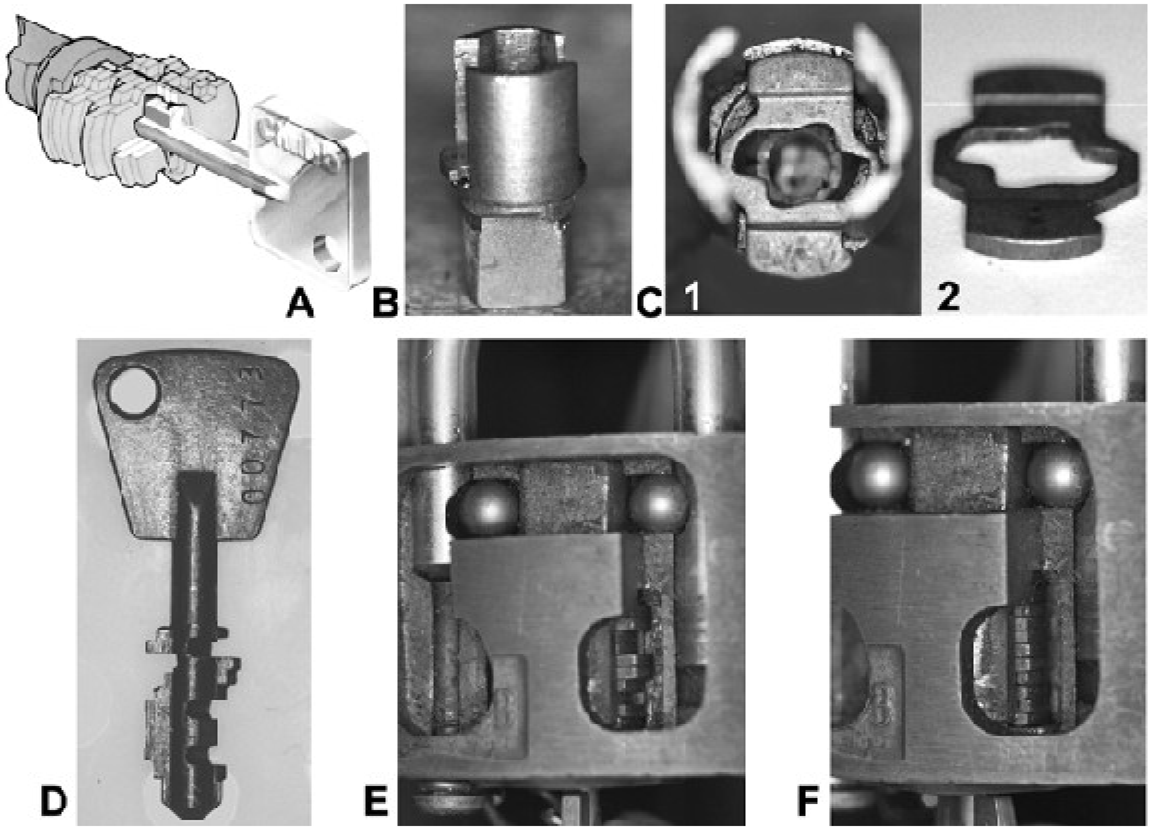
Detention locks used in jails and prisons are classified by security rating and are actuated by key, electricity, air pressure, or hydraulics. In many of the older facilities, large lever locks, replicating those used in safe-deposit vaults, are in wide use. Low-security locks are employed on individual cell doors and non-critical internal access points. For this application, standard high-security cylinders are utilized, such as Medeco. Generally, they are mounted into the door frame for added security. Medium- security locks are placed on certain exterior doors where inmates do not have access. Maximum-security devices are most often used on access points to the outside world.

Section 2: Wafer Locks

Detailed information regarding wafer locks can be found in **Chapter 15.** Wafer mechanisms are perhaps the most popular in the world as a low to medium-security device. There have been many variations of the original design; some in combination with other locking technologies.

17_2.1 Chubb AVA Wafer Slider Lock



This mechanism is found in Chubb padlocks, handcuffs, and other applications. It relies upon ten sliding wafers that move laterally as the key is inserted. The bitting has angled depth cuts corresponding to different sliding distances. The travel of each wafer is controlled by the rotation of the key and the angle of engagement.

This is a double-sided mechanism, much like the Chicago wafer lock. However, depth cuts are offset on each side of the key by a specified angle. The operating principle also resembles the Abloy DiskLock that is discussed in **Section 3.1** below. The mechanism provides a high level of security against picking and manipulation. It is used in Chubb's highest security padlocks and handcuffs.

17_2.2 Abloy DiskLock

Although the Abloy Disklock can be classified within the wafer tumbler family, that description is not altogether accurate. The design utilizes rotating discs rather than traditional single-plane traveling wafers. This lock is discussed in detail

in **Section 3,** Disk Wafers, because of the designs of the tumblers and the sidebar locking technique.

17_2.3 Briggs and Stratton Sidebar

The Briggs and Stratton lock was originally introduced about 1935 for use in automobiles. It is described in **Section 6.** See Johnstone (**3367156(177)**) for a description of a modified sidebar lock incorporating different sized wafers to be more resistant to forced-entry.

17_2.4 Winfield

Winfield produces a unique instant rekey wafer lock that is used predominantly in the hotel industry. The lock can be reprogrammed for any of 1,024 change keys, as well as different master keys, maintenance, and emergency access keys. See **Chapter 22** for a detailed description of this lock.

17_2.5 Evva 3KS

The **EVVA Three Curve System (3KS)** utilizes 12 locking pins and 18 control pins that ride in three separate tracks along the surface of the key. The keys are reversible for ease in use. Keys are also profile-coded, both top and bottom, for added security. The design of the 3KS was modified in 2001 to incorporate a modular concept that allows all EVVA systems to be interchanged within a profile cylinder system.

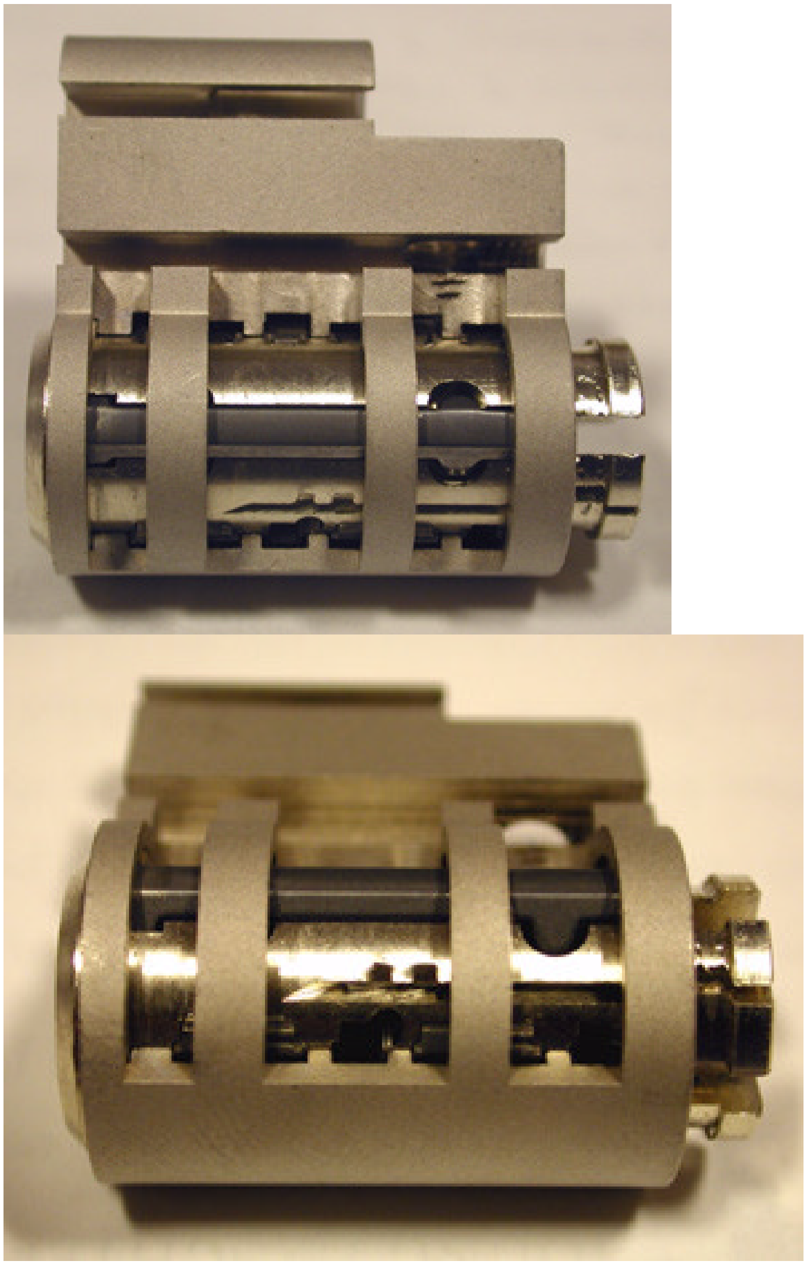


Figure LSS+1701 The Evva 3KS sidebar lock showing the sidebar in an unlocked and locked position.

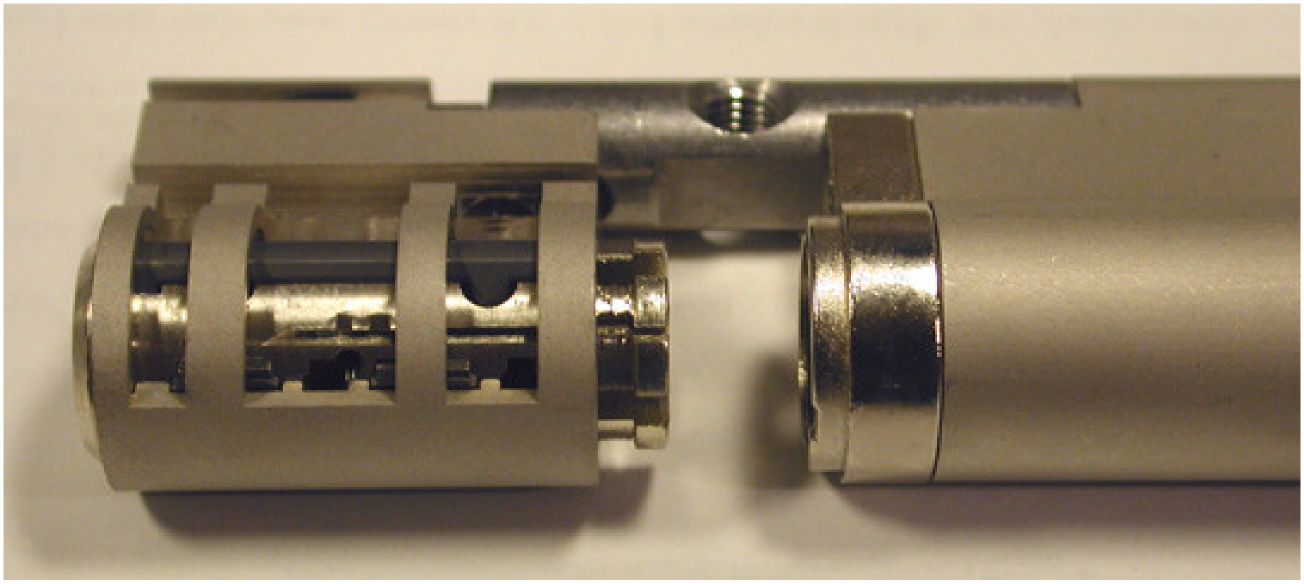
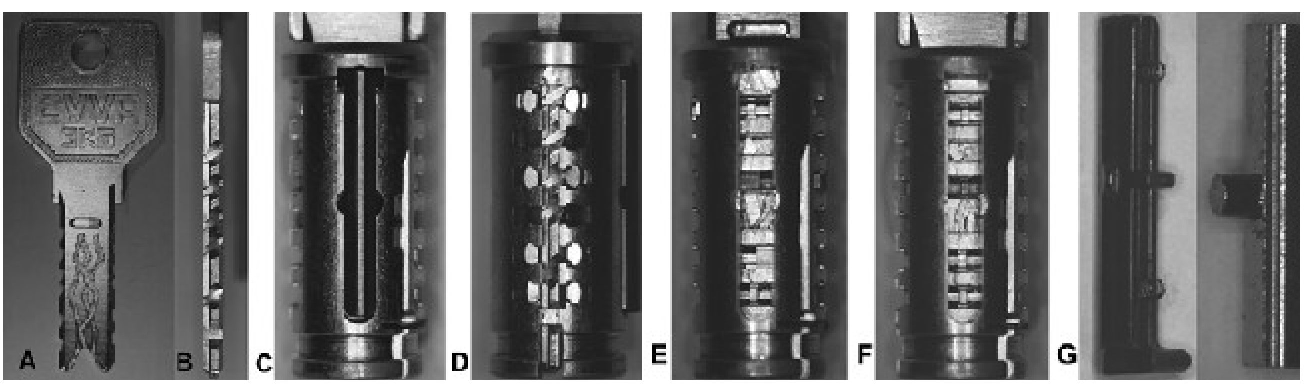
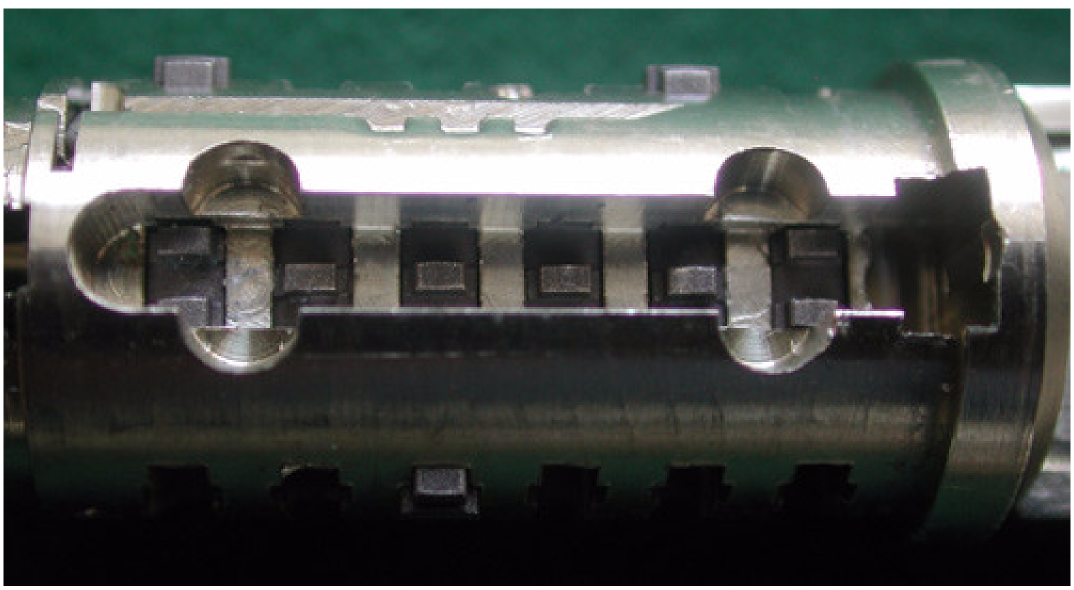


Figure LSS+1702 The Evva 3KS is a modular system. Shown is one cylinder in a locked position.

This lock utilizes the same general principle as other laser track systems but is more sophisticated because it also incorporates two separate sidebar mechanisms. In the photograph shown below, four of six sliders are properly aligned. The sliders on the ends, however, will not permit the sidebar to retract, thus preventing the lock from opening. Each of the sliders runs on the track, moving vertically into position. The lock incorporates two different slider designs. The sidebar fits on top of the dual indentation. Note the false gate below the true gates.







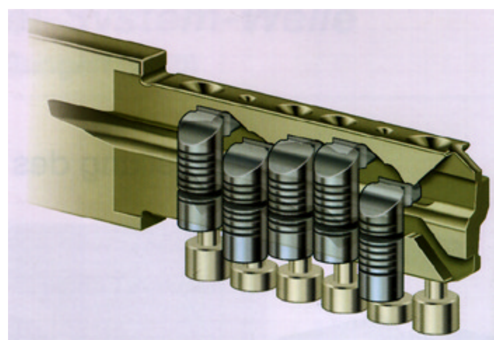
Patented in 1989 (**4977767(178)**), the lock features a unique flat key, having a blade formed with bittings along at least one of its edges. It has a pair of relatively shallow, open and parallel spaced grooves that extend across the longitudinal face in an irregular path. The sliding pins are shifted upon engagement with the grooves of the key. Two sidebars block rotation of the plug until all wafers are moved to the correct position to allow sidebar retraction. The pins are free-floating, providing high wear resistance and functional reliability. There are no springs.

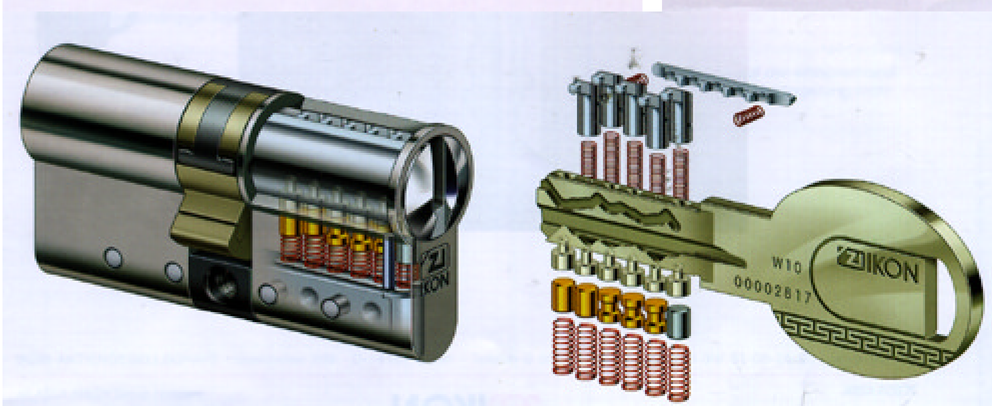
The manufacturer claims that there are a total of thirty trillion different combinations that allow master keying, construction keying, and instant rekeying. These cylinders also contain several internal security features including anti-drill pins, anti-torque, and plug pulling mechanisms.

17_2.5A IKON WSW System

The IKON WSW laser track sidebar system embraces a different design philosophy than the EVVA 3KS, and utilizes undercut finger pins that resemble the keyway technology introduced by Schlage in their Everest series of locks. The IKON mechanism is ideally suited to large master key systems. In such applications, reverse bitting surfaces on either side of the key are utilized. If high differing capability is not required, then only one sidebar is required, although the key is able to be inserted in either orientation. It will also be noted that the finger pins resemble those employed by ASSA, although the sidebar is a completely different design, as can be seen. Locking is accomplished by one or two sidebars and conventional pin tumbler bitting using dimples at the top of the key.







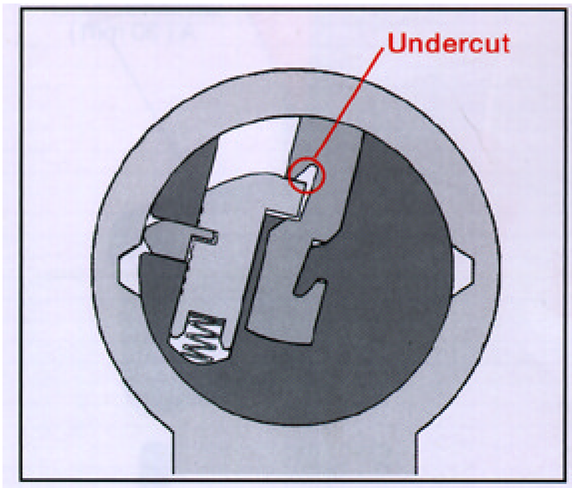
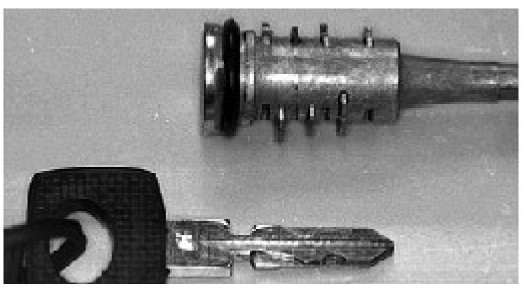
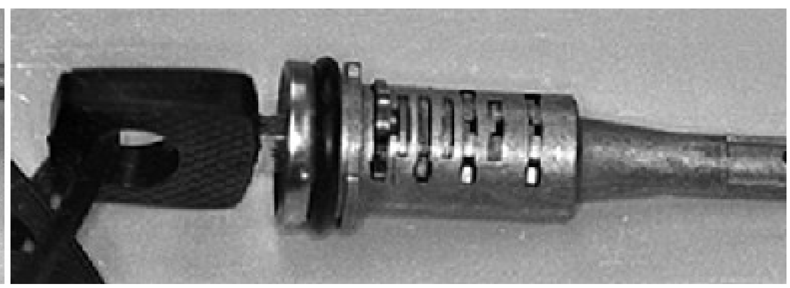


Figure LSS+1705 The IKON WSW Lock system

17_2.6 Laser Track Vehicle Locks





A number of automobile manufacturers, including Mercedes, utilize what has come to be known as laser track or laser cut locks to increase security. Mercedes utilizes four different track system locks in their vehicles, all manufactured by Huff of Germany. The first of these "track" locks was introduced in 1979, followed in 1980 and 1985 with different designs incorporating alarm features. The locks utilized both two and four-track mechanisms.

In the two-track systems, there is one track on each side of the blade; each key has two blade surfaces. Each lock has ten wafer tumblers having five depth positions. The two-track system is actually a modified double-bitted wafer lock in which the wafers ride on the side milling of the key rather than the traditional bitting.

17_2.7 Money Bag Locks

Courier bags used for carrying currency and gems utilize wafer

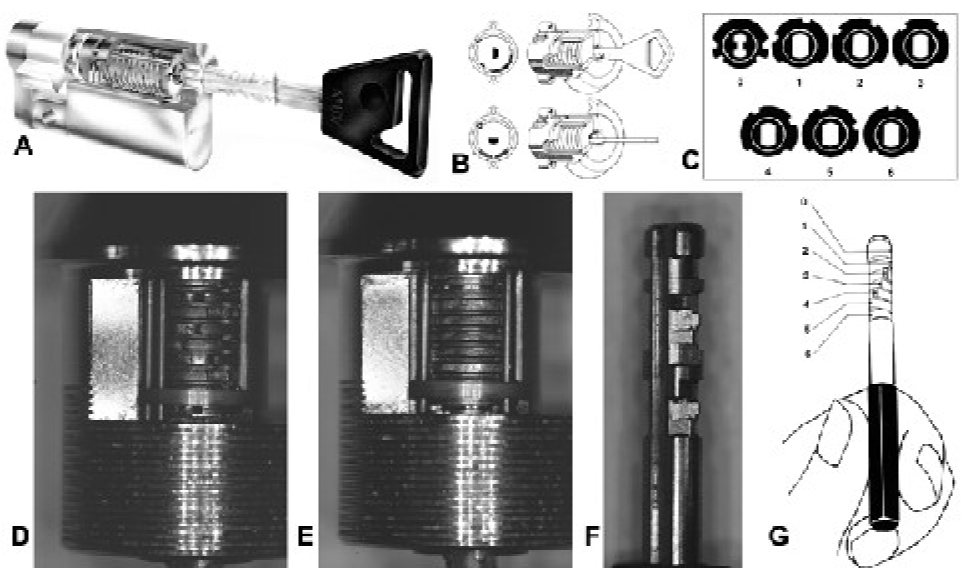
locks as described in **Chapter 15**. They are easy to pick and thus can be compromised without difficulty.

Section 3: Disc Tumbler Locks

ABLOY DISKLOCK

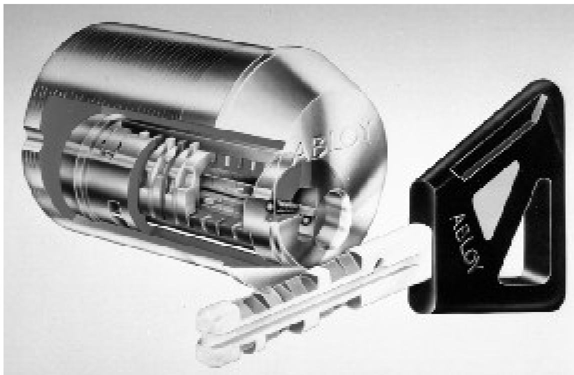
Disc wafer locks combine the attributes of traditional wafer designs with secondary locking systems, usually sidebar. Another distinction is that the wafers are **rotated** rather than moved in the normal vertical plane. These locks feature a key with different camming surfaces, having non-uniform radii from the central axis of the plug. As the key is rotated, it picks up different wafers based upon their internal spacing and structure. The operating theory of these devices resembles that of a combination lock to the extent that disks are rotated to align a sidebar. The sidebar can be likened to the fence that must enter all gates in order for the lock to open.

17_3.1 Abloy DiskLock



Abloy has developed a unique rotating disc sidebar locking system that distinguishes it from all other wafer locks (**3948065(179)**). The mechanism is comprised of rotating discs that resemble the wheel pack in a combination lock. Eleven discs provide up to 1.97 billion different combinations as well as complex master keying. The lock is somewhat similar in principle to the Olson

device that was patented in 1992 (**5086631(180)**). The position of the discs is automatically scrambled each time the key is removed in order to prevent visual decoding and impressioning. As an option, keys may be set to actuate a plug in one direction only or in both directions, allowing specific employees to lock or unlock certain areas.



Because there are no springs, the lock is impervious to dirt, water, freezing, poor weather conditions, and corrosion. Thus, it is suitable for use in difficult environments. Pick and decoding tools have been developed for certain series of this lock; however, picking can be quite difficult. See **Chapter 31** for information regarding the John Falle tools.

Forced entry of Abloy locks, and forensic indications, Courtesy of Hans Mejlshede.

17_3.1.1 Operating Principle

The operating principle of this lock is straightforward. Upon entering the keyway, the key meets no resistance because there are no springs. Discs initially remain in their locked position with their gate orientations scrambled. When the proper key is turned 90°, each disc is rotated a certain number of degrees corresponding to the radius of the cut. Each portion of the bitting will pickup its corresponding disc and rotate it until the key stops. The amount of travel of each wafer is dependent upon the angle of the cut. When all of the discs are aligned properly, a sidebar is retracted into the tumbler-pack and the plug is free to turn. As the key is turned in the opposite direction, the sidebar is lifted out of the gates into the locked position. The combination of the wafers is scrambled so that all of the gates are randomly placed. The key can then be removed.

The Abloy key is cut at varied angles, rather than traditional depths, which eliminates adjacent cut restrictions. There are seven different cut angles (identified as 0-6) and corresponding combination discs. Note that the discs are **not** reversible and are placed in the plug embossed side down. Discs 0-5 have two sidebar gates each; one for clockwise and counterclockwise turning. The number 6 disc only has one sidebar position and does not rotate. All Abloy locks have eleven discs and ten spacers sandwiched between the active discs; the spacers can be oriented in either direction. In addition, one-way spacers prevent discs from moving in both directions.

17_3.1.2 Master Keying

Master keying requires the use of discs with multiple gates (from 2-6 cuts on the side) resembling some early forms of lever locks. The same numbers of discs are utilized in all locks; just the gates are modified. A master keyed cylinder will have no more than four master discs loaded into the plug. The Abloy DiskLock is available in many configurations, including ANSI rim and mortise cylinder, high-security knob, European profile, cam, microswitch, furniture, and padlock.

Abloy master keying theory, Courtesy of Hans Mejlshede.

Section 4: Pin Tumbler Locks

EVVA GPI
MUL-T-LOCK
CORBIN-RUSSWIN EMHART
SARGENT KESO
DOM SPLIT KEY
IKON TK5S

17_4.1 The Basic Pin Tumbler Lock

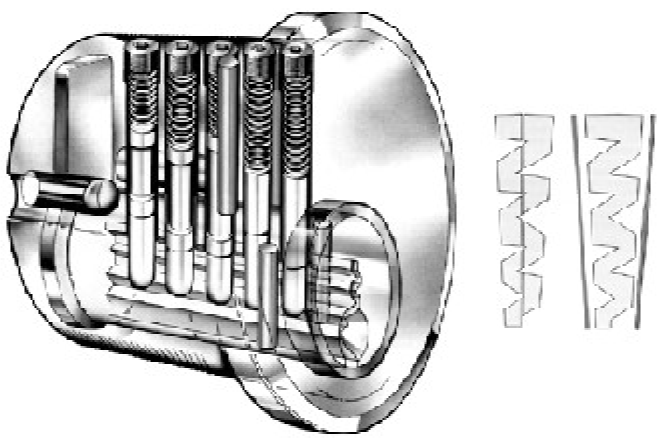
There are many unique variations of the basic pin tumbler lock discussed in **Chapter 16**. Several of these are described here because of their special application or unique modification to the basic pin tumbler concept. Not covered in this section are the family of tubular pin tumbler locks, hybrid designs, specialized industry locks, and those incorporating pin tumbler

"like" operation employing other technologies such as magnetics.

Several schemes rely upon the moveable pin tumbler as the basis for a locking mechanism. Many such locks have been omitted here due to space limitations. More importantly, the locks detailed in this section reflect the best and most significant mechanical designs. No inference should be drawn as to functionality, uniqueness, cleverness, or security just because they have been omitted.

17_4.2 Evva GPI Integrated Profile System

The EVVA **GPI** system integrates special design variations over the entire height of the keyway in order to increase the number of differs, security, and resistance to picking. The unique feature of this mechanism is the enhancement of the paracentric keyway function. Each profile rib overlaps the centerline and is distributed over the entire height of the keyway.



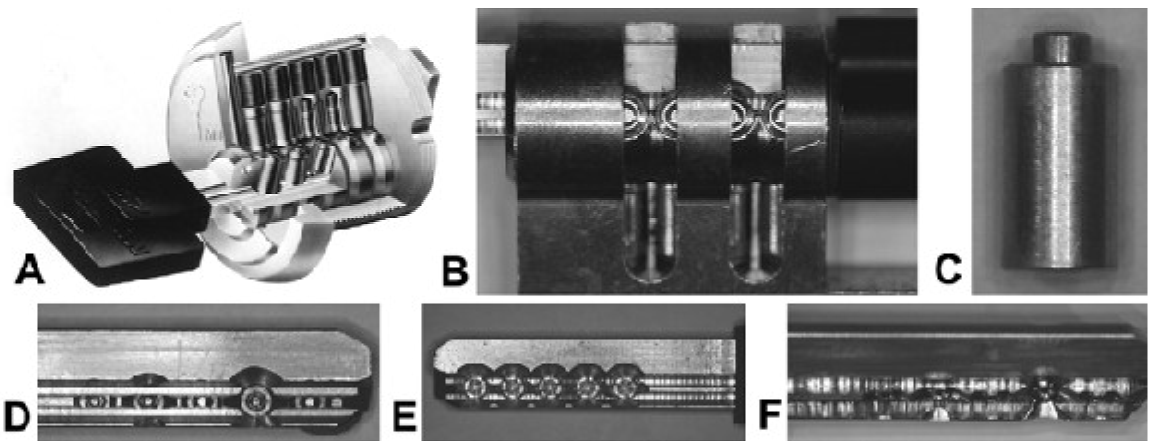
Both the key and the keyway are conical shaped. This virtually eliminates the generation of counterfeit keys, and more importantly, will make picking and probing of the lock difficult. The shape of the keyway and its sharp curves makes the insertion of any pick very difficult.

17_4.3 Mul-T-Lock

The Mul-T-Lock design was introduced in 1973 and has earned a reputation for mechanical excellence. The company, headquartered in Israel, is known for its quality assurance and innovation in

high-security products. The lock is manufactured to high tolerance and is recognized for its pin-within-a-pin telescoping tumbler concept (**4856309(181)**). The mechanism takes on characteristics of a dimple lock described below but more closely resembles conventional operation with a horizontal orientation of the keyway.

The primary locking concept is conventional, in that pin tumblers are utilized in a rotating plug. The addition of telescoping tumblers, requiring that both segments must be raised to shear line, provides a very high level of pick resistance.



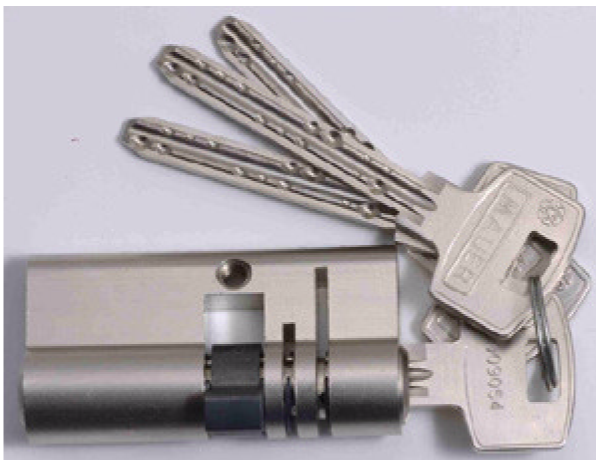
The company has received patents for the design, which provide for two independent pins within each chamber. Chicago Lock utilizes a similar concept in their high-security axial cam locks. However, Mul-T-Lock has engineered their telescoping pins to be a complete, self-contained assembly.

The plug is oriented horizontally within the shell. The four or five pin-sets are acted upon by the sides of the key, thereby reducing the space available for the action of a pick. Two types of pin assemblies are utilized: body pins, and plug pins. The Mul-T-Lock spherical plug is also different than other high-security locks. It is shaped so that a three dimensional shear line is created, engaging the entire contact surface between the pin and shell. This is called spherotation.

Pin surfaces are convex to precisely match the curvature of the plug with respect to the shell. The upper pins are concave. Thus, a three-dimensional shear line is attained and which provides very high tolerance. Keys are double-sided and may be inserted in either horizontal orientation. The double dimples that form the bitting are complex in their geometry. They have an

inner and outer ring to control the inner and outer telescoping pins. The locks are UL 437 listed and are available in a variety of configurations. John Falle has released, in 2004, a tool to decode these locks, based upon the pin and cam system design.

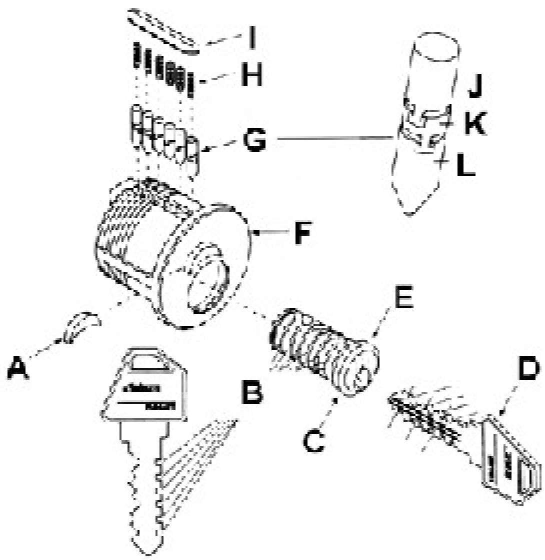
An interesting modification of the Mul-T-Lock was introduced by Mauer. Although this mechanism utilizes the European profile design, it employs one continuous set of bores and tumblers, rather than two separate plugs. The key is extremely long, and double-sided for insertion from either direction.



17_4.4 Corbin-Russwin Emhart High-Security

The Corbin-Russwin high-security cylinder is called the Emhart, first patented in 1978. The UL listed device was the first to allow integration of high-security cylinders into existing conventional system. All Emhart high-security cylinders use six pins and require keys with all cuts at one of two angles, or skews. The cuts are designated as left skew = 1, right skew = 2.

Security is attained through the use of interlocking pin tumblers. The end of each pin interlocks within the chamber and can only be released through the rotation action of the pin that is caused by the movement of the angled cuts on the key bitting surface.



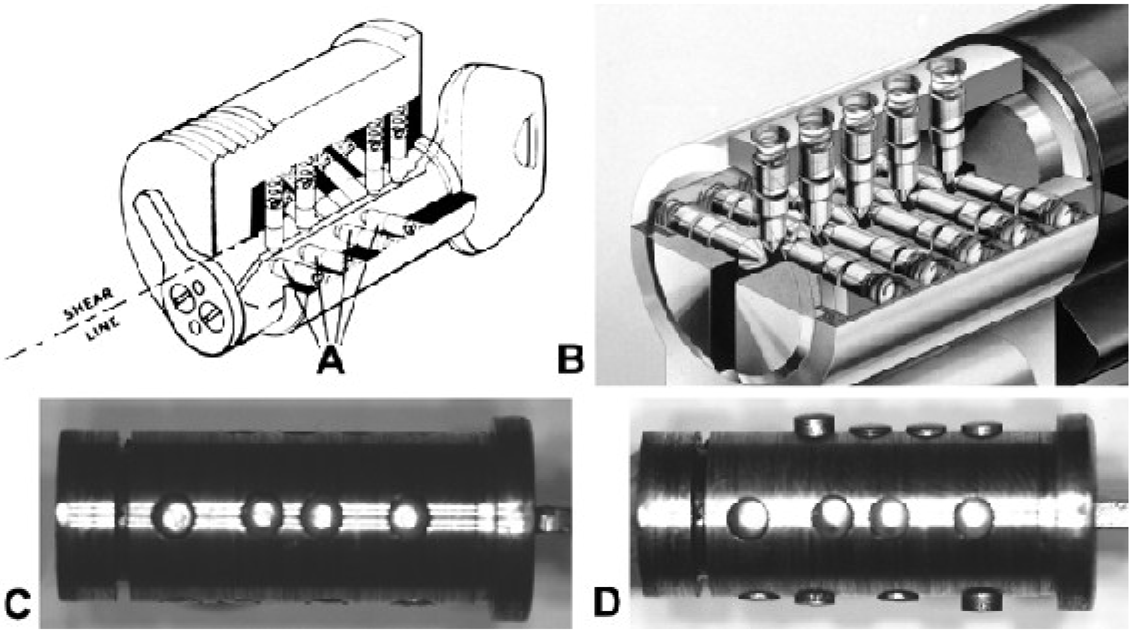
If the proper key is not inserted, the pins will remain locked together, forming, in essence, one solid tumbler (driver, master pin, and lower pin). The proper angled cuts on the key will release the pins from each other at shear line. Cuts are 20° offset, and there are no cuts that are perpendicular to each other.

There are also slotted grooves in the bottom of the key. These increase the difficulty of duplication and allow the projecting "T" of the top or master pin pin to pass over the key when the plug is rotated more than 180°. There are six bottom pin lengths and three master pin lengths. Conventional Corbin-Russwin cylinders may be mixed with high-security cylinders, much the same as with the Schlage Primus system. Thus, older installations may be fitted with high-security locks to protect critical areas. If an Emhart lock is to be disassembled for forensic examination, a standard follower cannot be used. All high-security cylinders must be top-loaded and disassembled.

17_4.5 Sargent Keso

Sargent introduced the first "dimple" pin tumbler lock in about 1968 as a licensee of Keso of Switzerland. This lock, as described in the first edition of this text, offered high-security through the introduction of a key with three active surfaces and twelve pin tumblers. The lock provides improved pick resistance, key control, and several levels of complex master keying with no loss of security. The highest security version of

this design features telescoping pins for maximum pick resistance.



17_4.5.1 Principle of Operation

Most dimple locks are based upon the same operating theory and mimic the Keso. These devices can utilize conventional or telescoping pins.

The Keso resembles a conventional pin tumbler lock with regard to the double-detainer locking concept. However, instead of containing five, six, or seven pins, the Keso uses from nine to twelve tumblers. The pins are arranged in three interlocking rows spaced in approximately 90° increments around the core. While the design of Keso key is unique, its basic operating theory is similar to a conventional pin tumbler lock, except that is has more pins.

The key is six-sided and is cut on all surfaces. In use, only three of these surfaces come into contact with the active tumblers. This allows insertion without regard to vertical orientation. The depressions in the key, usually four per surface, are flat bottomed. These match the height and position of the bottom pins and form the bitting surface. The tumblers are pointed, in contrast to conventional pins that are rounded or flat bottomed. This maintains a higher tolerance.

17_4.5.2 Differs and Master Keying

The lock can contain at most twelve tumblers (four per active surface). Each has four depth variations, creating millions of differs. This results from the fact that pins can be placed in any of **ten positions** on each surface. This placement of pins in selected chambers is known as a **positional keying system** and is more fully described in **Chapter 11**. Although only four pins are used, ten tumblers could be placed on each active bitting surface. This would provide a total of thirty different tumbler positions in the lock.

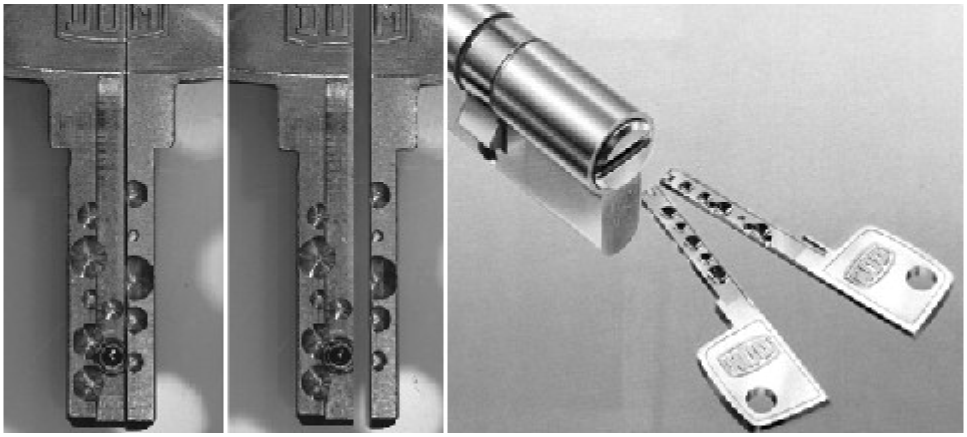
The combination for each cylinder is determined by the placement of pins in one or more chambers, for each of three surfaces. When group and master keying levels are established, identical patterns of chambers are selected. Whereas the **length** of a pin is determinative of the code for a key in the **conventional** lock, the **position** and **length** controls in the **positional** system. A matrix is established for each cylinder, defining the number of pins, chamber identification, and length. It can be seen that multiple keying levels are possible without the potential of cross-keying.

17_4.5.3 Security of the Lock

Dimple locks including Keso can be picked and impressioned. The success of such procedures depends upon tolerance, the use of security tumblers, and the number of pins.

17_4.6 Dom Split Key

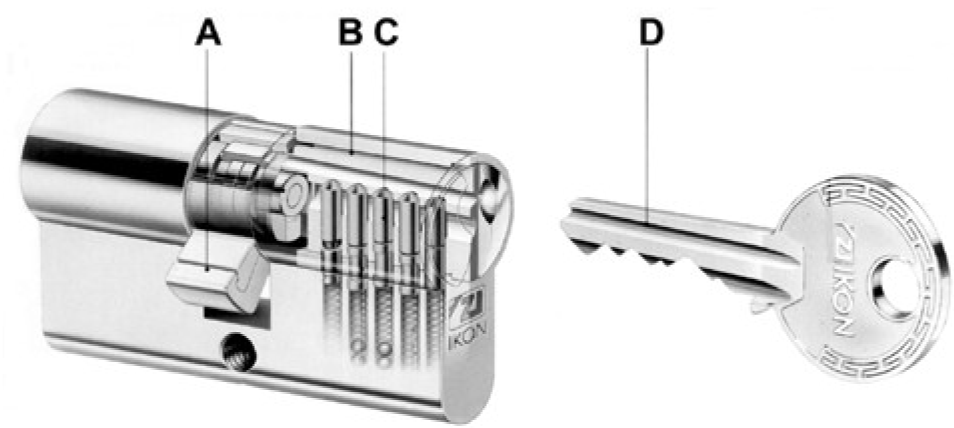
DOM (a Black & Decker Company) produces a high-security pin tumbler lock utilizing a dimple key. The uniqueness of this mechanism lies in its ability to "split" the key in half, thus making it ideal for dual-control entry. Both sections must be simultaneously inserted for the lock to open. See **Section 7** below for a full description.



17_4.7 Ikon TK5/S

Ikon has developed a conventional pin tumbler lock with a tapered keyway and rotational control pins. This creates special restricted keyways and a system that can be configured to allow access to a limited group of locks. Individual keys can be cut to restrict rotation of the plug to either a locked or unlocked position. This is a similar option to that offered in the Abloy DiskLock.

The Ikon TK5/S is a five-tumbler lock with two side pins, used to control rotation. There are corresponding protruding tabs on the side of the key that is positioned at 90° from pin chambers one and three (from shoulder). Square depressions are cut into the side of the plug at these pin positions.



If the proper key is inserted, the tabs will cause the pins to be extended from within the plug to shear line. If the tabs are

not present, the key will be blocked from rotating more than 90° in either direction. This occurs because the driver pins will stop the plug when they encounter the depressions. Keys are difficult to duplicate, based upon the angled broaching of the keyway and bitting surfaces.

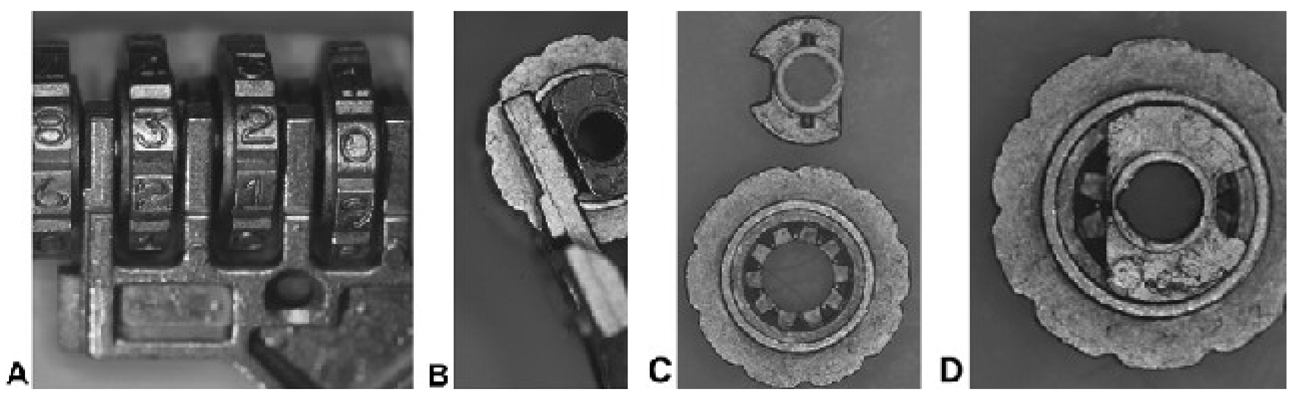
Section 5: Combination Locks

MASTER
S&G TIMBINATION
MAS-HAMILTON X-07

This section examines specialized mechanical and electronic combination locks. Conventional combination locks used in safes and vaults are more thoroughly described in **Chapter 34.**

17_5.1 Master Combination Lock

The Master four-wheel combination lock is extremely popular for padlocks and luggage. The Corbin Sessamee is of similar design (**4375159(182)**).



A traditional combination lock relies upon the rotation of a wheel pack to align individual gates. In this device, four discs are moved to the proper combination and may be instantly reprogrammed to a different number sequence.

The code may be changed by altering the relationship between the position of the disc, and the corresponding detent or flat-spot that forms the gate. Although there are 10,000 possible combinations, the lock may be very simply bypassed without the need to test every permutation. Each wheel may be rotated until

the detent is felt, while applying slight pressure to the shackle. The procedure is quite straightforward.

Another technique is to examine the individual wheels with an otoscope or borescope. There is a significant gap between the two halves of the lock casing, permitting a view of the discs. Simply rotate the wheels individually until a notch at the right of each wheel can be identified. Align all of the wheels so that each notch is visible, and note each displayed number.

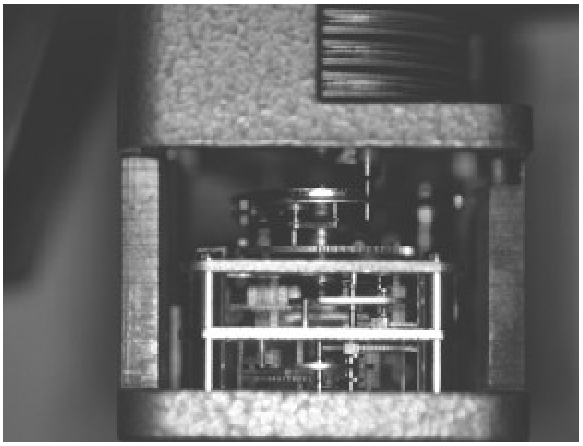
A corrective digit is then added to determine the correct combination. For certain models, 7 is summed to each individual number, dropping the tens place digit result. When the wheels are moved to this new combination, the lock will open. For example, if 8614 is displayed upon viewing each detent, the actual combination would be 5381.

	8	***6***	***1***	***4***	***Decoded Combination***
+	***7***	***7***	***7***	***7***	***Correction***

	5	***3***	***8***	***1***	***Derived Combination***

17_5.2 S&G Timbination Lock

The S&G Timbination movement provides an integrated short-term time lock within a standard 6730. A timer is triggered whenever the combination is dialed, requiring a delay of up to fifteen minutes before the bolt can be retracted. The lock is used to frustrate daylight robberies.



17_5.3 Mas-Hamilton X-07 Electronic Combination

Lock

The Mas-Hamilton X-07 is more fully described in **Chapters 18** and **34**. It is the most sophisticated electromechanical combination lock ever devised and is certified by the General Services Administration for use on top secret security containers.



The lock is microprocessor controlled, self-contained, and does not require any power supply for operation. It offers advanced security features that make it completely secure against all known forms of electronic bypass. Shown above is the Auditcon, which utilizes the same technology as the X-07.

Although S&G, LaGard, and other manufactures produce computer-based locks to replace their mechanical counterparts, none has attained the sophistication in design and security of the X-07. In the opinion of the author, the X-07 will remain the world standard for many years, based upon the restrictions placed on the duplication of their unique technology by the claims in the Mas-Hamilton patent.

Section 6: Hybrid Locks

ABLOY DISK
EVVA DPX
MEDECO

Assa, Schlage, Medeco, Abloy, Dom, Ikon, Keso, Mul-T-Lock, Chubb, Evva, and many other vendors provide a rich array of sophisticated high-security locks that incorporate what the author refers to as "hybrid" locking technologies. Hybrid locks combine two or more separate and interrelated locking mechanisms to offer higher levels of security against covert and surreptitious entry. Although there are many mechanical configurations, the most popular secondary locking system utilizes the **sidebar.** This method can be used in conjunction with wafers, discs, pins, and magnets.

There are, however, other systems. Axial cylinders in combination with traditional pins are popular in public locker applications. A conventional pin tumbler, complemented by data transmission, is prevalent in the automobile industry and is described in **Chapter 20**. Microprocessors can add intelligence to wafer and pin tumbler designs (**Chapter 21**). The telescoping pin, used by Mul-T-Lock, has also become very popular as a secondary locking device. See Section 4.3.

17_6.1 Sidebar Designs

During the past ten years, several manufacturers have developed extremely clever modifications to the original Medeco sidebar design. The most unique of these will be described in this Section.

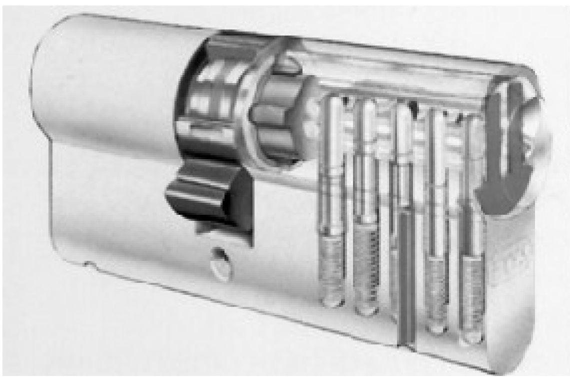
17_6.1.1 Abloy Disc

This lock incorporates a sidebar mechanism in conjunction with ten rotating discs, and resembles the wheel pack within a combination lock. The mechanism is fully described in Section

3.1.

17_6.1.2 Evva DPX

This system integrates a conventional pin tumbler mechanism with an innovative approach to the use of sidebar technology. The lock utilizes five conventional pins and a sidebar with different profiles that mate with indentations on the side of the key. The approach to sidebar coding that Evva has adopted resembles that of Assa. This lock does not provide secondary locking, as with Medeco and other similar mechanisms. Rather, the sidebar simply adds security to the keyway.

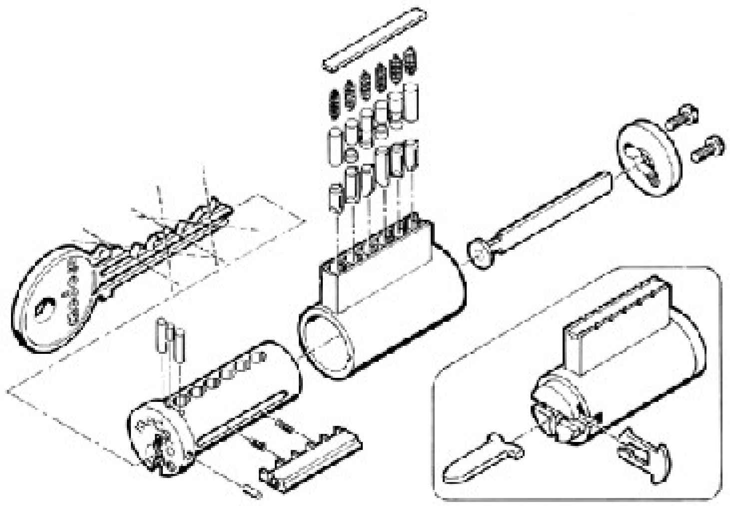




17_6.1.3 Medeco Twisting Tumbler Sidebar

Original Pin Tumbler
Biaxial Pin Tumbler
Cam Lock
BiLevel

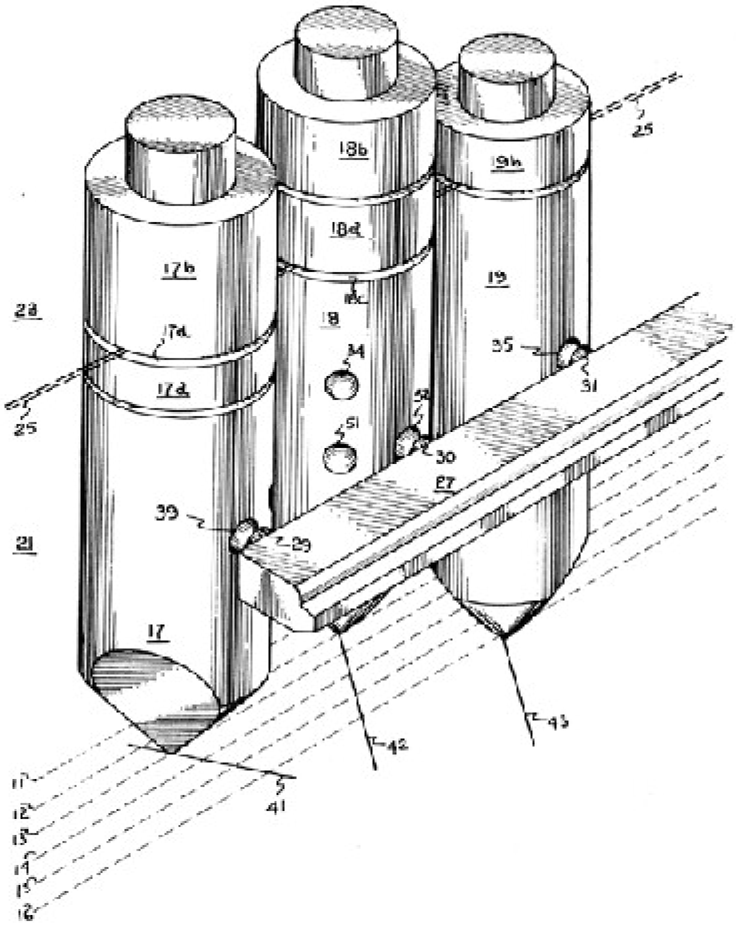
Spain and Oliver invented the concept of the rotating tumbler lock. The Medeco Lock Company offers three distinct designs that employ this principle.



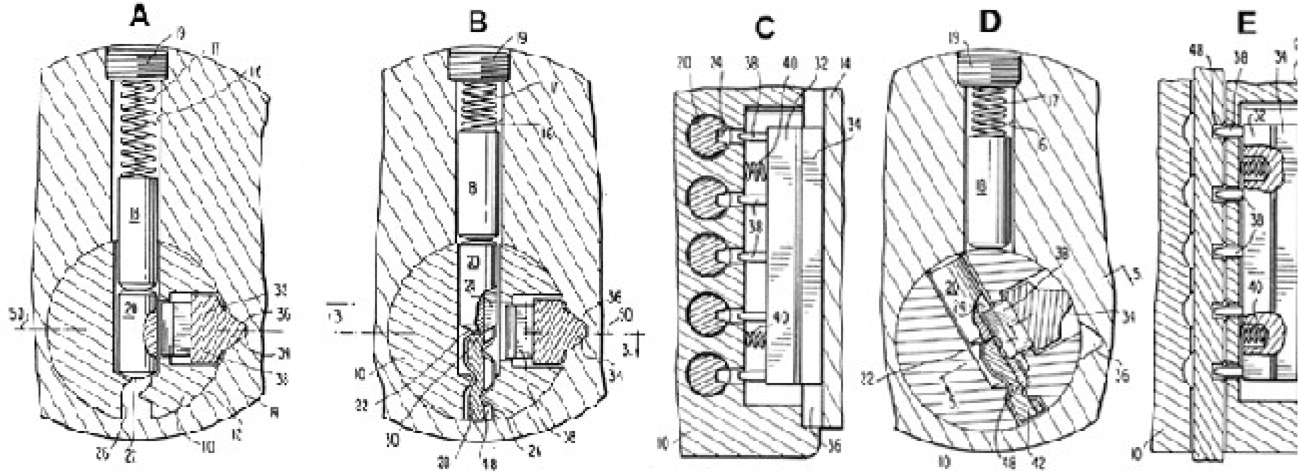
17_6.1.3.1 Original Pin Tumbler Design

The original Medeco rotating tumbler cylinder was introduced a short time before the first Edition of this text was published in 1970. The design was revolutionary and literally transformed the concept of high-security locks. The original patent, issued to Spain and Oliver, described a completely new and innovative locking technique (**3499302(183)**, **4723427(184)**, **3722240(185)**). It relied not only upon the traditional double-detainer principle first invented by the Egyptians and refined by Yale but introduced the theory of the **rotating** or **twisting** tumbler.

There have been many modifications to the concept described within the Spain patent since its first grant. Changes have been made both by the original inventors and by many others who altered the design in an effort to improve upon it, and to capitalize upon its uniqueness and ingenuity.



In the original patents, two distinct designs were claimed. Thirty years later, they have become the most successful high-security locks in use worldwide. In reality, it might be said that the invention was but a long awaited refinement of the Briggs and Stratton sidebar wafer lock first introduced in 1935 for the automotive industry.



The Briggs and Stratton lock relied upon the use of wafer tumblers; the inventors of the Medeco used pin tumblers. The combination of pins and sidebar produced a high-security lock that would be extremely pick resistant.

There are two basic Medeco sidebar designs. The first is used primarily for vending, gaming, alarm, cash container, and in control applications requiring substantially higher security than can be obtained from a standard wafer cam lock. The other is a high-security pin tumbler cylinder design.

The first Spain patent was premised upon the standard pin tumbler lock that required that all conventional pins be raised to a shear line in order that the plug might turn. That is where all similarities to the original Yale design ended. The inventors integrated a sidebar mechanism into their lock that had to be retracted into the plug in order that rotation might occur.

The sidebar is a spring-biased bar with protruding pegs corresponding to slots located in the side of each tumbler. **The security of the design is based upon the mating between sidebar pegs and tumblers, in order that retraction might occur.**

There is a small hole within each pin with a diameter that will just allow the sidebar peg to enter the slot within the tumbler. The tumbler must be raised to shear line **and also rotated** to the precise point that allows entry of the protruding pegs. Once this occurs, the sidebar will retract and the plug can be rotated. In the original design, each pin could be rotated to one of three positions: **right**, **center**, or **left**. If any tumbler is not raised to the shear line or is not perfectly aligned to allow

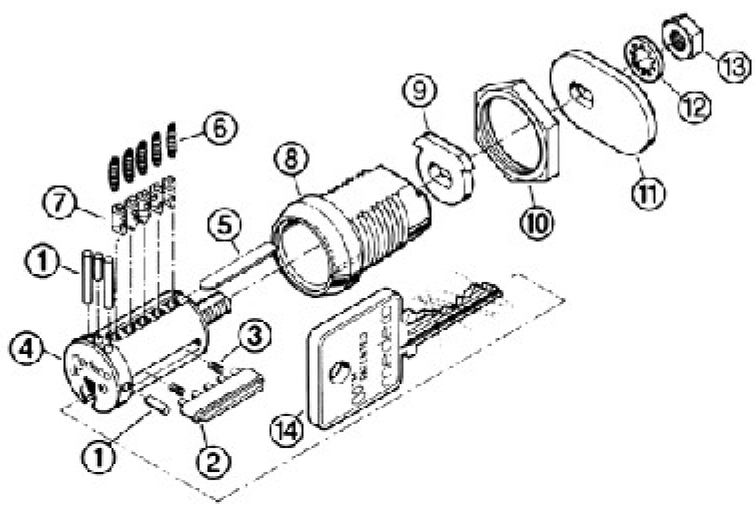
the pin from the sidebar to enter, then the lock cannot be opened. In 1994, Peter Field patented a design modification to the Medeco pin shape (**5289709(186)**) that provided for the interaction of the pin tip and key bitting in a unique fashion. This system provides additional differs and extremely high-security.

The Peter Field (Medeco) patent for a security tumbler. Courtesy of Hans Mejlshede.

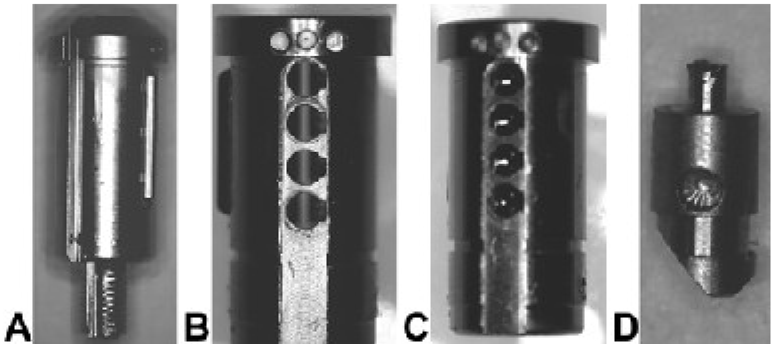
17_6.1.3.2 Cam Lock

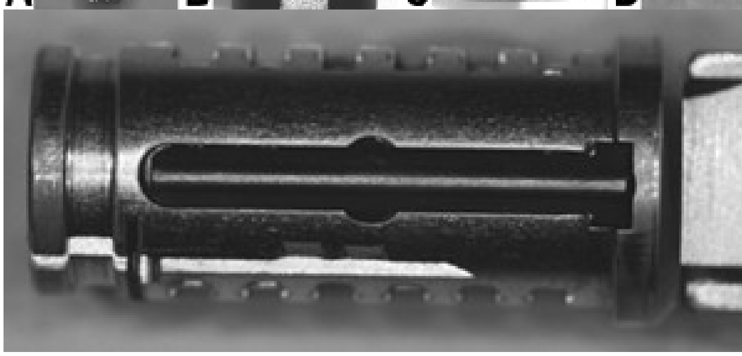
Forensic analysis of the Medeco cam lock. Courtesy of Hans Mejlshede.

The second patent provides for a modified pin tumbler design that is even closer in concept to the Briggs and Stratton lock. It relies upon the use of only **one** pin tumbler per pin chamber. The pins do not create a shear line but rather are the vehicle for the control of the sidebar.



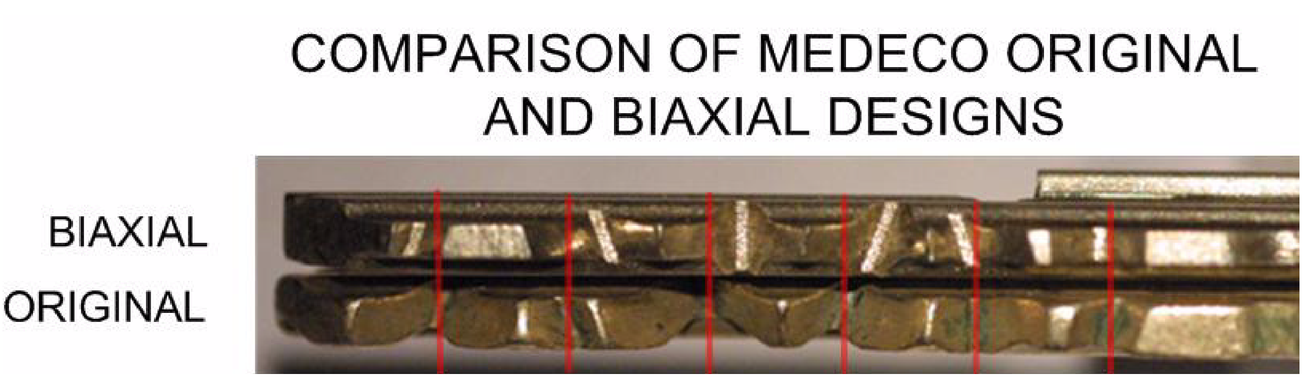
Each pin has a precise hole in its side corresponding to a pin extending from the sidebar. Although each pin tumbler is lifted and rotated, there is no secondary shear line created by a top set of tumblers. The only function the pin tumbler performs is to be lifted and rotated for alignment of the sidebar.

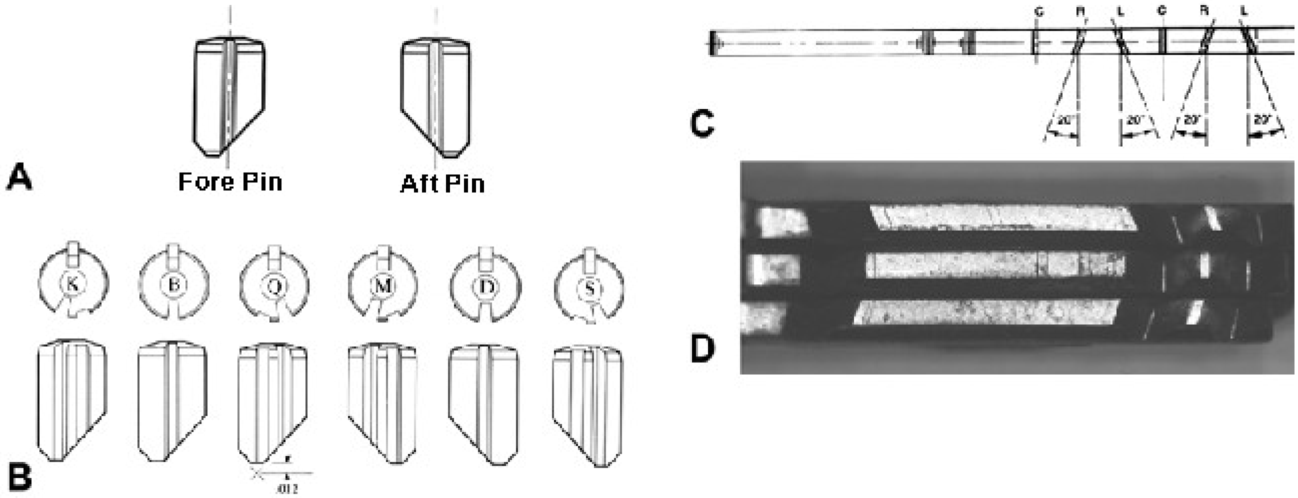




17_6.1.3.3   Biaxial

In 1985, modifications of the original Spain pin tumbler configuration, referred to as the Biaxial was patented. This patent claimed an alteration of the original tumbler and key bitting design that affected the position where the chisel point of each lower tumbler came to rest on the key bitting surface. The photograph shows a comparison of conventional and Biaxial bittings. The red lines are referenced to the center of the root on the conventional key. It can be seen how all cuts on the Biaxial are either before or after centerline.





The new patent accomplished two primary functions: it kept the original patent alive for another seventeen years and it introduced a lock with complex keying abilities surpassing the original design.

Whereas the original chisel-points would rest in the root of each cut, the Biaxial was designed to cause each of the pins to rest at **different positions** along the bitting surface. This would allow for extremely complex master keying and a greater number of differs for a given keyway. The Biaxial pinning scheme incorporates three variables to increase the number of differs: depth of cut, rotation of tumbler, and position of tumbler-bitting interface. The Biaxial lock thus provides for six angles, taking into account rotation and tumbler position.

There are six possible depth cuts for Biaxial keys in .025” increments. Rotation of tumblers varies by 20^{o} from center (perpendicular to the blade of the key is considered as center). In addition, tumblers may be located **fore** (toward the bow of the key) or **aft** (toward the shoulder). Thus, the Biaxial provides for 36 different orientations for each bottom pin.

Biaxial pins and their chisel angles are identified by letter codes relating to whether the pin rotates left or right of center and whether the movement of the pin is based upon a fore or aft cut. The system can identify all six possible angles by single letter, extrapolated from **L** (left), **C** (center), or **R** right initial designation. The letter immediately before L, R, or C is used if the pin employs a "fore" cut; immediately after for an "aft" cut. Thus, K, B, and Q would indicate left, center, and

right "fore" cuts; M, D, and S, "aft" cuts.

The Biaxial bottom pin has a projection at the top called a locator tab that will limit pin rotation. There is also a vertical channel, cut into the side of each tumbler, which corresponds to the sidebar peg. The channels and tabs are correlated (K,B,Q,M,D,S) depending upon the coding of the tumbler so that rotation is always properly limited.

The slots or vertical channels have six positions, consistent with the orientation of the chisel points at the tip of the pin. Thus, channels are oriented to the left of, right of, or "on" the centerline of the pin. There may also be false channels cut around the pin for added pick-resistance. Top pins are made from brass or hardened steel, .135" in diameter, and are of varying lengths corresponding to the bottom pins. One or more mushroom tumblers will also be incorporated within each set of top pins.

17_6.1.3.4 Other Medeco Security Enhancements

All Medeco locks incorporate hardened steel rods for added security. In the case of the pin tumbler cylinder, Medeco uses four hardened steel rods, two hardened steel crescents, hardened steel top pins, and a hardened steel ball bearing.

Medeco maintains strict key-blank control. There are at least four widely available commercial keyways (00, 60, S1, S6). There are also many restricted keyways exclusively designed for the use of one customer. Keys for all Medeco locks must be duplicated on special key machines, such as manufactured by Silca and HPC. They cannot be copied on conventional cutters because of the required angled cuts.

17_6.1.3.5 Medeco Bilevel

Medeco has introduced their Biaxial design in the European market under the name of Bilevel. It appears to be essentially the same design, and provides for a second rotational axis upon which the chisel-pointed tumblers operate. It will be remembered that in the conventional Medeco design, tumblers can have a left, center, or right twist. In this design, there are in effect two angled cuts that are available, thus increasing the differs. There is also an offset tip pin (OTP) in the last position, also with a new tab slow location. The design has received a European patent (EP 0651846). Medeco claims there are 75,582,720 (453,496,320 with sectional keyway) differs in their six pin locks, and

4,199,040 (25,194,240 with sectional keyways) in the five pin mechanism. There are 75,000 master keying combinations with sectional keyways for the six pin lock, and 15,000 for the five pin model.

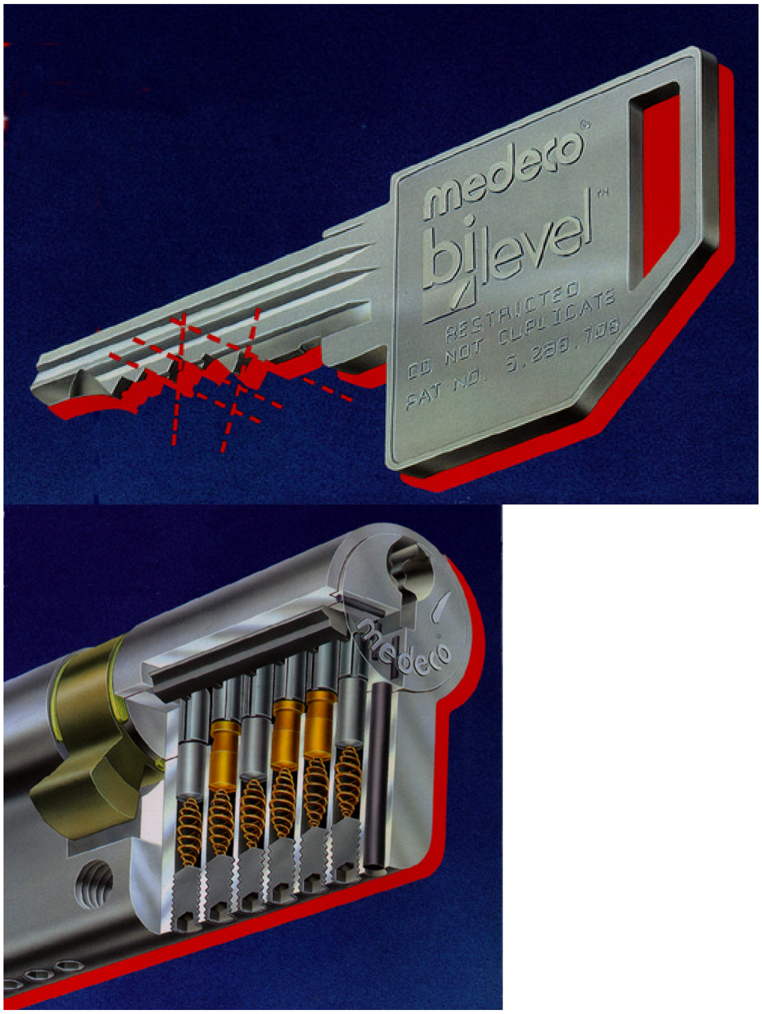
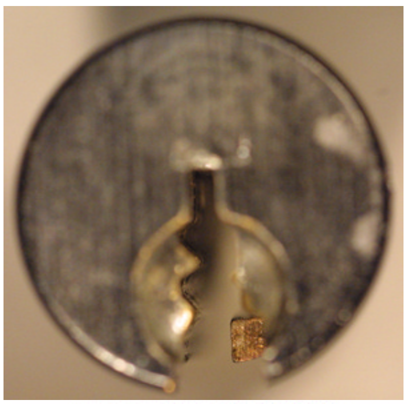


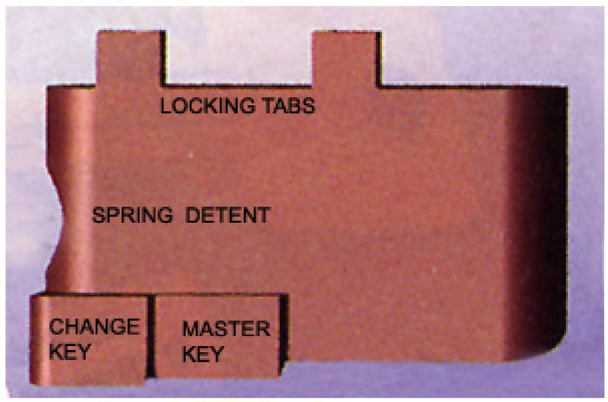
Figure LSS+1704 Medeco BiLevel key and internal sidebar design. Courtesy of Medeco.

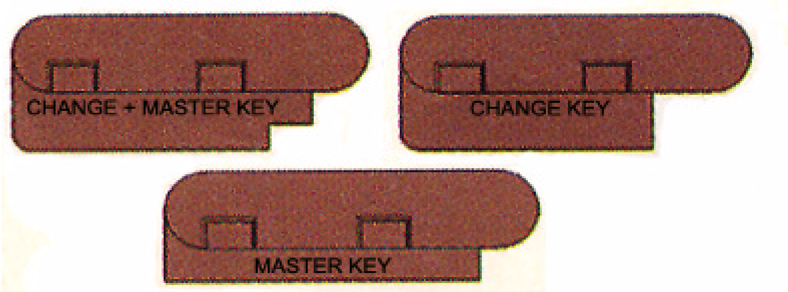
17_6.1.3.6 Medeco M3 System

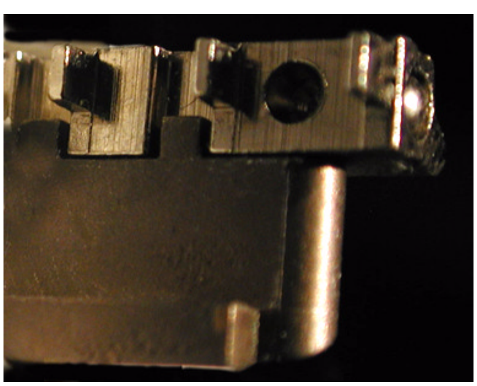
The Medeco M3 slider system (U.S. Patent 6,477,875) was introduced in 2003 and adds another level of security to the Biaxial design. See the discussion in Chapter 31, regarding its enhanced security and integration within a master key system. A slider has been added to provide for complex keying requirements and to extend the patent protection of the Biaxial. The lock has

all of the attributes of the Biaxial, but a sliding component has been added to mate with the sidebar. Locks can be configured to operate with change keys only, master keys only, or change and master keys. The design can prevent the alteration of change keys for use on cylinders designated for master keys only. Likewise, locks that are set for change keys only cannot be operated by any master key. Cylinders can also be defined for either change key or master key. This coding is accomplished by two levels of steps or protrusions within the design of the keyway. There are six slider variations for each level, and a total of 27 permutations of slider step positions. The slider makes contact with the side millings on the key as it enters the keyway.









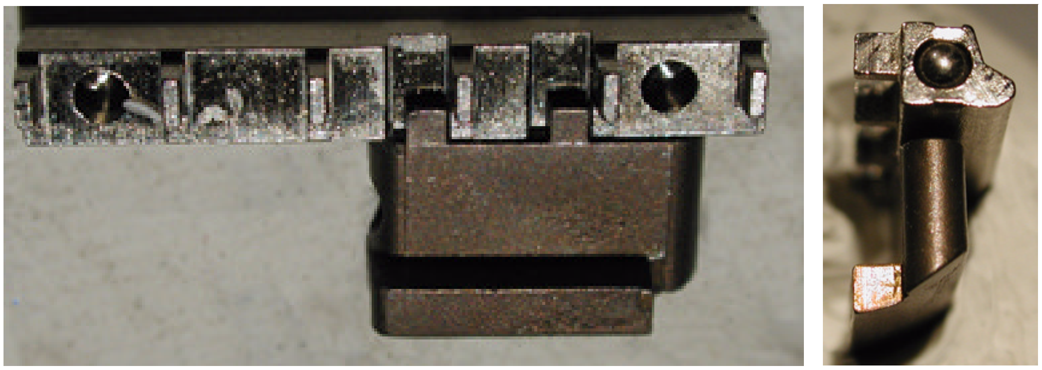


Figure LSS+1706 shows the critical component of the M3 system. The slider is actuated by side milling protrusions, as shown. There are a total of 27 sliders available. The steps on the slider correspond with the side milling on the key, which cause the slider to be moved in the proper position so that its two tabs precisely mate with the gates in the sidebar. Shown in the photographs (top left) is the face (step) of the slider that makes contact with the key in the keyway; (top center) a slider with both steps; and (top right) the three different slider combinations. If the slider is not moved to the correct position, then the sidebar is prevented from retracting into the plug. The bottom photographs show how the slider tabs mesh with the gates in the sidebar. It can be seen that if the slider is not moved into the correct position, the sidebar is blocked. In these photographs, the plug is oriented so that the keyway is on the right. The slider is spring biased toward the face of the lock. The photograph (bottom right) shows the slider properly aligned with the sidebar gates, as it would appear within the plug. The side millings on the key would make contact with the front step of the slider.

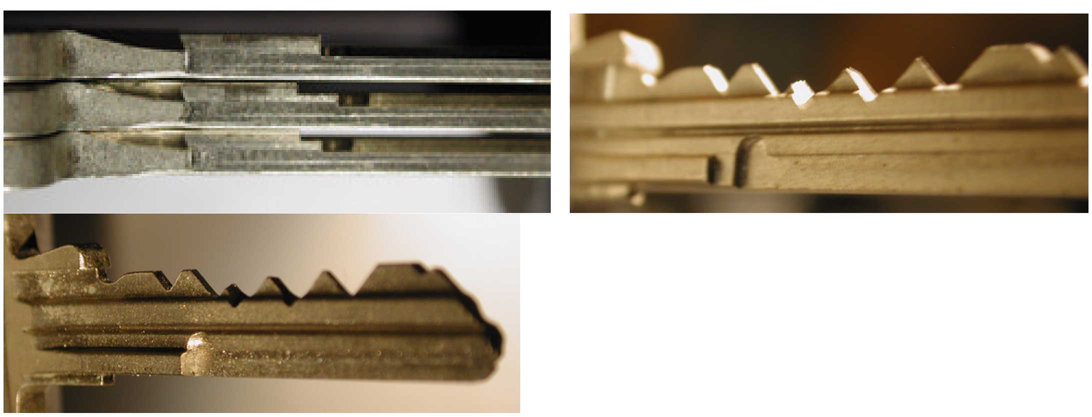
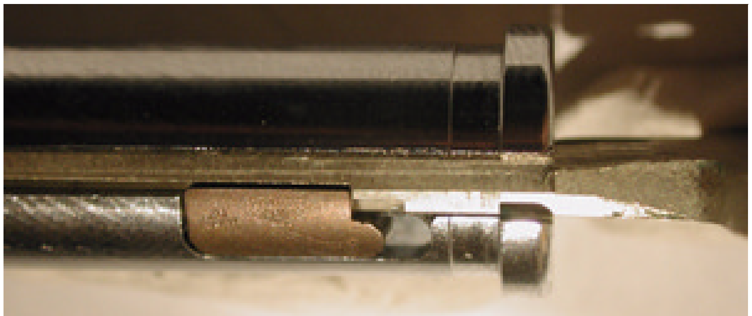
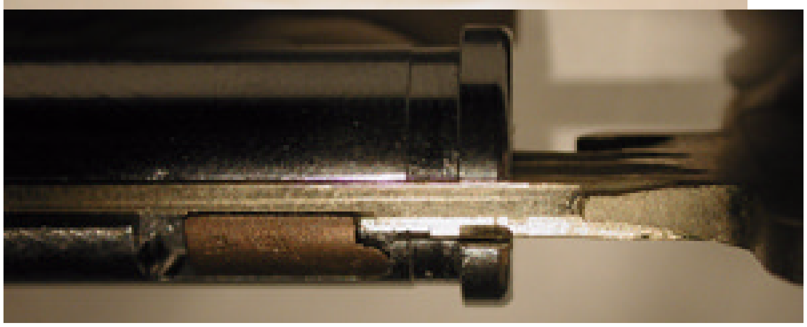
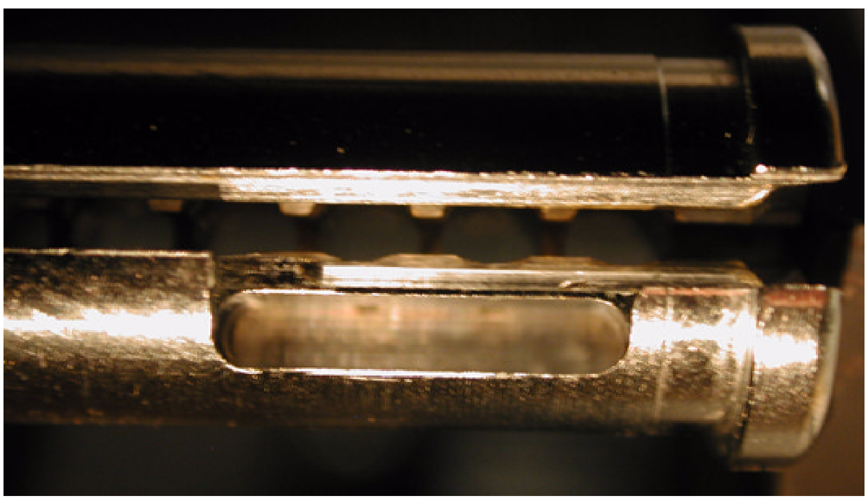


Figure LSS+1707 shows a comparison of the side millings for three different keys. The top key (left photograph) is a master key, the two other keys are change only. Note that the first side milling toward the shoulder is for the master key step on the slider. The center photograph shows a change key side milling, and the right photograph shows a master key milling.







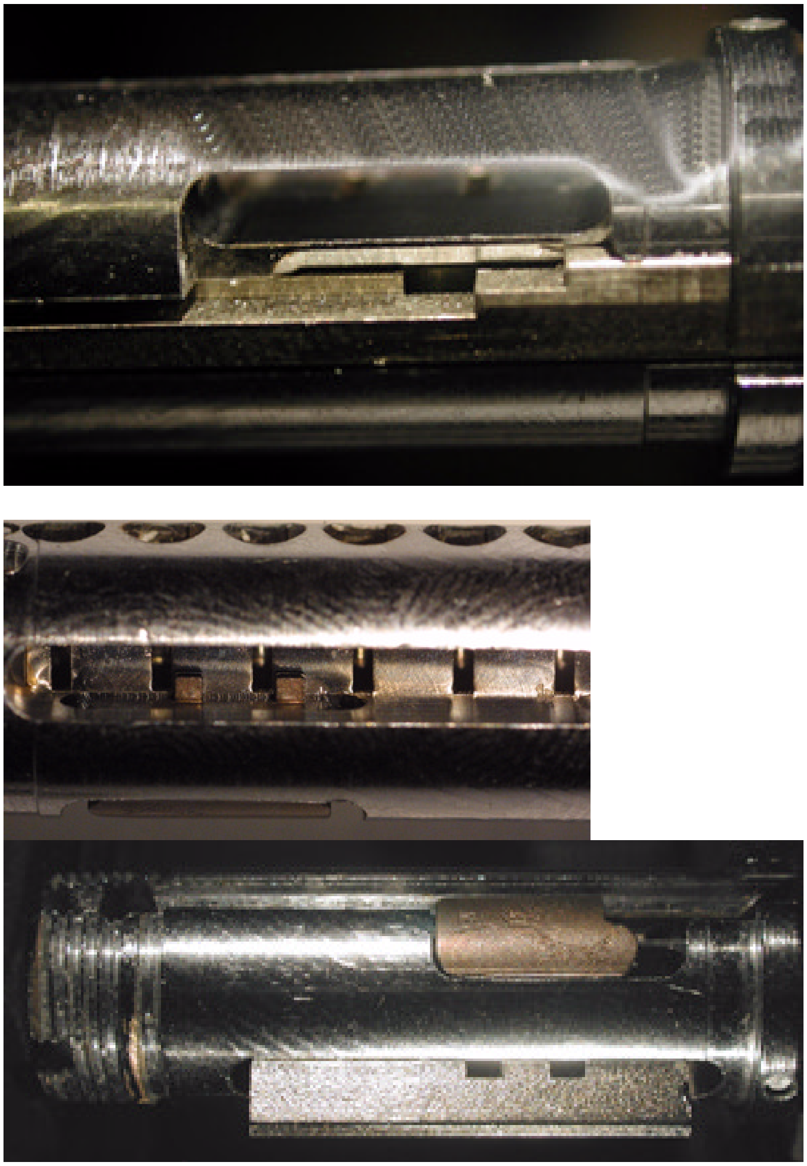


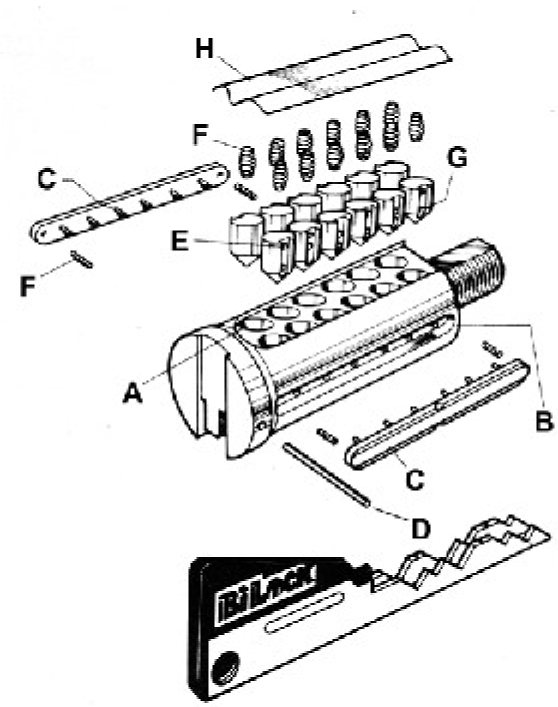
Figure LSS+1708 shows the plug, slider, and sidebar. In the photographs (top) the action of the key upon the slider step is shown. As the key is inserted into the keyway, the slider is forced backwards until its tabs align with the gates in the sidebar. In the photographs (center) the plug is shown without the slider inserted. It can be seen that the front step of the slider is designed to make contact with the side millings on the key, as shown (right center). The photograph (bottom left) shows the slider tabs protruding into the area where the sidebar resides. The photograph (bottom right) shows the sidebar partially inserted into the plug and how its gates integrates with the slider. The gates must mate with the sidebar tabs in order for the sidebar to retract.

17_6.1.4 BiLock Pin Tumbler Sidebar Lock



Figure LSS+1703 A BiLock key is distinctive in its dual bitting configuration.

The BiLock was first patented in Australia and has been available in that country since 1981. Its inventor designed both an eight and twelve-pin tumbler lock with dual sidebars that resembles both the Briggs and Stratton and Medeco mechanisms in certain respects.



Exploded view.

The plug contains two parallel rows, each with six (or four) pin chambers, and slots for sidebars at the 9 O'clock and 3 O'clock position. Each of the rows of pins act independently of each other. A "U" shaped keyway allows the insertion of a uniquely shaped dual-bladed key. Keyways can be altered with the introduction of a special profile pin through the center.

Much like the Medeco cam lock, there is only one set of tumblers in each pin-stack: the shear line is created by the sidebar interacting with each pin. A hole is drilled in the side of each tumbler, vertically positioned to correspond with the depth-cut of the key. When raised to the proper height, a projecting pin from the sidebar will enter a corresponding recess. When all pins are aligned properly, the sidebar is allowed to retract into the plug. In the Medeco cam lock, the pins are raised and rotated; the BiLock only requires that the tumblers be raised to the proper height. All BiLock pins are of identical length.

17_6.1.5 Schlage Primus and Assa

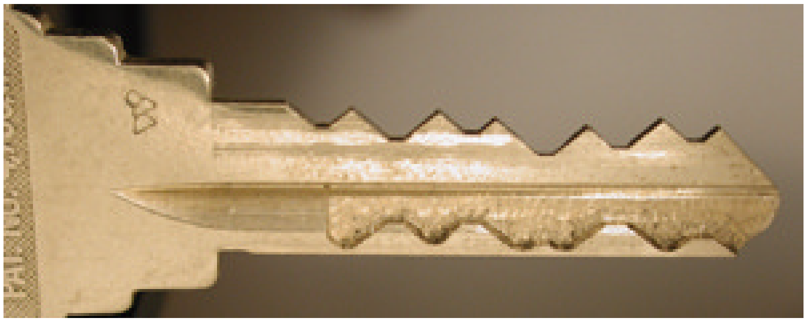
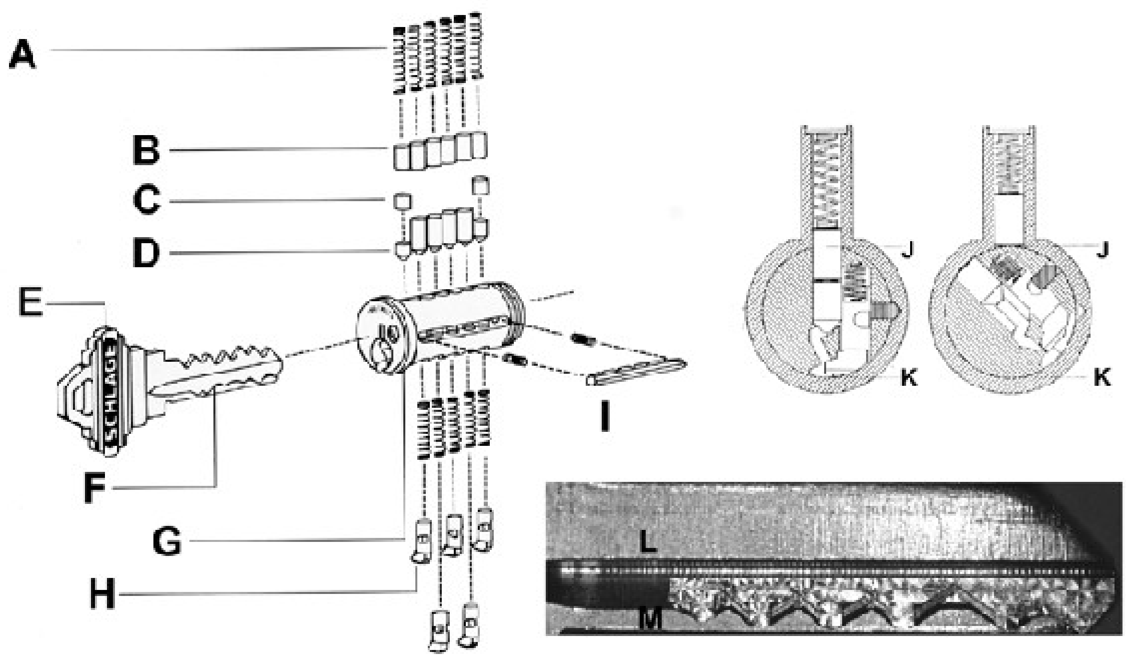


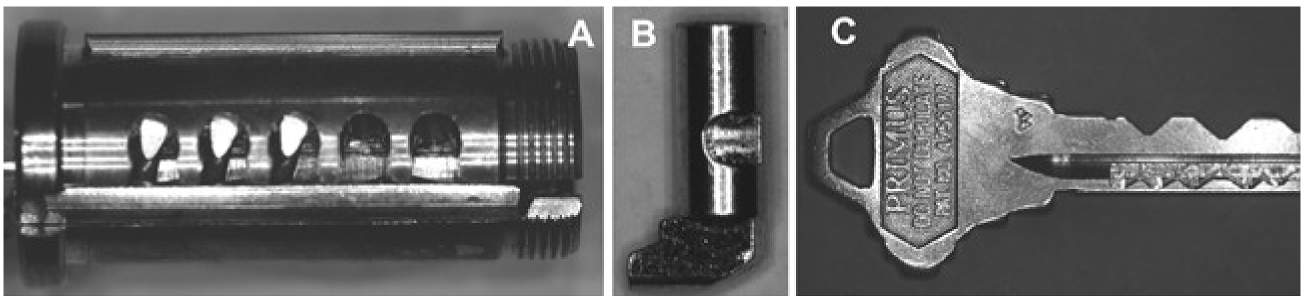
Figure LSS+1709 A schlage Primus key, showing sidebar millings with a code of 23624. There are three rotations and four actual depth increments that are available with Primus.

Schlage introduced the Primus series in 1989 as a high-security lock that could be easily integrated into conventional Schlage systems. The cylinder was primarily designed to facilitate key control, and it utilizes both conventional pin tumblers and a sidebar. Special **side bit milling (SBM)** is employed to control the "fingers" which determine the position of the sidebar.



The same inventor who conceived of the Assa mechanism, Bo Widen, designed the Schlage Primus lock. Assa has been in business in Sweden since the early 1800s. The **Assa 6000** series is the counterpart to the Schlage Primus.

The Primus is a pin tumbler lock with a second line of five finger-pins that allow the operation of a sidebar. These secondary tumblers are located to the side of the keyway and toward the bottom of the plug. The pins must be raised to their own shear line, thereby allowing the sidebar to retract. Millings into the keyway to various levels are produced at the factory. Thus, the locksmith must only cut the standard bitting with a precision key machine. The factory maintains close control of the secondary key differs. A unique pattern is assigned to each locksmith or distributor of the product, or to specific customers.



Primus keys will work with conventional Schlage plugs; however, the converse is not true. This allows high-security locks to be integrated within a conventional system without disruption. Conventional keys cannot be cut to fit Primus cylinders. In the view of the author, the Schlage Primus and the Assa lock offer excellent **key control**. They do not afford the level of security of other competing **high-security** locks, such as Medeco, Ikon, and EVVA, with respect to unauthorized key duplication and generation, or extrapolation of the TMK within a master key system. See **chapter 31**. Pick resistance, however, is excellent.

There are two versions of the Primus: the model 20-500 series which is UL 437 listed, and the unlisted model, 20-700 series. The listed version contains hardened anti-drill rods.

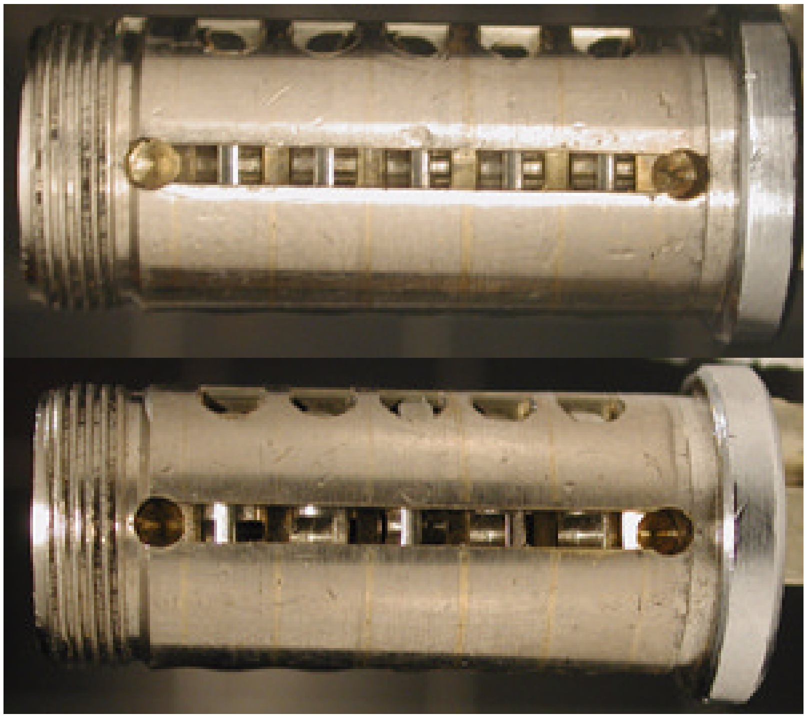


Figure LSS+1710 The sidebar has a vertical gate that must precisely align with the protrusions on each finger pin, as shown on the left. The pins on the right are not elevated and rotated to the correct position, preventing the sidebar from retracting into the plug.

A modification of the Primus concept was introduced by Schlage, based upon the Bo Widen patents (**4715717, 4756177, 4815307 and 5809816(187)**) in 1998. The key is unique in this system, having an undercut profile groove at one side surface and a corresponding profile tongue with a downward projecting end, which fills up the undercut portion of the key profile groove upon insertion into the keyway. See the discussion regarding the Everest cylinder in Chapters 6, 8, and 29.

17_6.1.5.1 Security of the Primus

The security of the Primus and Assa locks is premised upon the high-tolerance pin tumbler set, coupled with the second locking mechanism provided by the sidebar. Schlage and Assa chose a different approach to their sidebar designs than other manufacturers. They opted to split the action of the traditional pins and the sidebar to provide for a double independent locking system. Medeco, in contrast, linked the action of raising the conventional pin tumbler and its rotation in one mechanical

movement.

Schlage and Assa offer an excellent approach to key control, but security suffers for two fundamental reasons. The side millings for the sidebar pins can be duplicated on a precision-milling machine, and entire systems can potentially be compromised by obtaining the sidebar codes that are utilized within that geographic area or by the same locksmith.

17_6.1.5.1.1 Sidebar Codes

Generally, each locksmith or major distributor is given a unique sidebar combination for all locks delivered for resale. Although Assa and Schlage carefully monitor these codes to assure that no reuse occurs within a given geographic area, the problem of security is inherent in the overall scheme. Both Schlage and Assa has established five levels of security to control distribution of blank keys. The lowest level of security as defined by Schlage is Level One. This allows for Primus to be stocked locally, with standard side bit millings. Keys can also be generated at the local level. The highest level, Level Four, the factory maints control of all Primus key systems. SBM are assigned by one of two methods: either the side bit milling (SBM) will be assigned to a customer by time zone, or nationally. The end user or the factory can control keys and keying. If needed, all keys can be zero bitted and combinated locally.

Assa defined levels of security are:

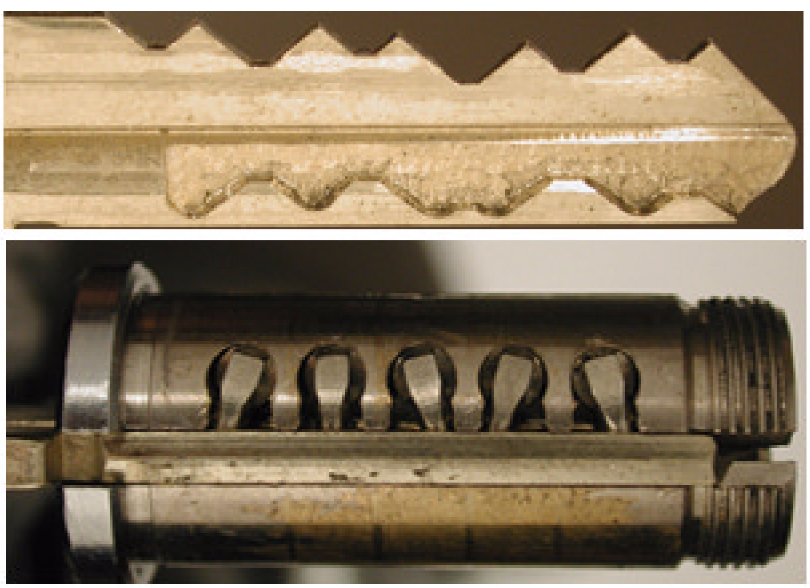
- **Gamma: Regionally shared, locksmith restricted, controlled and serviced;**
- **Beta: Statewide exclusive, locksmith restricted, controlled, and serviced;**
- **Delta: Nationally exclusive, distributor restricted and controlled. Serviced by distributor or locksmith;**
- **Alpha: Regional or national exclusive, end-user controlled and serviced;**
- **Factory: Controlled and serviced by Assa.**

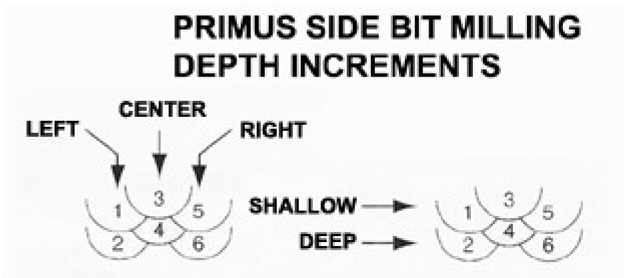
In Gamma and Delta levels, all customers of a given locksmith will have the same sidebar codes. The locksmith will be issued blank keys, all precut with identical sidebar millings. A customer could potentially order locks with specific codes, or keys could inadvertently be cut for one customer which could be

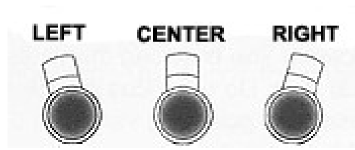
modified or re-cut to codes for a different customer. If the keyways are the same, then no increase in security has been attained using the sidebar insofar as unauthorized key duplication is concerned.

Primus utilizes five finger-pins with three different orientations (left, center, right).
As shown in the diagram, there are six defined depths, but only four actual variations.
The depths are denoted as 1,2,3,4,5,6. Left rotation is pointing toward the bow; right toward the tip of the key (from the bottom of the plug). The deep cuts are 2 (left) and 6 (right), shallow cuts 1 (left) and 5 (right), and center cuts 4 (deep) and 3 (shallow). All side bit millings must be read in reference to the **primary bittings** and their center points. Remember that for each angle, there are only two depths: deep and shallow. Bittings can be visually read with practice. Note also that center cuts are shallower than left or right cuts, and their depth is one half increment between equivalent left and right cuts.

There are restrictions as to the level of finger-pins that can be utilized with different depth cuts in the primary bitting of the key. The photograph shows the relationship between rotation angle and side millings. In this lock, the difference between left, center, and right angles are quite pronounced.







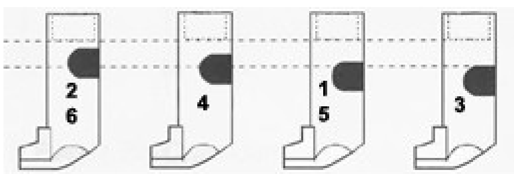


Figure LSS+1711 The code for the above key is 23624. There are a total of four actual depth increments, as shown in the representation of finger pins. Reading of the position of the finger pins is from their base.

17_6.1.5.1.2 Picking

Another security issue raised by the Assa and Primus approach involves resistance to picking and impressioning. A cursory analysis of these designs would lead one to believe that the locks are highly resistant to forms of surreptitious attack. This is true if one **only** considers penetration by an intruder walking up to the lock without prior intelligence gathering. Attempting to bypass the lock by picking or impressioning without added assistance in the form of precut keys having the same sidebar code and keyway will present significant difficulty.

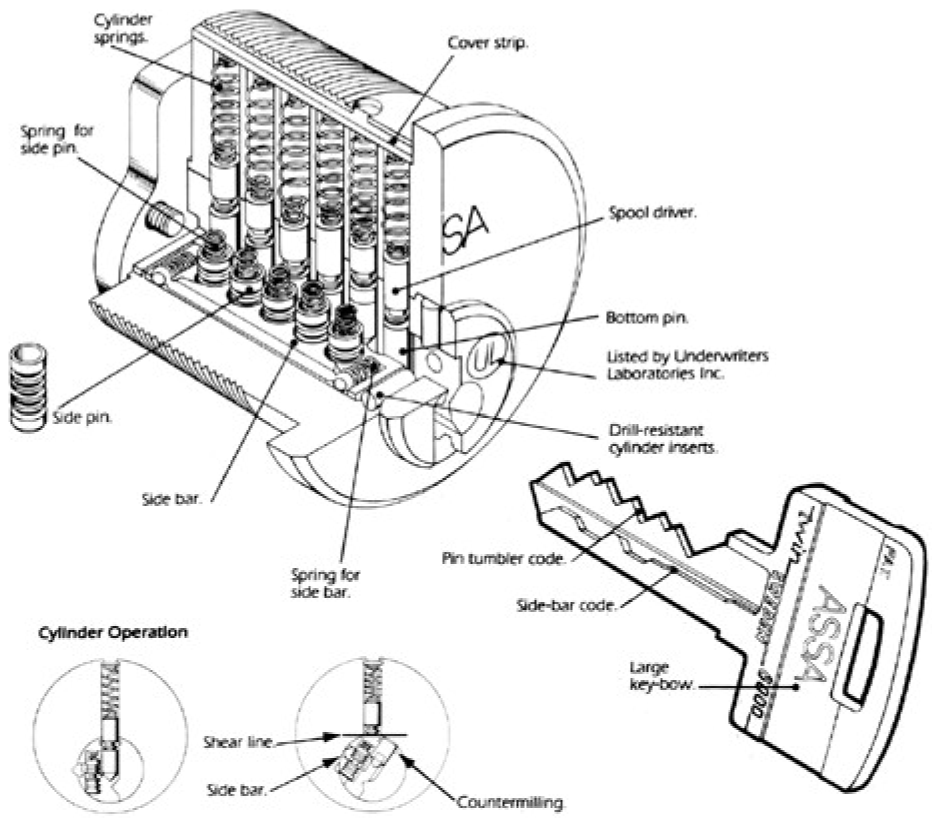
However, if one has obtained keys with the identical sidebar code and primary keyway in advance, then the lock can become substantially easier to pick or impression. The precut key is made into a torque wrench by cutting away the top bitting area. This will remove the sidebar as a security device. Then, we are left with a standard high-tolerance pin tumbler lock.

The operation of both the Primus and Assa requires raising the conventional tumblers to shear line and the five finger-pins to align in order that the sidebar may retract. Each set of pins operates independently. The plug will only turn when both sets of pins are set properly.

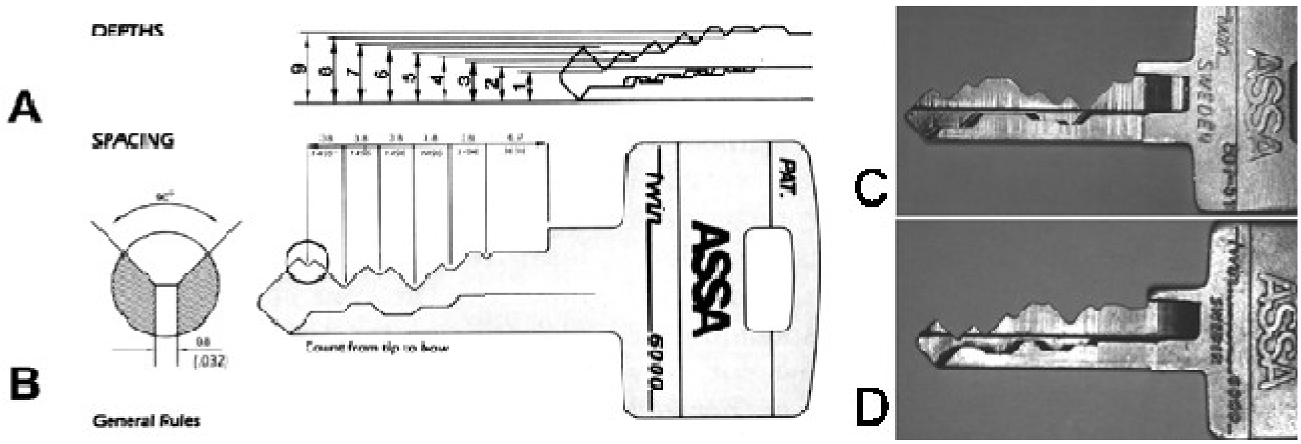
17_6.1.5.2   Assa Sidebar Design

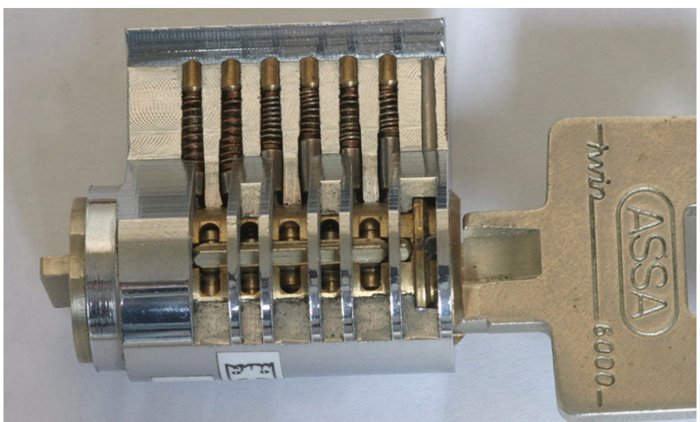


Assa has taken a different design approach to that of Primus. Whereas the contour of the Primus sidebar is uniform among all locks, the Assa sidebar **matches** a particular milling pattern on the key. All of the sidebar tumblers or fingers are identical in the Assa.



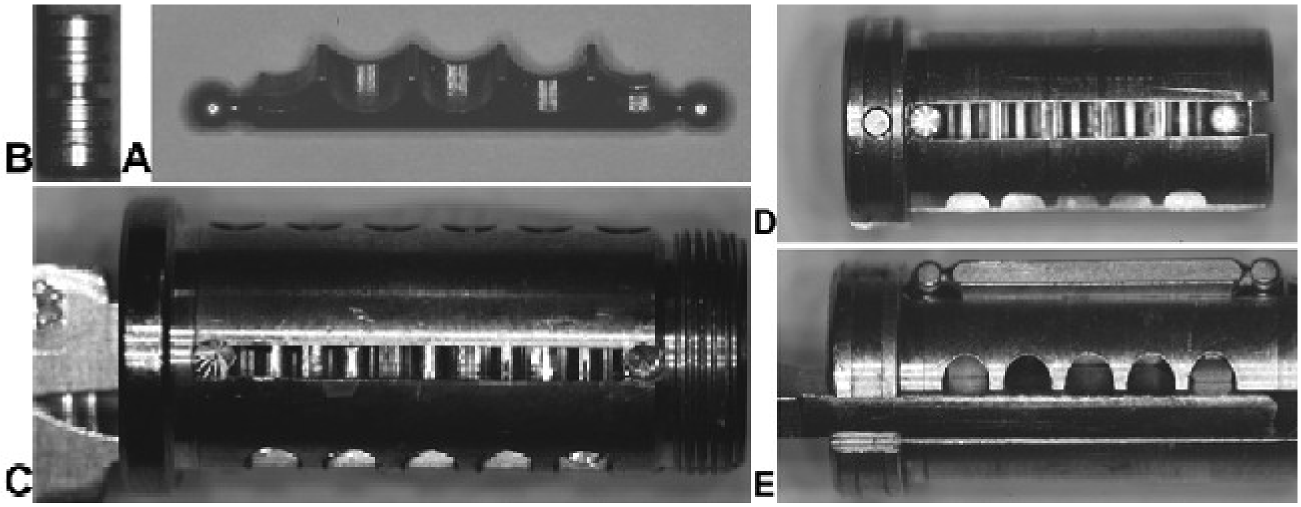
Schlage requires that the different finger-pins be raised to the proper level and rotated in order to allow the sidebar to clear. Assa mills a unique sidebar, with projections in different vertical positions to correspond with detents in the middle of the sidebar tumblers. Each tumbler is raised according to the millings on the side of the key, to align the detent with the sidebar projection. If the correct sidebar-milling pattern is present on the key, the tumblers will be raised to proper alignment. There is a detent or slot to receive each of the individual sidebar projections.



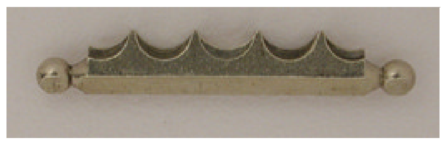




There are five side pins, each with five different depths, for a theoretical 3,125 combinations. Not all finger-pin positions are available for all depth cuts, and there are actually 1402 useable pins per sidebar side (the sidebar can be reversed within a cylinder for another 1402 codes). See the discussion in chapter 31 regarding the Assa V10 7000 cylinder utilized in high security master key systems.

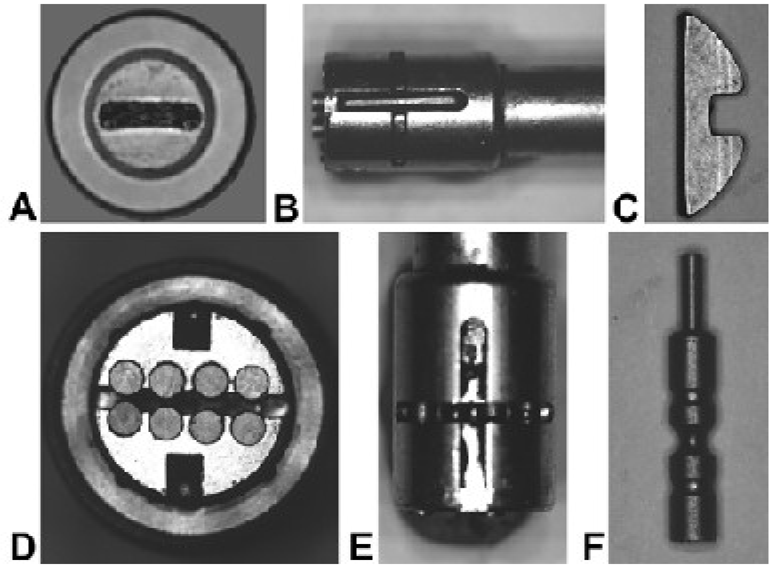






17_6.1.6 Chicago Tubar

The **Tubar**, manufactured by Chicago Lock, is a modified axial mechanism incorporating two sidebars. Utilized primarily on vending machines, it features eight pins (two rows of four) which must be aligned for the sidebars to retract. A notch in each of the tumblers provides a gate. An examination of the keyway, using an otoscope, will reveal grooves on the side of each pin. There are usually three false gates per pin. Four depth increments are available for each pin.



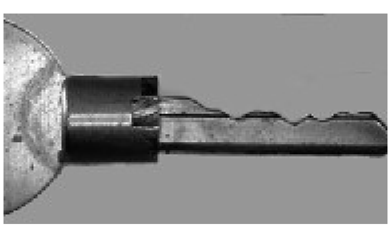
Exploded views 1, 2, 3.

17_6.1.7 Briggs and Stratton Sidebar

The Briggs and Stratton sidebar design was invented in 1935. It utilizes a wafer mechanism with a secondary locking sidebar. The lock is fully described in **Chapter 23**.

17_6.2 Storage Locker

The American Locker Company has produced a hybrid pin tumbler lock that has been extremely popular for use in storage containers during the past forty years. It combines a conventional pin tumbler mechanism with a seven-pin axial design. This combination offers high pick resistance and makes keys almost impossible to duplicate.



Section 7: High-Security

17_7.1 DOM IX Series

The DOM series IX is a dimple pin tumbler high-security lock that features a split key for dual control. The key has bittings on both lateral sides, so insertion may be in either vertical orientation. This lock is ideal for safe-deposit, vault, and other applications where two keys are required to be simultaneously inserted to actuate the bolt. A single key, which is simply a composite of the two halves, may also be utilized. This is a rather novel approach to dual-key control and warrants consideration in such applications.



Although the mechanism resembles other dimple locks in some respects, a number of sophisticated and unique features have been incorporated. The lock is essentially a nine-pin tumbler device; there are two rows of tumblers that interact with the lateral surface of the key. In addition, there are added side-pins for increased security.

The lock achieves extremely precise shear line tolerance by incorporating an oblong-shaped pin set. The tumblers are keyed so that they fit into the chambers with a precise orientation. This is required because each tumbler surface is cut at an angle, which equals the radius angle of the plug. The top surfaces of the lower pins (those making actual contact with the bitting of the key) are convex in shape, to follow the rotational curve of the plug. The bottom surface of each top pin is concave and matches exactly the corresponding convex lower pin. Lower pin tumblers are uniquely shaped, with angular ramps making contact with the bitting. The dimension of the ramp determines the depth of cut.

A floating steel ball bearing is pressed into the surface of the key in the last tumbler position toward the tip. This bearing

actually is free to move up or down, depending upon the way in which the key is inserted. The bearing will make picking extremely difficult. As the key is inserted, a protruding pin permanently pressed into the bottom side of the plug will force the bearing upward within the key. A corresponding small floating security pin in the tenth chamber is located precisely above the bearing that is lifted to shear line with the proper key. A special top pin with a pointed tip will enter this security pin chamber if the bearing is not present. The driver will block any rotation of the plug.

This technique for immobilizing the plug is extremely clever. In order to pick this lock, the security pin must always be raised above shear line. Normal picking procedures will not accomplish this. Several specially designed mushroom and spool tumblers are also utilized to further frustrate bypass.

CHAPTER EIGHTEEN: CONVENTIONAL DESIGNS

Electromechanical Locks

Master Exhibit Summary

EMHART
MAS-HAMILTON X-07

18_1.0 Introduction

Electromechanical locks incorporate electronic circuitry into traditional mechanical locking devices for enhanced security and access control. This chapter will examine some of the systems that utilize this hybrid technology. There have been many examples of locking devices operated by an integration of electronic and mechanical means. They are predominantly used in safes and vaults (4901545, **5061923(188)**, **4745784(189)**), access control applications (4866962, 4891636, **4868559(190)**, 5094093,

4684945, **4712398(191)**, 4766433), and in the lodging industry (4887445, 5020345, **GB 2174452A(192)**, **GB 2158870A(193)**, 4802353). See also (5092148), for a pry-proof computerized mechanical lock.

Within the past five years, many companies have introduced mechanical locks with integrated microprocessor logic. These combine the action of a conventional or hybrid locking mechanism with intelligence and memory provided by computer control. See Chapter 21 for a discussion of smart keys and locks.

18_1.1 Survey of Electromechanical Locks

Abloy, Medeco, LaGard, Sargent & Greenleaf, TrioVing, Ilco-Unican, DOM, Evva, Chubb, Union, and many other manufacturers have introduced electromechanical locking systems. Many vendors provide direct replacement of conventional locks with the more sophisticated systems. This practice is especially prevalent in the hotel industry and for safes.



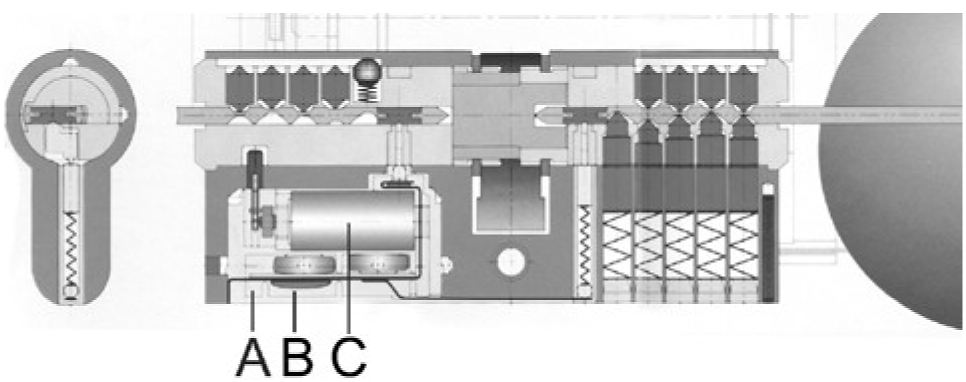
Several patents had been granted for locks that incorporated some form of electronics prior to the introduction of the X-07. All of these can be distinguished from the Mas-Hamilton design.

In 1988, Gartner (LaGard) patented a conventional combination lock with a means to sense when the correct combination was entered in order to release a solenoid (**4745784(194)**). Several other related inventions disclosed similar prior art sensing technology (3968667, 3758734, 3702070, and 4038846). Bacon, in 1990, was granted a patent (4901545) for an electromechanical locking device completely contained within a doorknob. This invention integrated an access code device with a traditional cylinder. When the correct sequence of numbers is input, a solenoid would release a locking pin, allowing the conventional mechanism to actuate the bolt.

Other similar electronic systems have been integrated into conventional locking devices, by Ben-Asher in 1990 (5094093), Clarkson in 1987 (**4712398(195)**), by Pinnow in 1989 (**4868559(196)**), and Rieker in 1990 (4891636). The Rieker invention (4891636) described an electronic keylock system comprised of a key with a precision resistance and a receiver for decoding the key. An analog-to-digital converter provided information for comparison with a programmable array logic to verify the insertion of the correct key. This system was designed for use on point-of-sale terminals and other commercial applications.

In 1989, Pinnow received a patent (**4868559(197)**) for a security system which employed an optical key-shaped reader to photoelectrically derive an electrical signal from a shape characteristic of a key. The system provided heightened security over standard key- operated devices and was designed for use in automobiles. The technique can offer higher security than the VATS resistor pellet sensing system used by vehicle manufacturers. See **Chapter 23** for a discussion of the VATS system.

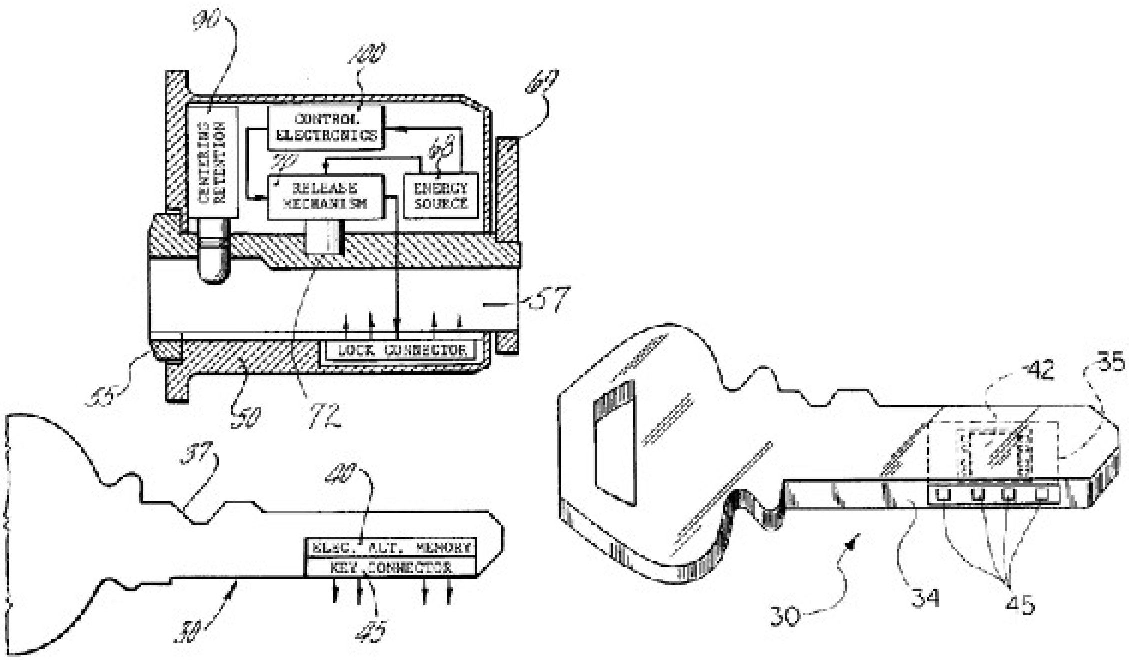
Yale Security Products patented an electronic keylock in 1989 (4866962) that provided for a mechanically actuated reading device. Two separate reading elements within the lock could determine key coding based upon grooves or notches in the blade of the bitting surface.



18_1.2 Emhart Electronic Locking System

Clarkson patented an integrated locking system in 1987 (**4712398(198)**) that was comprised of a pin tumbler cylinder containing an EEPROM memory device for storing codes. A matching

programmable memory chip was contained within the bitting of the key. Upon insertion of the key and a verification of the codes, an electrically controlled release pin would allow the plug to rotate. This lock is somewhat different to those described in **Chapter 20**, relating to induced fields for the transfer of information from the key. The Clarkson device relied upon physical contact points on the bottom of the key for the exchange of information.



Exploded views 1, 2.

18_2.0 Access Control

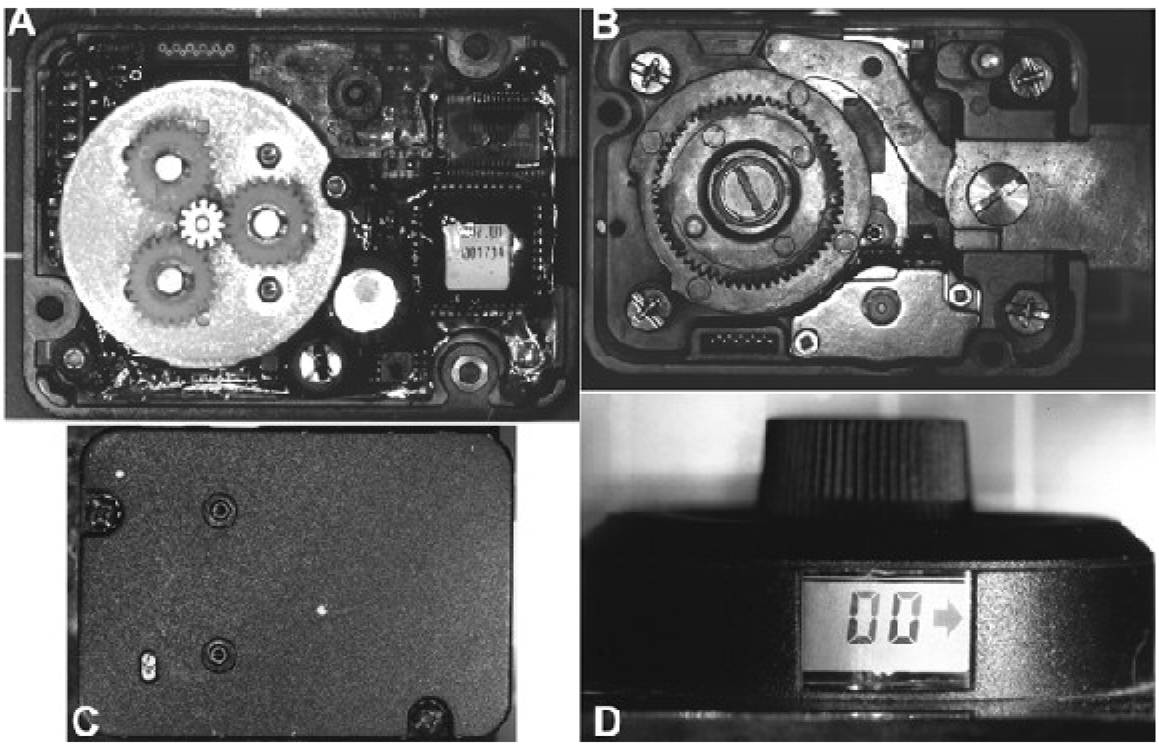
Many locks combine mechanical and electronic systems for use in access control. They are especially popular in hotels. Typically, these devices utilize keypads, magnetically coded cards, smart cards, and proximity sensors in combination with conventional cylinders or lock sets. The units can be self-contained battery operated or connected to a central computer system for enhanced audit and control functions.

Intelock Corporation (4802353), Ilco-Unican, and many other manufacturers produce an access control system for use in the lodging industry. These provide for sophisticated security and auditing functions and are essential due to issues of liability inherent in the hotel environment. The Ilco system, for example,

will provide detailed information regarding each time the lock is accessed. Automatic lockout can be accomplished so that access rights “expire” upon checkout date and time. The lock can be interrogated by security staff for a complete transaction summary. It can be reprogrammed upon demand or automatically by the next guest to insert a card having a different code.

18_3.0 Mas-Hamilton X-07 Electronic Combination Lock

The Mas Hamilton X-07 was the first self-powered fully computerized high-security electronic combination lock (**5061923(199)**) for a safe or vault. It was introduced in 1992 and was the result of intensive research and development by some of the foremost lock experts in the United States. The design integrates advanced electronic features with sophisticated mechanics to provide the highest level of security in a true 1,000,000 permutation keyless lock.



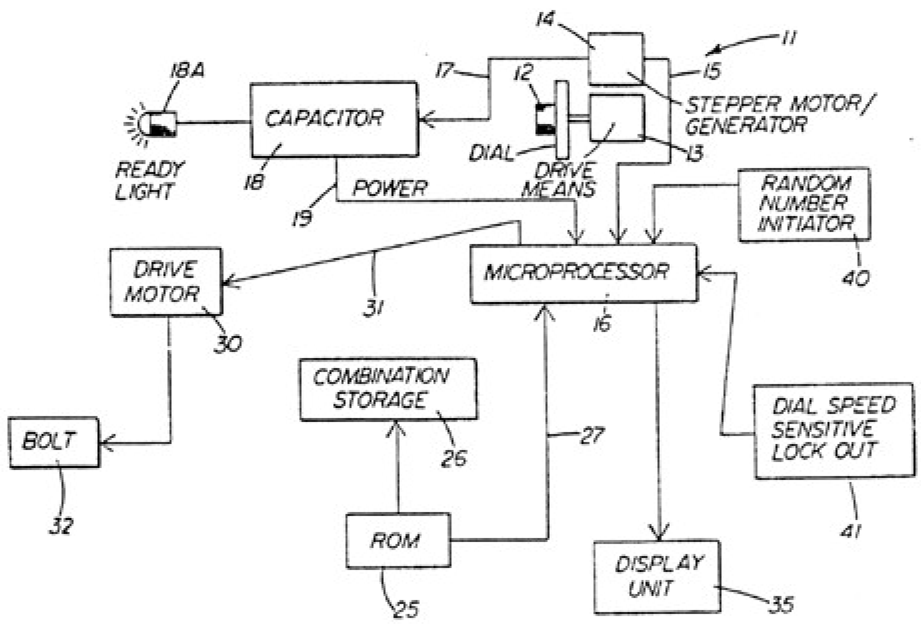
The stepper motor also provides input signals in the form of code sequences to a microprocessor. It processes the signals to initiate the operation of a drive motor to release a lock bolt once the proper combination has been entered. A read-only memory

(ROM) determines the correct combination and provides the data for a comparison with that entered by the user. As each dialing sequence is begun, a random code generator provides a different starting position in the sequence, so that surveillance techniques cannot be employed to derive the combination.

A speed-sensitive lockout device that also controls the microprocessor thwarts robot dialing. This effectively prevents any attempt at auto-manipulation. An on-board generator and stepper motor, actuated by the turning motion of the dial, powers the microprocessor, solenoid, and liquid crystal display. Energy is stored in super capacitors contained within the lock. The system can theoretically remain idle for many years without concern for the status of batteries found in other similar designs.

Once the dial is initially turned, the LCD will display the dial position and direction. To open the lock to the factory combination (50-25-50), the dial is rotated to the left, stopping at 50; then rotated to the right, stopping at 25; then again rotated to the left, stopping at 50. The dial is then turned to the right, until OP (open) is displayed, causing the bolt to be retracted. The lock is extremely user friendly. In contrast to conventional combination locks, the user need not be concerned about counting the number of turns between numbers.

The lock offers many sophisticated features, including audit trail, invalid attempt logging and lockout, dual control, supervisory control, and high-security against manipulation and surreptitious entry. The lock was the first to be accepted by the GSA for government security containers. See **Chapter 34** for a detailed discussion of security options incorporated within the X-07.



CHAPTER NINETEEN: MAGNETISM

Magnetic Locks

SHOWA
CORKEY
MIWA
EVVA
GIBRALTER

Master Exhibit Summary

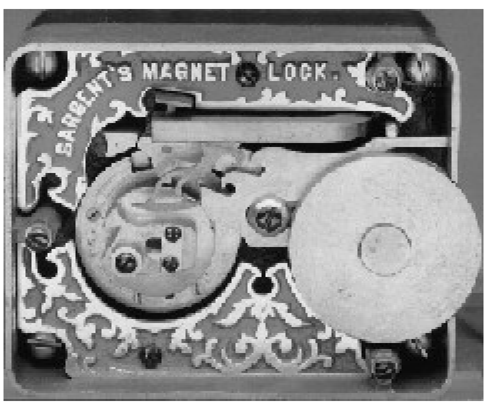
magnetic lock
Figure 19-12 Gibralter magnetic lock

19_1.1 Introduction

This chapter provides information about locks that employ magnetic fields for actuating, setting, rotating, or moving tumblers in order to create a shear line. Included are cylinder locks that replicate the action of conventional pin tumblers, and magnetic card locks that use barium ferrite or other materials to allow the placement of magnetic spots throughout the surface. In some cases, high-security, versatility, and reliability have been attained using magnetic pins, discs, and wafers. In others, manufacturers have represented levels of security that simply do not exist.

19_1.2 Magnetism and Locks

Lock manufacturers have relied upon many mechanical design approaches in utilizing magnetic fields to control internal mechanisms. The theory of magnetism, however, is relatively simple when applied to locks and their construction.



Essentially, all mechanical locks that utilize magnetics will function based upon two fundamental laws of physics: **opposite fields attract and like fields repel**. Every design will incorporate one or both of these principles. These basic concepts have spawned extremely clever designs.

19_1.3 Bypass of Magnetic Locks

The author has conducted forensic examinations, evaluated many magnetic locks throughout the world, and found that some devices

are extremely easy to compromise. Certain magnetic locks can be rapidly and surreptitiously decoded through a variety of techniques. For that reason, the author cautions the reader that many systems are simply access control devices that provide no significant measure of security.

In some cases, it has been possible to surreptitiously produce, duplicate, and decode change keys. In others, it was possible to decode locks and then derive and produce master keys for entire systems. The result was the total compromise of major commercial facilities. The problem with many magnetic locks is the ability to decode and compromise both individual and master key codes quickly, silently, and without taking the lock apart.

The author has developed extremely effective methods of surreptitiously reading magnetic key codes in seconds, from many locks, without fear of detection and without trace. This information can then be rapidly translated to produce keys for individual locks and for all locks in a system. Some magnetic locks, especially those used in the hotel industry, are particularly vulnerable to surreptitious bypass. Certain magnetic-based locks, particularly those manufactured by Chubb for use by the Home Secretary in the prison system in England, and the EVVA (Austrian) lock (also manufactured by Ikon of Germany and Ankerslot of Holland), are extremely secure. While others may **represent** high levels of security, they are, in the opinion of the author, merely access control devices offering very low protection against surreptitious attack.

19_1.3.1 Materials for Decoding Magnetic Locks

Several technologies can be utilized for decoding active locking components within a magnetic lock. These include:

- **Special films for observing the location of domains on BFV cards;**
- **Spray powder for viewing the position of magnetic spots and for reading magnetic stripes embedded within plastic cards;**
- **Recording medium for directly capturing and decoding the placement of magnetic pins within a lock, so that a key can be generated based upon such information;**
- **Gauss meter and Hall-effect probe, for sensing the position and polarity of magnetic fields;**

- **Field disturbance generators for reorienting magnetic pins;**
- **Probe and audio sensing for testing the polarity of each magnetic domains.**

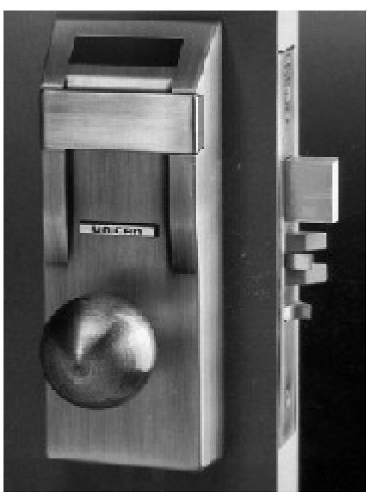
Chapter 31 provides additional information regarding decoding techniques.

19_1.4 Magnetic Card Locks

Magnetic card locks fall into two primary design categories and are based upon whether **physical position** (barium ferrite vinyl based cards) or the sensing of **data** (magnetic stripe cards) is utilized as the security technology.

19_1.4.1 Magnetic Stripes

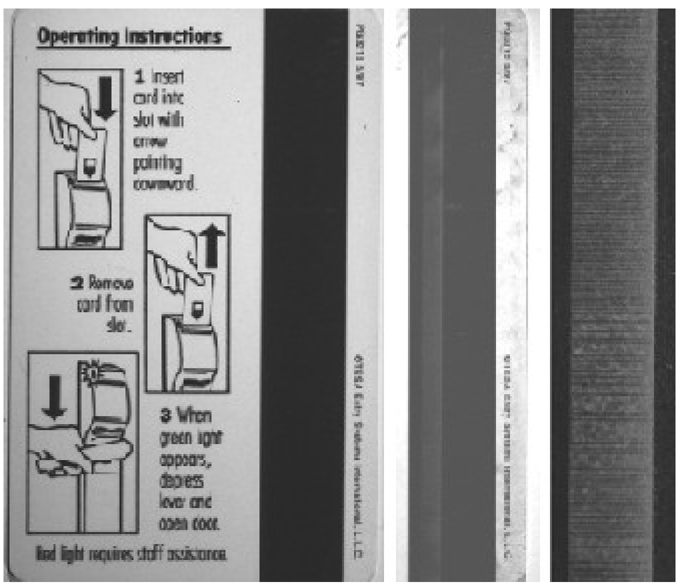
The first classification utilizes plastic cards with magnetic stripes that are used for the storage and transmission of information in the form of binary data. Magnetic stripe cards resemble credit cards. They have a strip of magnetic material embedded within the plastic that is equivalent to bonding a piece of audio recording tape to the surface. The stripes are electronically encoded with a number of binary data bits contained within tracks. While most credit cards have three separate tracks that hold different card holder information, cards encoded for locks generally have only one readable track.



The data, created by magnetic flux reversals, can be observed under the microscope as a series of very small parallel lines

having changes in spacing and polarity. Each line is a bit. As the card is moved across a read head, a coil detects changes in polarity. This creates a tiny voltage that is amplified, squared (turned into a square wave), and processed. The series (or stream) of bits combine to form bytes of information that can be read and compared to data stored within the non-volatile memory of the lock.

Some cards are encoded following the International Standards Organization (ISO) standards for magnetic information. Data may be placed on the cards in low or high-density formats. Other lock companies have developed their own secure, encrypted formats that may be difficult to compromise.



Card encoders/decoders that will read both low and high-density formats for all three tracks are available commercially or can be easily constructed. One industry leader in the production of readers is **American Magnetics** in Los Angeles, California.

19_1.4.2 Barium Ferrite Vinyl Cards

BFV is a relatively hard material in comparison with soft ferrite that is used as antenna cores or forms and easily magnetized. Barium ferrite cards have magnetized spots or **domains** located in various positions across the surface. They will coincide with the location of magnetic pins within a lock. Generally, all magnetic card locks that employ floating pins utilize this technology.

BFV is a material that is capable of being magnetized and retaining the information over long periods of time. Barium carbonate and iron oxide are mixed to produce the magnetic medium. The material must have a high **coercivity.** This means the ability to resist attempts to change or demagnify unless high Orsted levels are attained (up to 9,000). It is important that average strength magnets will have no effect on data encoded on BFV cards.

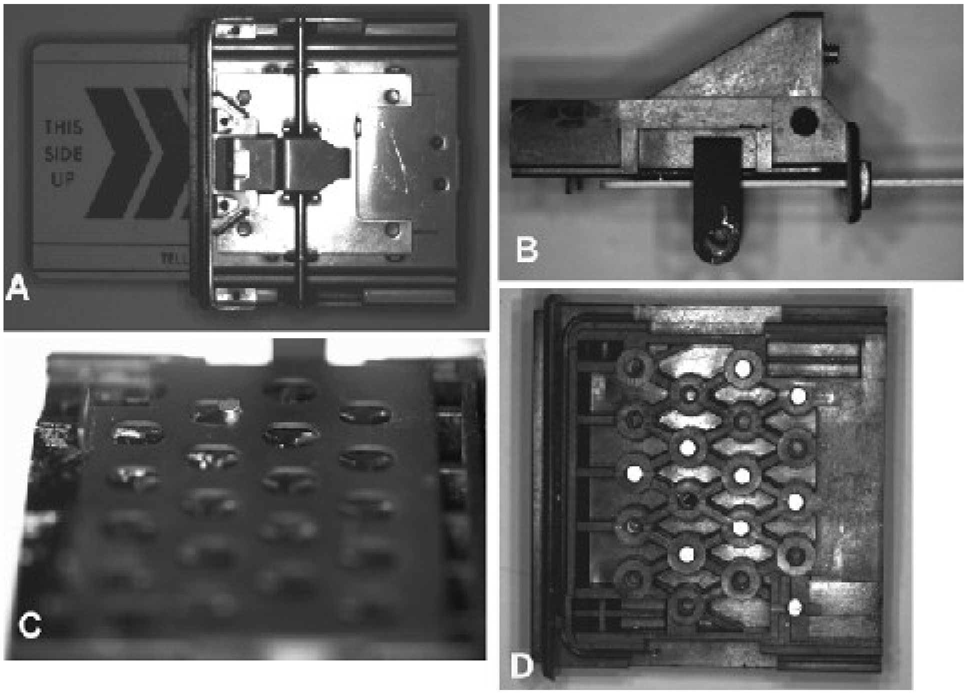
Characteristics of BFV material have significantly changed during the last twenty years. 3M Magnetic Products has done a great deal of research and development with flexible magnetic materials including BFV. When they began examining the technology, they found that rubber-based materials were common, with a magnetic sensitivity of about ½ gauss.

A BFV-based lock requires that the magnetic card material have fields of sufficient strength to be capable of repelling internal magnetic pins so that they can be moved above the shear line.

All BFV-based cards can be decoded using a variety of techniques. The result is the ability to easily decode the information contained on the card as to the number of magnetic positions and their polarity. Once that data is known, virtually any locking system using this technology can be compromised.

19_1.5 Showa Magnetic Card Lock

Showa Lock Company (Japan) produces a card lock similar in principle to the Corkey system (Hong Kong) and Schulte-Schlagbaum(Germany) but with several distinct differences. The Showa system creates a shear line as in a conventional pin tumbler lock, with free-floating magnetic pins. These are allowed to vertically travel between a moveable platen and the body of the lock.

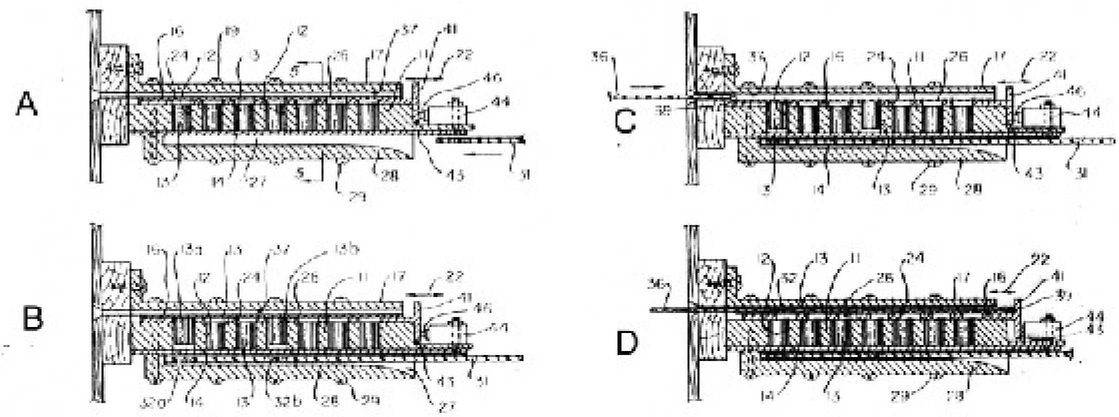


An encoded barium ferrite card is inserted into the platen, with magnetized domains placed to correspond to the pins. The proper card will cause all pins to be repelled or lifted upwards, so that the platen is free to move. As with the Corkey system, the security of this lock rests in the number of pins, their location, and individual polarity.

This lock can be easily compromised due to its construction, number of pins, strength of the magnetic field required in the barium ferrite card, and spacing between pins.

19_1.6 Corkey and Schulte-Schlagbaum Lock

Corkey (Hong Kong) and Schulte-Schlagbaum (Germany) produce a series of patented magnetic card locks for the hotel industry that can be easily programmed in the field (**3611763(200)**, **3834197(201)**, **4133194(202)**, **4676083(203)**, and German patent 0-276-444-A1). Corkey has developed a system based upon the random placement of small cylindrical magnets in any of 45 chambers, within each lock.



These free-floating pins perform the same function as conventional pin tumblers. The magnetic field of corresponding magnetized domains on a removable barium ferrite card, rather than the bitting of a key, control the movement of pins.

As with the Showa devices, this lock contains a sliding card platen. It is linked to the strike mechanism within the door and cannot be moved to a locked or unlocked position unless all magnetic pins are raised above shear line. The shear line physically separates the platen from the body of the lock. When the correct magnetic card is inserted, the pins are repulsed and forced upward so that the platen is free to move. Corkey has incorporated certain anti-decoding features to frustrate compromise. However, these measures are not totally effective. The security of the Corkey system relies upon knowing how many magnetic pins are contained within any given lock, their position, and the polarity of each.

19_1.7 Magnetic Pin Tumbler Locks

Several manufacturers produce cylinder locks utilizing moveable rotating or sliding magnetic pins. Some designs emulate traditional pin tumbler mechanisms, while others combine sidebar technology for high-security. In all cases, magnets are attracted or repelled in order to control the rotation of a plug.

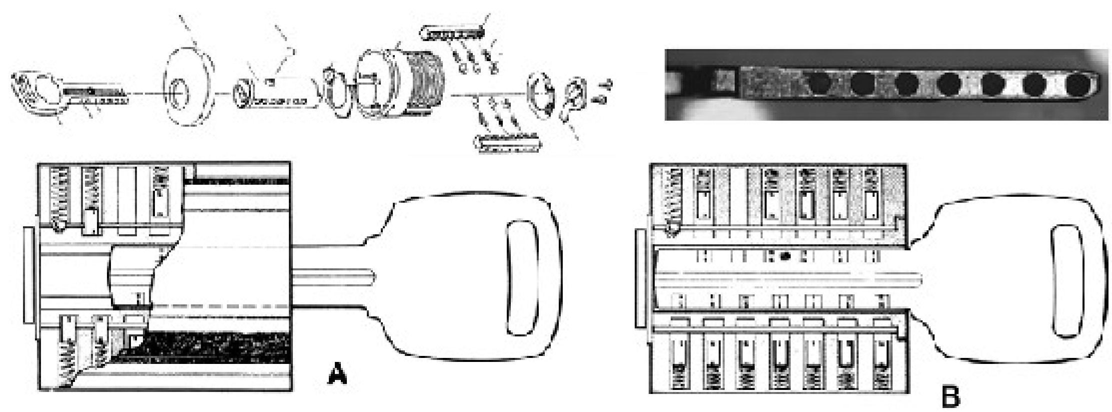
19_1.7.1 Miwa and Ankerslot (Netherlands)

The Miwa Lock Company (Japan) and Ankerslot (Netherlands) manufacture two primary series of magnetically based locks. Although they are not well known or recognized in the United

States, the company has been in business since 1935 and is one of the largest lock manufacturers in Japan.

19_1.7.1.1 Series EC

The **Miwa EC** is a magnetic cylinder that can be bypassed with limited technical ability and technology. The security of this lock as well as the Corkey, Showa, and others, is based upon two criteria: **the polarity and location of each magnetic pin or spot.** In the Miwa EC and to a lesser extent in the Corkey, if one knows these two pieces of information, the lock can be decoded and opened.



19_1.7.1.1.1 The Key

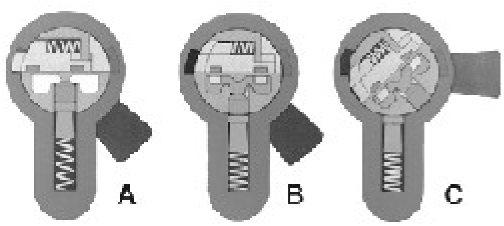
There are seven magnetic pins impressed on each side of the blade where the bitting would normally appear in a conventional key. They will interact with corresponding magnetic tumblers within the lock. There is a lateral channel and corresponding ridge running along both sides of the key to simulate a keyway. The key is not reversible and can only be inserted in one orientation. There is also a dimple on one side of the key as part of the keyway configuration. The dimple mates with an internal ball bearing that retains the key within the keyway once the plug is rotated. The position of this bearing can be altered during manufacture to create different keyway series.

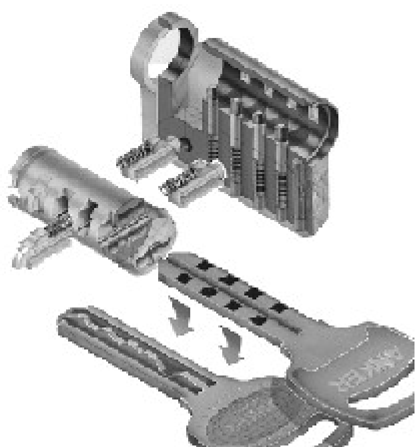
Although there are fourteen chambers within the lock, only seven of these positions are usually filled. A magnetic tumbler with either polarity may be utilized in any position. Corresponding magnets are placed in holes in the blank key. The unused holes are filled with neutral pins so that the position of magnets

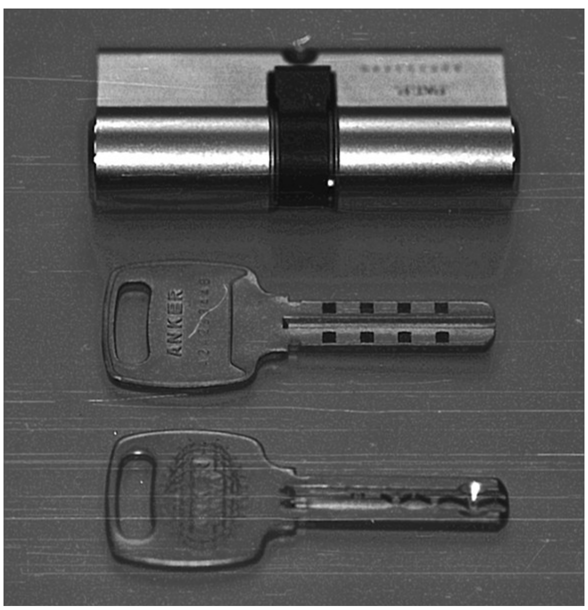
cannot be readily determined. Keys are assembled by the locksmith by placing magnets in the proper pin locations and blank pins in the remaining holes. The key is then crimped to retain all inserts.

19_1.7.1.2 Miwa High-Security Lock (3800)

The Miwa high-security lock (also manufactured by Ankerslot, Holland) is the competing product with the EVVA and Chubb magnetic designs. It operates on a slightly different principle than does their EC series, although it still relies upon attraction and repulsion between magnets within the key and the tumblers within the lock.





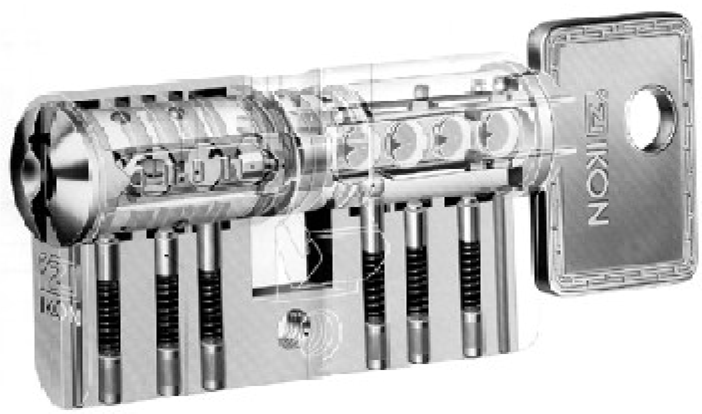


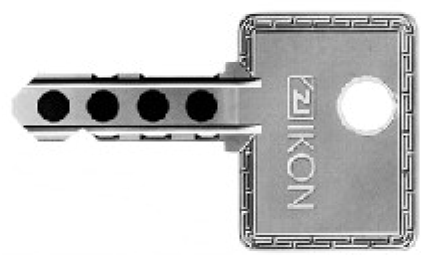
The 3800 is more complex than the EC in its operation. There are eight magnets placed in two rows of four on each side of the key. These inset magnets are magnetized in quadrants, so only a portion of the magnet acts in concert with the four pairs of sliding magnetic tumblers. The action of the field is a great deal more precise than encountered with the EC version. Four conventional pin tumblers ride in the center channel of the reverse side of the key for added security. Thus, the inner cylinder is double locked: vertically with pin tumblers and horizontally with sliding magnets.

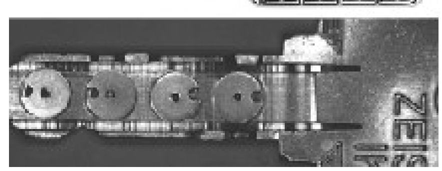
19_1.7.2 Evva Magnetic Code System (MCS)

Evva (Austria) and Ikon (Germany) make a high-security dual-sidebar magnetic lock incorporating eight rotating discs that is essentially pickproof. Evva uses rare earth Samarium Cobalt (SmCo) magnets that have a high coercivity requiring over 6,000 gauss to reorient their domains. A Swiss company owns the process that is used to produce the material, known as UGIMAG.

The Evva MCS lock features three independent locking systems, presenting an extremely high resistance to surreptitious attack. The mechanism offers 2.9 times 10^{26} differs, making it ideal for large installations requiring complex master keying.



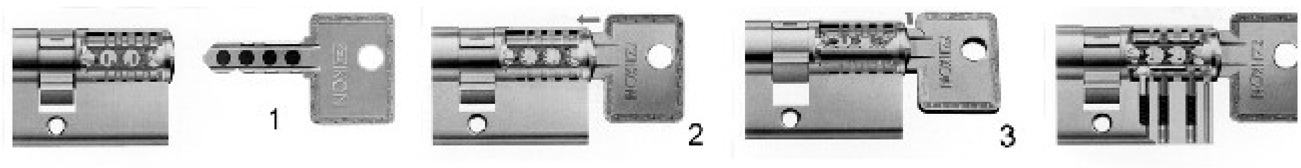




There are eight rotating magnetic discs within the plug- four on each side of the keyway. They correspond with magnets embedded into the bitting surface of the key. This will allow eight different field orientations per magnet, or 8^8 permutations. There are also side-wards in the keyway that provide another 768 permutations.

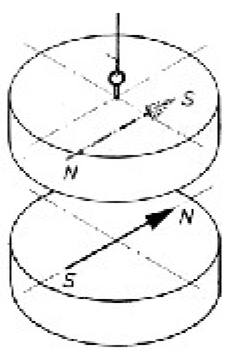
Evva and Ikon use a process that allows them to magnetize each of

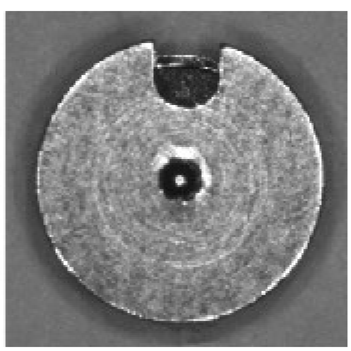
the discs with eight distinct orientations, much like a piece of pie sliced into eight sections. Thus, each magnet is polarity-coded at a different rotational position in 45º increments.



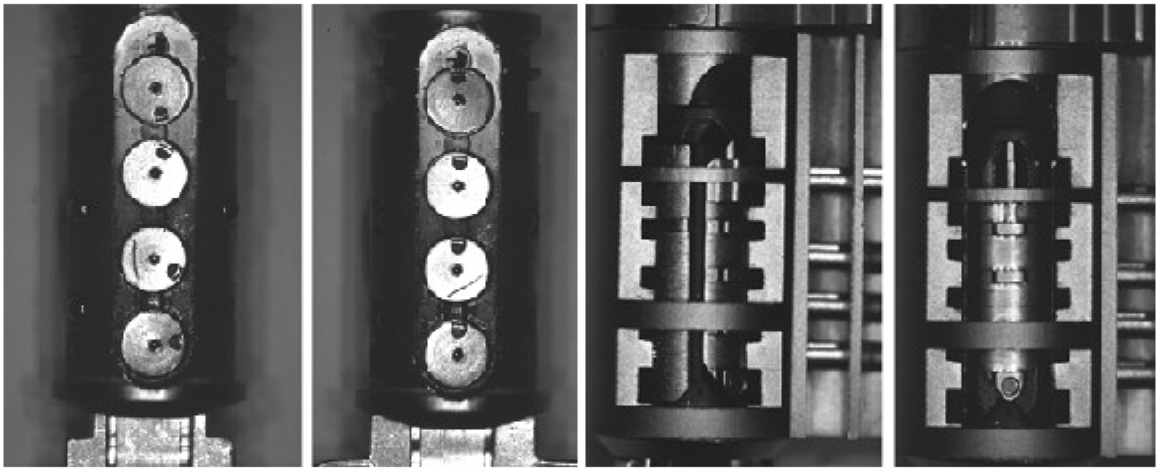
Extremely precise rotation can be achieved to allow for very close tolerances between each fence and gate. The magnetic discs can only be moved to their correct gate positions upon insertion of the proper key.

The rotors contained within the plug resemble individual wheels in a combination lock wheel- pack. Each of these discs has a gate that must be aligned with a fence in order that sliding sidebars may retract. The corresponding magnets embedded within the key cause each rotor to spin to the proper position, based upon the attraction and repulsion of fields.



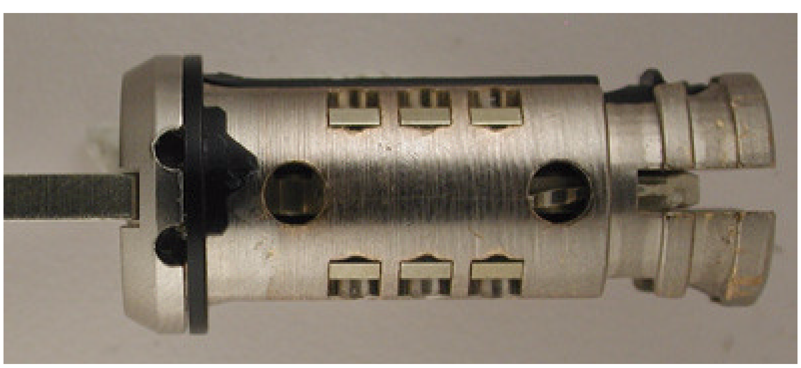


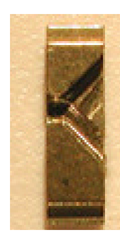
Sidebars on each side of the plug can retract only if all of the gates are properly aligned on the rotors. When the key is withdrawn, the magnets are moved to random positions to prevent decoding. For added security, a secondary ball bearing locking system must also be activated by indentations on the edges of the key.

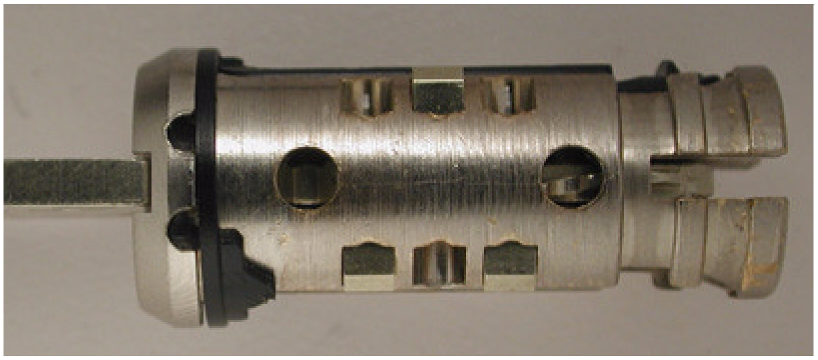


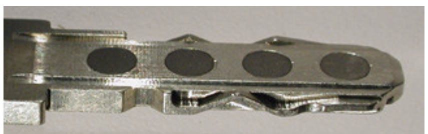
Exploded view of magnetic disk orientation.

The Evva and Ikon design, in the view of the author, is a great deal more sophisticated than many other magnetic devices. This is because of the rotating gate concept and the precise magnetic fields required to properly orient the discs. Decoding of the lock will not provide any information as to the relative positions of each gate. Evva has implemented a revision to their original design, and incorporates three separate locking systems to secure the plug. In addition to two sidebars, there are seven sliders (three on top and four on the bottom of the plug) that are controled by variable ridges at the top and bottom of the key that interact with sliders, as shown. Two additional pins at the top front and rear of the plug prevent rotation until lifted and depressed by the key. In the photograph (top left) a key is inserted with the proper combination for the three top sliders. In the (top right) photograph, the sliders protrude from the plug, preventing rotation. The bottom photographs show the ridging on the top and bottom of the key that interacts with the sliders.





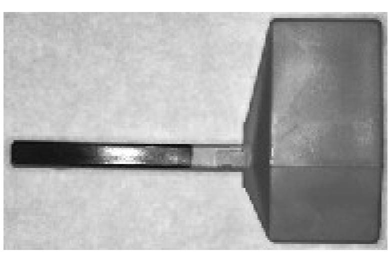






19_1.7.3 Gibralter Magnetic Lock

A lock was developed for use in the hotel industry that employed a magnetic stripe as a replacement for the conventional bitting surface of a key (**4616491(204)**). Information encoded on the stripe is read upon insertion, similar to that of a credit card. The system never attained a significant market penetration. It is, however, an interesting adaptation of magnetic stripe technology to simulate a conventional key.



19_1.7.4 Other Design Approaches

Inventors and manufacturers have tried many design approaches to exploit the magnetic properties of materials for use in locks. Chubb spent five years developing a magnetic- based locking system for the Home Secretary for use in prisons throughout England. It closely resembled the Evva and Ikon technology (GB **2151295A(205)**). DOM produced and patented (**5010750(206)**) a

mechanical lock that contained both conventional and magnetic tumblers. A coil mounted within the lock body senses an embedded magnetic code in the key. If the proper code is not present, the plug is prevented from turning. Bo Widen obtained a patent (**4507944(207)**) in 1985 for a cylinder lock that utilized pin tumblers, and a decoding system to read information in the form of regions of mutually different magnetic permeability. As the key moves in the lock, these regions cause variations in a magnetic flux that are decoded and evaluated.

Technology similar to that developed by Evva, involving rotating magnetic tumblers, was disclosed in British and American patents (GB **2214226A(208)**, **3633393(209)**).

CHAPTER TWENTY: WIRELESS

Wireless Exchange of Coded Information

Master Exhibit Summary

20_1.1 Wireless Technology

This chapter describes several relatively new wireless technologies that employ invisible infrared light beams, radio frequency energy (RF) and inductive fields to transmit coded information between keys and locks. **Infrared technology** (**IR**) relies upon the same basic scheme that is used in television, VCR remote controls, and alarm systems. The IR is utilized as a carrier to convey information passively between a key and electronic decoder.

Three infrared schemes are examined in this chapter. The VingCard utilizes a punched card that is popular in the hotel industry. Marlok resembles a conventional cylinder that employs a unique key with holes placed laterally through which infrared beams pass during the insertion process. Abloy combines IR with their

rotating disc lock for high-security access control.

Radio Frequency (RF) has been utilized for many years in access control devices such as garage door and gate openers. These systems rely upon low-power transmitters that are digitally encoded with a specific address. They communicate with a local receiver that controls relays, locks, or other devices. These systems are also utilized for motor vehicle access.

More sophisticated RF systems rely upon passive devices. These utilize circuitry embedded in identification cards. They may also employ special material that senses RF fields and in effect reradiates altered or processed signals, RF, or data back to a receiver. Examples of the use of RF can be found in access control applications. In such cases, the user possesses a badge or ID card that will receive and radiate signals that are recognizable by a device located at the entry point. Ranges of up to twelve feet can be achieved by such systems.

In the simplest of these schemes, small pieces of wire or etched printed circuits are placed in books or on merchandise to deter theft. If the encoder is not disabled, an alarm will sound upon exit.

20_1.2 Infrared Systems

Infrared systems have found wide acceptance throughout the world. In most instances, they are reliable, are not prone to failure, and cannot be easily bypassed or compromised.

20_1.2.1 VingCard Electronic Lock Model 3000

See Chapter 23 for a discussion of the VingCard mechanical version of this device. VingCard utilizes a plastic key with a matrix of holes to control the transmission of infrared light between the card and receiver. There are seven **IR LED** transmitter and receiver pairs located on either side of the card entry slot. A microprocessor reads the holes in the card through the transmission of IR. It then compares the unique bit stream created by the holes with data stored within non-volatile memory in the lock.

Unlike its sister product (mechanical version models 1040-1050-1060), the 3000 is quite secure against surreptitious entry involving bypass of the processor and memory system. The lock incorporates an essentially non-repeating algorithm for code

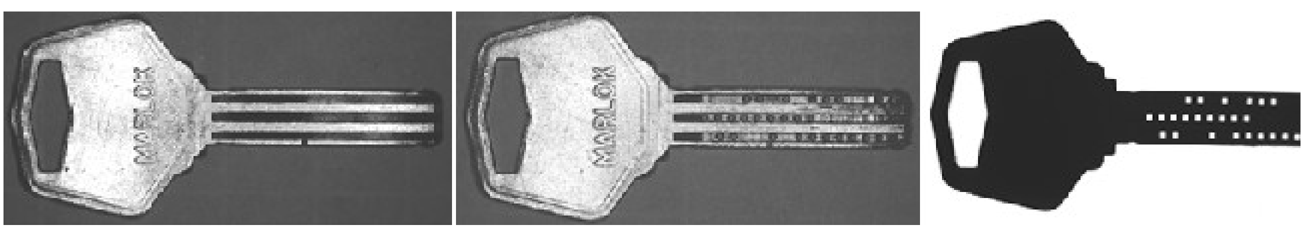
combinations. Each time a new hotel guest utilizes a key, the lock resets to the updated code. There is no predictability to the matrix of holes in each key, and therefore the lock offers millions of useable permutations. It is impossible to decode the present combination contained within the software. This is because Ving has utilized proprietary processor and memory chips that cannot be read by external devices connected to the circuitry.

Although the mechanical versions of this lock are not secure against bypass techniques (**5355701(210)**), the models that utilize IR present an excellent defense against decoding.

20_1.2.2 Marlok

The Marlok is a programmable lock that uses infrared as the transmission medium for the exchange of digital information between the key and internal microprocessor. The system allows the integration of retrofit cylinders into existing installations. Either stand-alone or remote reporting locks can be utilized.

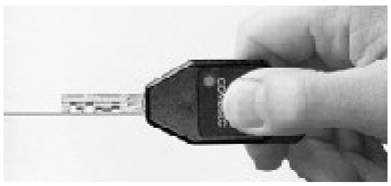
The key is shaped like its conventional counterpart. However, rather than traditional bitting, it contains three data tracks embedded across its lateral surface. A unique pattern of holes creates a stream of infrared pulses that are transmitted through the key as it is inserted. These are decoded and matched with the code for a given lock.



Keys are activated or deactivated by programming individual locks for their specific code, thereby allowing them to be reused within the system. The manufacturer claims 14.5 million differs are available. Keys can be photographed, decoded, and simulated without difficulty. The process is somewhat more involved than copying an ordinary bitting surface, however. The Marlok system also provides for remote reporting of transactional information for security and audit functions.

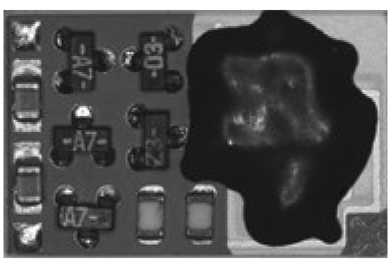
20_1.2.3 Abloy Combisec

The Abloy Combisec is a microprocessor-controlled electronic locking system that utilizes IR embedded within the head of the key. A 40-bit code is transmitted to the lock from up to four feet away. Up to 200 different codes can be stored in each lock. Each lock has several programming options to allow key enable, disable, time of day/week usage, audit trail and other functions.



20_1.3 Induced Fields

Many patents have been granted in the U.S., England and Europe for locks that utilize an induced field for the transmission and exchange of coded information between the key and lock. Some of these devices appear in this text under the category of Instant Keying (**Chapter 22**) and Intelligent Locks and Keys (**Chapter 21**). The technology is currently in use in a variety of applications, ranging from automobile locks to access control. A passive integrated circuit is embedded within the body of a key that communicates with a transmitter and receiver within the lock.



An exchange of information occurs to validate the code that has been programmed into the memory of both the lock and key. If the code is correct, then the lock is allowed to operate normally.

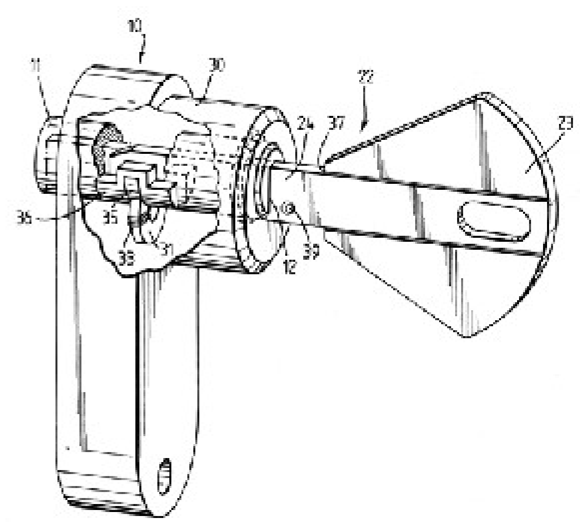
These devices require the generation of an alternating magnetic field in a region through which the key passes. The key has circuits that control an inductive transmission element in order to modulate or alter the field. This enables detection of a code that has been programmed into the key. The power for the circuit within the key is derived by rectification of the induced voltage from the alternating field without requiring direct connection to

the key.

20_1.3.1 Chubb Inductive Code Transmission System

In 1992, Chubb was granted a series of patents for an inductive code transmission system (GB **2252356A(211)**, **2273128A(212)**). It was distinguished from prior art in the United States Denmark, the EU, and England (DE 2634303, EP-0115747, **WO-88/03594(213)**, GB 2158870, GB-2174452, GB 2174452, US **4549176(214)**, **4602253(215)**, WO 88/03594).

The Chubb device emulates a conventional cylinder in function and appearance. An inductive decoder within the lock can read the code from the key when inserted into the keyway. Chubb sought to maximize the linkage of magnetic flux between the key and lock for optimum performance and stability.

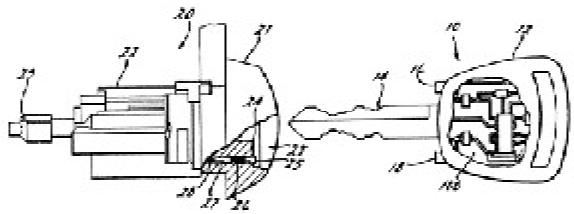


Within the bitting of the key lies an inductive code transmission element in the form of a coil wound about an axis that allows maximum energy transfer. The key is comprised of a Nickel Silver metal blank, having an aperture at the tip wherein the integrated circuit is mounted between two ferrite pads and sealed in epoxy. The IC includes a memory programmed with an authentication code that is read by the receiver.

20_1.3.2 Ford Motor Company

Ford Motor Company has been granted patents for directly connected and induced field systems that are used in conjunction with ignition locks in their automobiles. In the original system

(**5003801(216)**), an electronically coded circuit was embedded in the bow of a conventional key. It had electrical terminals extending forward that contacted with the lock body when fully inserted. The invention was distinguished from cited prior art (4200227, 4298792, 4366466, (GB **2174452A(217)**).



This device functioned similarly to those utilizing induced fields. A programmed code within the circuitry of the key would be transmitted to the decoder incorporated within the lock. If the data was validated and the bitting pattern was correct on the key, then the conventional portion of the lock could be actuated. The vehicle could be started based upon the exchange of information between the lock and the electronic ignition system.

Ford later introduced an inductive system on certain model vehicles that parallels the operation of the Chubb device described in Section 1.3.1. These locks will also allow the instant programming of blank keys by the vehicle owner.

20_1.3.3 Abloy Electronic Lock

Abloy has developed an electronic lock utilizing inductive coupling for the transmission of power and code information (GB2158870A). This mechanism utilizes a traditional Abloy rotating-disc cylinder which is operated by use of a key, accompanied by an electronic system. Within the bow of the key is a processor and memory, together with an inductive pickup coil.

The circuitry is designed to receive activating power from an external unit that is mounted in the door or door frame. The programmable circuit in the key will transmit a code to the receiving unit by the inductive circuit. One feature provides for the ability to change codes on a designated schedule, including every time the key is used.

The Abloy system allows for the programming of both the lock and key to be changed to fit any system requirements, based upon time of day, location, and usage. The device provides for either

conventional mechanical operation or combined usage with the electronic portion, thereby offering higher security as well as the verification and registration of keys.

When the key comes within range of the transmission system, a carrier is transmitted that conveys power to the integrated circuit embedded in the bow of the key. This radio frequency energy can be set to a frequency of up to 27 MHz depending upon range requirements. A unique code is stored within the internal memory. When activated by a carrier frequency, the code modulates a return carrier that is sent back to the receiving unit for validation.

20_1.4 Radio Frequency (RF) Transmission

The use of RF as a transmission medium for locks and keys is widespread. Digitally encoded systems can be found in alarm sensors, keyless vehicle entry, access control devices for gates, parking ramps, garages and buildings, and for product security tags. The technique is also utilized for proximity detectors and house arrest systems.

20_1.4.1 Digitally Encoded Transmitters

Digitally encoded transmitters have been integrated into alarm sensors, access control devices, and vehicle entry systems. Many of these units operate within a standard frequency allocation of 305 MHz. A coded signal, with 40 data bits or more, is transmitted to a receiver within the lock or control system. Upon receipt of a validated code, a microprocessor, relay, or other actuating circuit is enabled. The transmitters emit extremely low power with a useable maximum range of 50 feet. Signals can be intercepted, decoded, and regenerated without difficulty within a short distance of the source.

20_1.4.2 Proximity Detectors

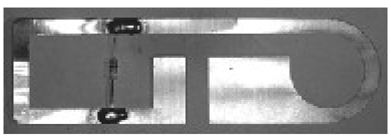
Proximity detection is the latest form of access control device. They are becoming extremely popular and will find wide acceptance within the lodging industry within a short time. Most systems operate in similar fashion to that of a security tag but have a greater sensing range and provide addressable keys.

An encoder is located at an access point. In operation, it will transmit a bitstream of data, together with sufficient energy to power a passive circuit within the key card. When an authorized

device is brought within the proximity of the encoder, a validated return signal will be transmitted and the lock can be opened. Each card or device can be programmed with a unique electronic serial number that can be distinguished by the host. These systems are ideal for applications requiring authentication of the user, without the necessity of the insertion of a physical key into a lock.

20_1.4.3 Security Tags

Although they cannot be considered as a lock in the strict sense of the word, a security tag performs a similar function to an electronic padlock. Most retail establishments affix security tags to high-value items in order to prevent theft by shoplifters. The devices are physically attached to clothing and other goods and cannot be removed without a special tool or magnetic field. Libraries embed similar devices in books, and manufacturers can "mark" goods during production.



If tags are permanently attached to an article, then they must be disabled prior to the customer leaving the store. If not, security staff will be notified at an exit location.

Electronic security tag manufacturers utilize many technologies, including radio frequency energy, magnetics, acoustics, and embedded integrated circuits. Some tags can now be encoded with serial number information and may be turned on and off electronically. "Smart tags" closely resemble access control devices that utilize proximity detection circuitry.

Certain devices utilize RF and a modified form of induced field for their operation. In order to function properly, a carrier frequency is transmitted within a limited radiating area or housing. A checkpoint is usually placed at an exit location through which the customer must pass. If a security tag is brought within close proximity of the RF, magnetic, or sonic radiating source, the active element will become excited. It will emit harmonics, resonate at a certain frequency, or change characteristics from which an alarm can be triggered. The RF modulated tag is actually a short antenna and tuned circuit having a specific wavelength. A diode forms part of the "antenna" and causes energy to be retransmitted. The harmonic or

difference in frequency is received at the sensing point, processed, and used to initiate an alarm.

20_1.5 House Arrest Systems

House arrest systems have become extremely popular within the past five years. They are used to restrict a criminal defendant to a specified location as part of a court-ordered sentence. They consist of a personal transmitter and base station receiver that is connected to a central monitoring facility by telephone line. The transmitting device periodically sends a digitally coded signal to the base station to provide physical verification that the defendant is within 100 feet of the receiver. In older units, the transmitters utilized encoding technologies similar to alarm and access control devices. In the third generation systems, spread-spectrum transmission is employed for security against interference and tampering.

CHAPTER TWENTY-ONE: SMART DEVICES

Intelligent Keys and Locks

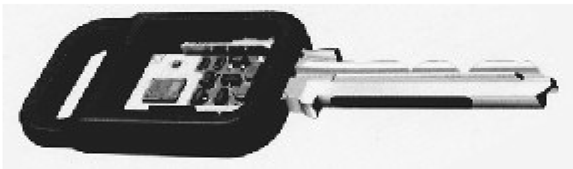
UNION-CHUBB
MEDECO IN-SITE

Master Exhibit Summary

21_1.1 Introduction

This chapter surveys innovative mechanical and electronic locks that incorporate "intelligence" into their design. These systems allow planners and administrators to closely match individual access restrictions and requirements with the location, its personnel, and security. Sophisticated microprocessor control circuitry is integrated in both the lock and key to provide many functions that are unavailable in conventional hardware. The "intelligent keys and locks" allow for a precise record of entry,

together with instant authentication of users, based upon security level, time of day, location, ingress and egress, and many other parameters. These locks are finding wide acceptance because of the versatility they bring to access control.



Due to the overlap in technologies, certain locks have been included in other chapters that may just as well fall into the category of "intelligent keys and locks." In **Chapter 23**, intelligent card locks that are used in hotels are described.

21_1.2 Union/Chubb

In 1991 and 1994, Union Works, a part of the Chubb Group in England, received patents for an extremely sophisticated intelligent lock that is instantly reprogrammable. The Union **Electro** described in **Chapter 20** has a processor and sensor system built into the lock housing. A small read-only chip is impregnated into the bitting. Each key has a unique factory-encoded electronic signature. Only if the lock recognizes the data from the key can an opening occur. Any one or more locks can be programmed to accept or reject one or more signatures (keys) within seconds.



21_1.3 Medeco Security Electronic *InSite*

Medeco was the first to introduce an integrated high-security encrypted access device. The system consists of a smart key that

works in conjunction with an intelligent door controller, hard-wired to a central processor. The DES encryption algorithm is utilized for all communications within the host network.

Smart keys utilize dual technology for optimum security. The rotating tumbler mechanical design, coupled with a read/write memory device and processor within the bow, allow unparalleled resistance to bypass.

The system provides customized access control to meet the requirements of any installation. Internal circuitry within the key can store a significant amount of data to clearly indicate the identity, authenticity, and access authority of the bearer. Additional data fields can be programmed into the key to include:

- **Key Holder Name;**
- **Key ID Number;**
- **Unique Facility Security Code;**
- **PIN Number;**
- **Key Class Field;**
- **Key Valid Date;**
- **Key Expiration Date Field;**
- **Number of Uses;**
- **Extra Time Allowance.**

The Medeco InSite system was introduced in 1991. It provided the model for subsequent intelligent access products that would be introduced by different manufacturers. Today, many vendors offer intelligent locks and keys that provide extremely high-security and functionality.

21_1.4 Ikon CLIQ

The Ikon CLIQ (**Cy**linder **IQ, or smart cylinder**) is one of the third generation intelligent systems to be released in 2002. Other manufacturers, such as EVVA, KABA, BKS, Medeco, and KESO have also introduced sophisticated systems that integrate traditional mechanical sidebar security with microprocessor control. All of these systems perform essentially the same functions with respect to central monitoring, programmability of keys, access, egress and ingress, timing, logging, system integration with older locks, and audit functions. Although each vendor has adopted different power, processor, and transponder technology, all of the locks perform the same functions.

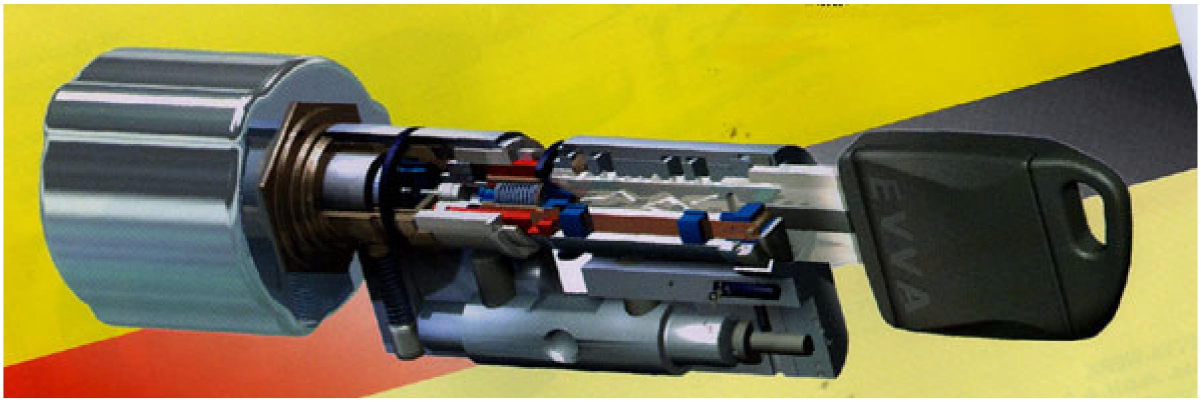


Figure LSS+2101 The EVVA Electronic Modular Cylinder is another intelligent lock. Note the same power and transport technology as the IKON shown below, through the use of contacts on the key.

With respect to security, all of the intelligent systems are virtually impossible to bypass, either with traditional means, or electronically. This is assured by the required coincidence of a very secure mechanical lock with transponder data exchange between specified keys and the lock, or central processor.

Some of the locking systems utilize passive circuitry within the key head; others power a processor within the key by small internal button cells. Some of these systems communicate by RF energy interchange between key and lock, while certain manufacturers, such as EVVA and IKON, hardwire link the key to the processor within the lock each time the key is inserted, via two contacts, as shown below. The IKON key head also has a LCD to indicate battery status.



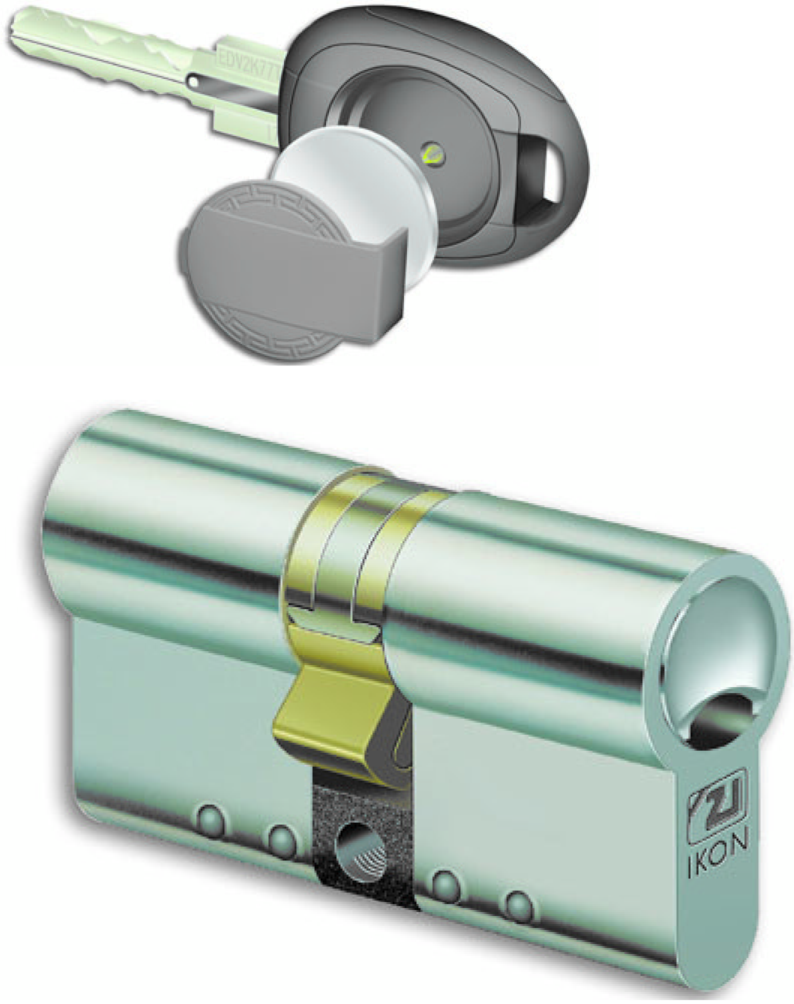


Figure LSS+2102. Details of the IKON CLIQ system are shown, including the programmer.

CHAPTER TWENTY-TWO: CHANGING DIFFERS

Programmable Locks and Keys

VINGCARD 1040 MECHANICAL
MASTER LOCK COMPANY
VANLOCK

WINFIELD
UNION ELECTRO
FORT GEMATIC
BEST
LEFUBURE
S&G 4110
CHANGEABLE COMBINATION LOCKS
INSTAKEY PROGRAMMABLE CYLINDER

Master Exhibit Summary

22_1.1 Introduction

Manufacturers of safe and vault locks have produced changeable wheel pack and lever mechanisms for many years. In combination locks, several techniques are available to alter the relationship between spindle and gate position in order to change the combination. Levers and their corresponding gates can be moved to fit any key. See **Chapter 34** for a discussion of these mechanisms.

The ability to quickly reprogram locks and keys first became important in the lodging industry in the 1970s. This was a result of the failure of guests to return keys and the resultant losses of property and personal injury claims. Today, most large hotels as well as many businesses and government agencies utilize electronic or mechanical locking systems that provide the ability to instantly alter the key bitting or access code.

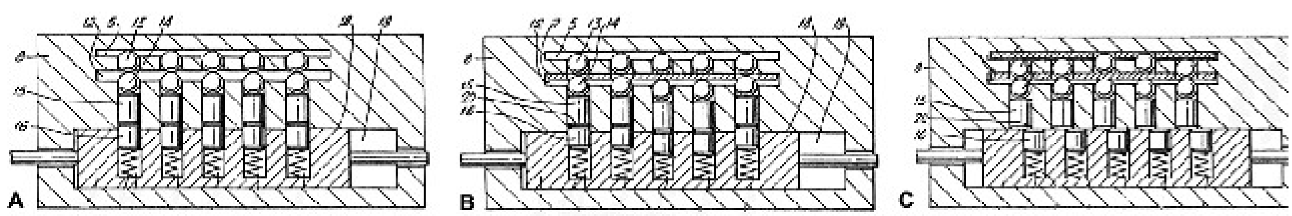
This chapter provides information about systems that can be programmed by a control key, change key, card, or code, at the lock or from a remote location. There are, of course, many similarities between these locks and other "smart" devices described in earlier chapters. Our discussion will focus on locks that have been specifically designed to allow a change to be made in the code or key that opens them. Other devices, such as those that utilize induced fields for example, may ultimately accomplish the same result but with different technology.

22_1.2 VingCard 1040-Series Card lock

Ving manufacturers a series of mechanical and electronic card locks for use in the hotel industry. The infrared system is described in **Chapter 20**. A bypass cylinder, present in most installations, is provided for hotel security and maintenance staff.

The 1040 mechanical card lock introduced an extremely innovative and clever design that provided for instant card change capability (**4149394(218)**). Unfortunately, the system can be bypassed with few implements and little skill. The author was granted a patent (**5355701(219)**) for the tools and techniques needed to decode and open these locks.

The mechanical version consists of a 32-pin tumbler lock, oriented in a matrix of 7 x 5 chambers along a horizontal plane. A programming card is placed into the rear of the lock that sets the pin code for the change key. A shear line is created between the fixed portion of the lock and the moving platen that holds the card during insertion.



Exploded view.

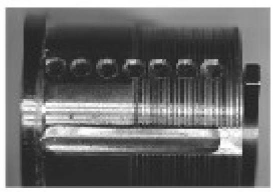
When the key card is inserted from the front, it must **block** or allow to **pass** specific tumblers, based upon the matrix of holes in the **program** card. If all positions are correctly programmed, then the platen is free to move and actuate the bolt. If there are any holes or spaces present in the key card that do not match

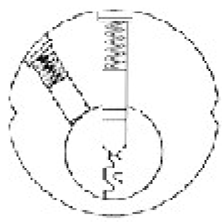
the program card, then the tumblers are lifted above shear line and the lock will not open. There are normally from seven to ten active holes within any key card out of a possible thirty-two useable positions. The security of this lock is based upon the random placement of these holes.

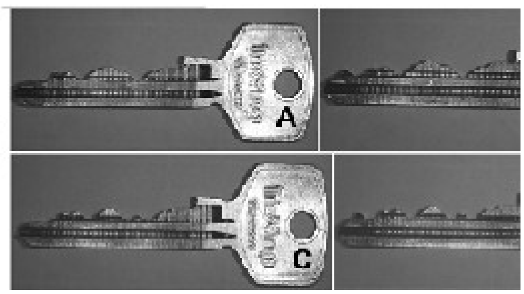
22_1.2.1 Instant Rekey Cylinder Lock

Bypass cylinders are installed for use in case of mechanical failure of the primary lock. They are manufactured to high tolerance and have a paracentric keyway to frustrate picking. The design features two sets of chambers within the shell, permitting master pins to be "parked" in the second location. This allows an instant combination alteration to be made for the change key.







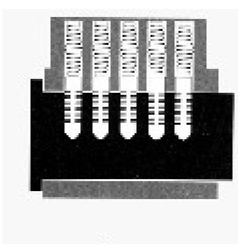
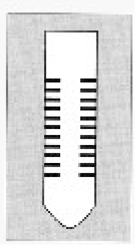


The plug contains seven lower pins. The upper chamber, aligned vertically when the keyway is set at the 12 O'clock position, has seven drivers and springs. In this orientation, the lock functions in the standard fashion. Offset approximately 30° clockwise is a second set of bores in the shell containing **six** drivers and springs. The last pin of the key (cut nearest the tip) is not present in the "control" chamber. Thus, only a specially cut master key can be inserted and removed when the plug is rotated to the control position. The first position on these keys is cut lower than the deepest depth.

In operation, a master key is inserted, the plug rotated to the control position, and the key withdrawn. A new master key is inserted, the plug rotated back to the normal vertical orientation, and the key removed. The new change key, having the same combination as the most recently inserted master key, will now operate the lock. No other change key will function. When the plug is rotated to a control position and a different master key inserted, master pins are parked in the offset group of chambers. These wafers are no longer part of the pin-stack, and thus, a different combination is set.

22_1.3 Master Lock Company Universal Pin Keying System

Master Lock, in 1994, introduced a fast, convenient, and easy method to combinate most of the major residential keyways without disassembly. The system relies upon the use of a special serrated pin in each chamber. The serration points correspond with each manufacturer's depth segments. For example, a pin for a Schlage **C** keyway would have serrations every .015". A Kwikset pin would have serrations every .023". The pins have sufficient serration density to accommodate most depth coding systems. In practice, the specific change key is inserted into a cylinder that has been loaded with the special pins. The lock is then placed in a pinning fixture. Using the wrench provided, a bolt at the rear of the fixture is turned. This causes the plug to be forced forward slightly, thereby breaking the pins at shear line. By this action, the lock is set to the desired combination.

The system is not designed to be used with cylinders of standard construction. It requires a change in metal content by the manufacturer, so that internal deformity does not result from the stress induced during the shearing process. Master keying is not recommended. Sufficient testing has not been performed to determine the impact upon the security, pick resistance, or impressioning of the cylinder. This system is useful in allowing the locksmith to rapidly rekey standard cylinders at the change key level.

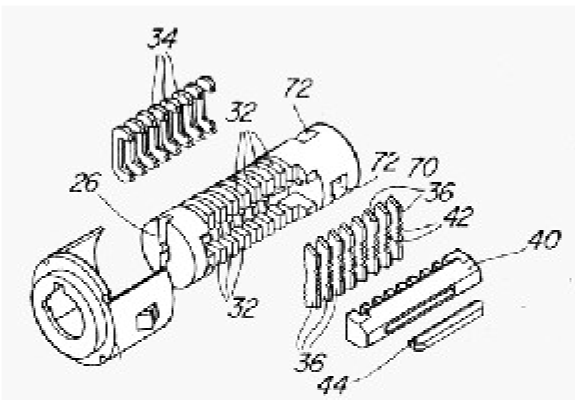
22_1.4 Vanlock Axial Pin Tumbler

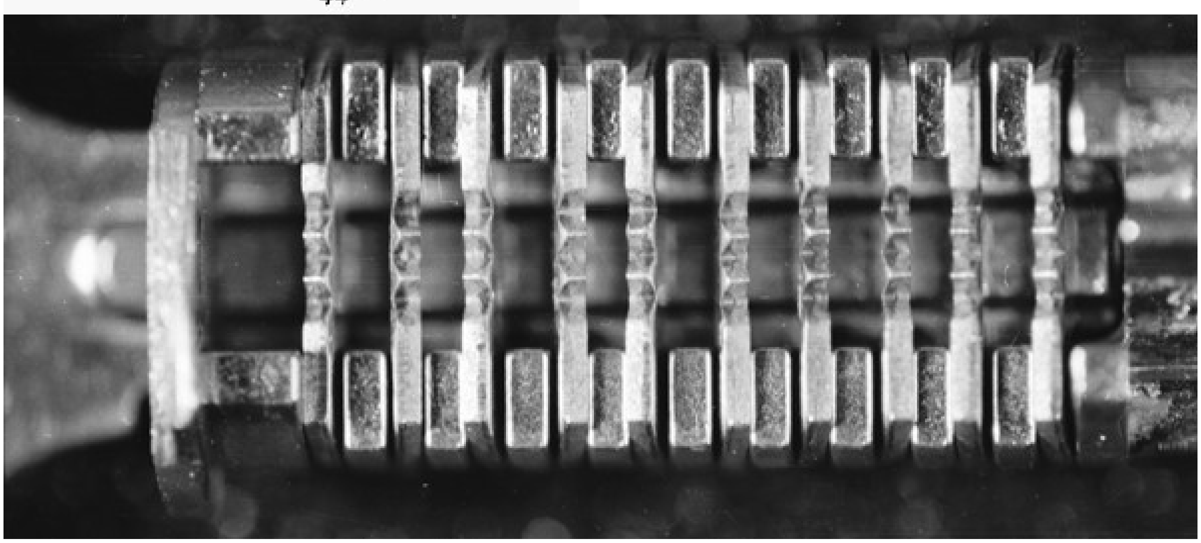
This lock is popular in the vending industry. It utilizes a special seven-pin tumbler key having removable pegs that correspond to axial pin tumblers. The lock can be reprogrammed by first altering the pin-stack in each chamber, then inserting the corresponding pins into the key. When mated together, the pegs will force the first set of tumblers to shear line. See **Chapter**

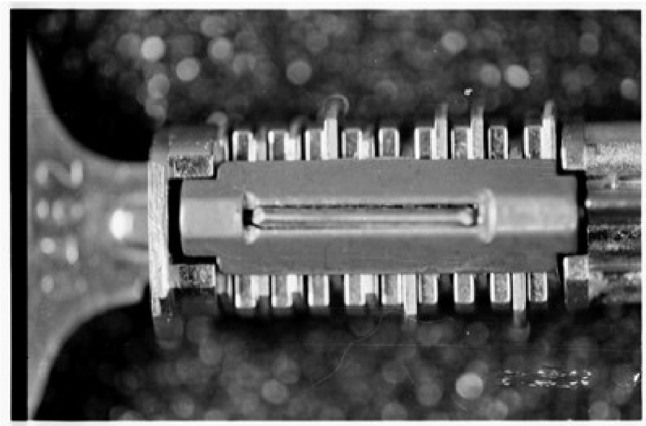
23 for a full description.

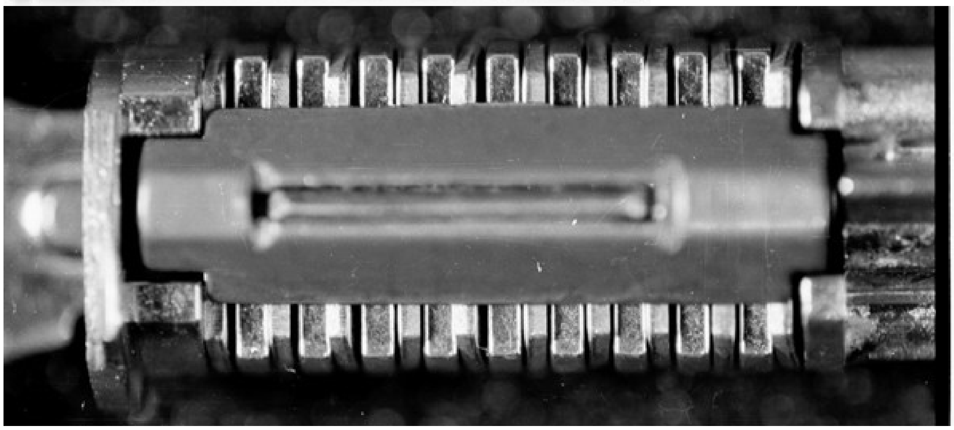
22_1.5 Winfield

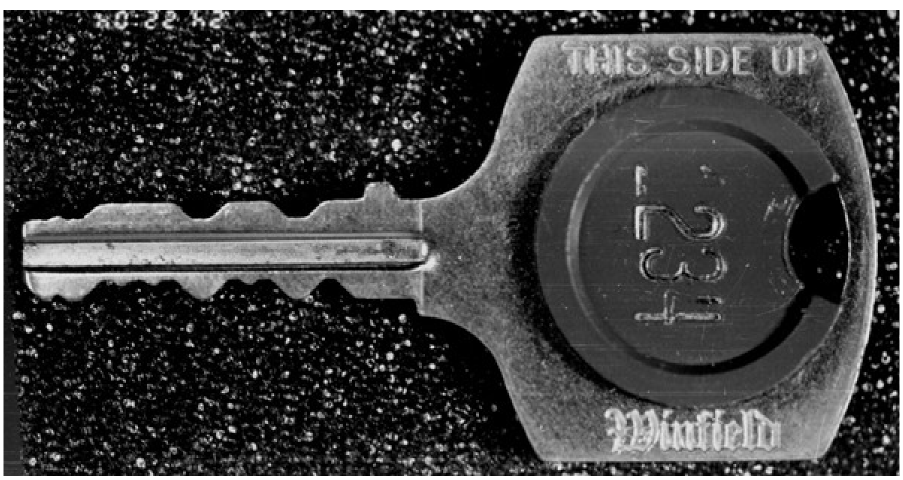
The Winfield Lock Company developed one of the first instant rekey locks and received patents for the design in 1978 (**4069694(220), 4966021(221), 4376382(222)**). The mechanism is extremely innovative and has found immense popularity in the hotel industry worldwide. The cylinder features two keyways: one for the change key and one for maintenance, programming, and emergency access. A view of the wafer pack is shown by use of a **borescope**. This enlarged photograph shows the precise position of each of the moveable wafers. The lock can be decoded through this process.







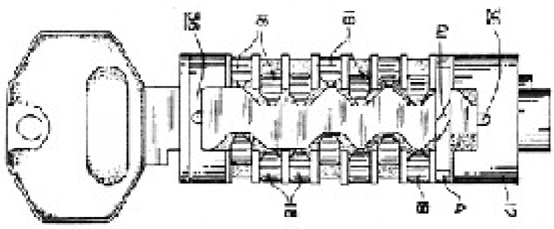


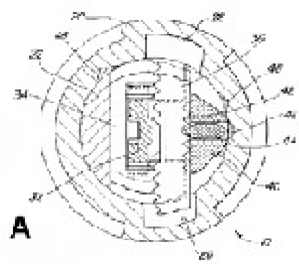


The design utilizes ten wafers to secure the plug within the shell. The unique feature of this lock is that each wafer is programmable to two different depth codes (full cut or no cut). There are 2^{10} or 1,024 possible combinations for any given lock. Only one keyway is available. The photographs above show the wafers in a aligned (proper key inserted) and misaligned state.

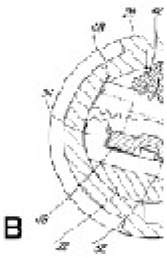
The tumblers are a split-wafer design. The **relative** internal spacing can be changed to match a particular bitting depth by use of the control key. When inserted into the second plug, it causes the two halves of the wafers to be separated and reoriented.







A



B

A master key operates the second control keyway and will open every lock in the system. A maintenance key, when inserted into the control keyway, allows instant reprogramming of this lock to any change key or master key combination.

Although found in hotels everywhere, this lock does not provide any real measure of security and can be picked and otherwise compromised. The lock does offer ease in reprogramming, however, and can provide immediate entry into a room, even when the mechanism is double-locked from the inside.   The original inventors set the standard for instant rekey in the hotel industry. T

22_1.6 Union Electro

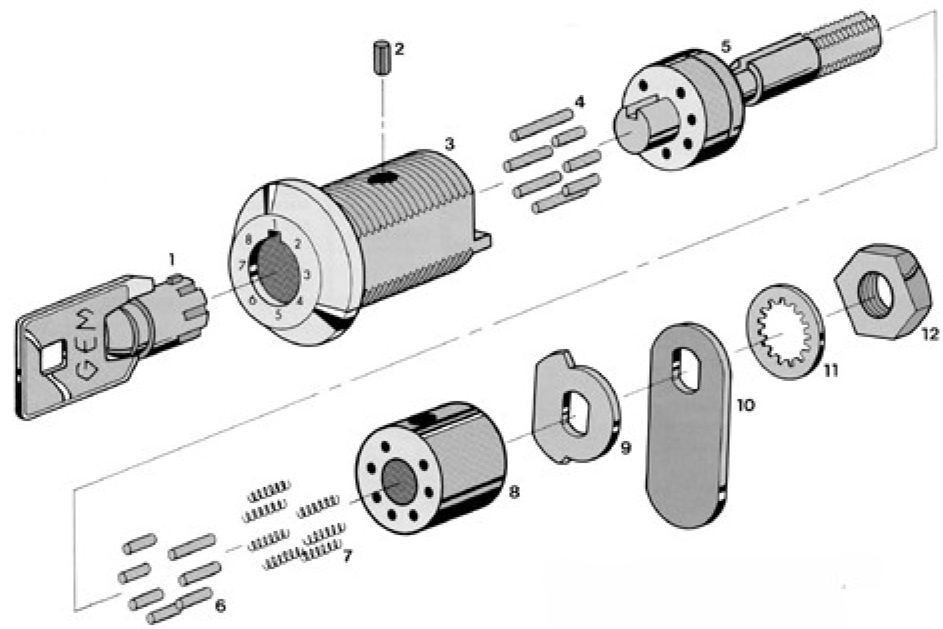
The Union Electro, more fully described in **Chapter 20**, provides for instant programming by the insertion and removal of a control key. The lock receives coded information from an integrated circuit memory chip embedded in the tip of the bitting. This integrated circuit is powered through energy transmitted by induction, from the lock housing. An internal microprocessor within the lock verifies the unique code in the key and actuates a mechanical release.

22_1.7 Fort Gematic Tubular Lock

The Fort Gematic series of locks is instantly programmable to any one of eight preset combinations. Although the Gematic resembles the Chicago Lock changeable system, it is somewhat simpler to operate and only requires two keys. It is used primarily in the

vending industry and in merchandise display cases where keys may be lost or compromised. The Gematic looks like most other tubular locks from the exterior. It has seven radially positioned active pins, although there are actually eight lower tumblers. The eighth pin is non-active and is required to fill the void left in one of the chambers as rotation of the control plug occurs.

The lock is constructed to create two distinct shear lines: one for the individual change key and the other for combination control. Two discs, each with eight chambers, are stacked above the core to form the individual shear lines. These discs are equivalent to two concentric plugs in a conventional pin tumbler lock.



In theory, the system closely resembles the Corbin master ring, or the Best removable core lock, except that the second shear line controls the orientation of the lower set of pins with respect to the change key position.

In the normal axial pin tumbler lock, the key is inserted and all lower tumblers are brought to shear line. The cam may then be rotated. In the Gematic, the relative position of the lower tumblers, with respect to the fixed combination of one or more change keys, can be altered. Thus, the entire set of lower tumblers is rotated in one of eight positions, much like the hands of a clock. The correct key reflects the same tumbler pattern and orientation.

In operation, the change key will cause the first and second moveable discs to rotate in concert; the second disc forming the active shear line. When the correct key is inserted, the spindle may be turned because all pins are aligned to the second disc. The change key can only be inserted where the vertical index guides correspond on the cam and shell. Thus, the key will only make contact with the pins when it is inserted properly. It cannot work in any other radial position, because the key is blocked from entry.

A separate control key will bring all lower tumblers to the first shear line. The combination of this key will be different than any of the change keys because of the creation of a **control** shear line. The control key allows the plug with lower pins to be rotated to any one of eight radial positions. The control disc is not linked to the spindle and thus can be rotated freely once all tumblers are aligned.

The control key may be derived from any of the change keys by adding the precise difference between the operating and control shear lines to the combination of a change key for each tumbler. In other words, if the base combination of the lock is 1234123 and the thickness of the operating shear line equals two depth cuts, then the control key would be 3456345.

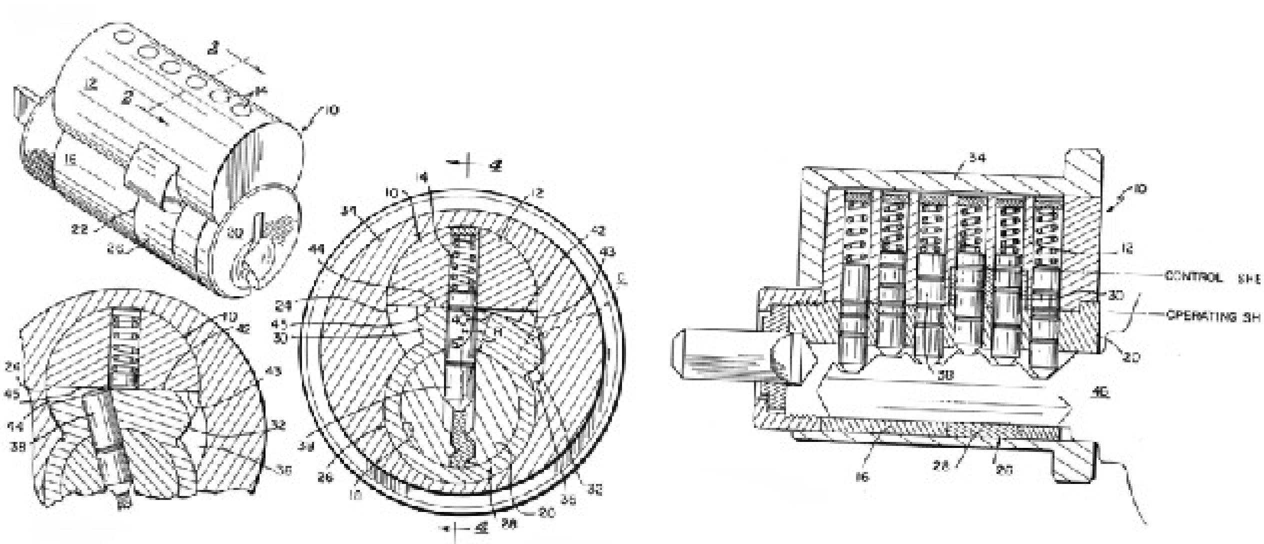
The ability to change combinations is based upon the orientation of the lower pin-stack with reference to the index guide. The control key sets a different combination by varying the relative position of the pin-stack, with respect to the index of the change key. There are eight such positions. To change combination, the control key is inserted to the current relative position (1-8). The entire plug is then rotated and the control key withdrawn at any of the eight permutations. The **apparent** combination is now changed, and only the corresponding change key with the correct cut pattern, as referenced **to the index**, will operate the lock.

The control key has been specially milled so that the top and bottom index has been removed. This allows the key to be inserted in any of eight positions. The control key will not rotate the spindle; it will only allow turning of the control plug containing the bottom pins.

22_1.8 Best Removable Core

The Best Lock Company produces a series of interchangeable core locks (**A2, A3, A4(223)**) that are used in large complexes where immediate on-site key change ability is desired. The locks are available in mortise cylinder, key-in-knob, and padlock. All cores are interchangeable between hardware designs.

In normal operation, the lock functions the same as any other pin tumbler device. When, however, it becomes necessary to change the core, a special control key is used. This key is inserted and turned 15° to the right. The entire core is then withdrawn from the shell and a new one inserted. With the new core inserted, the old key is useless.



22_1.8.1 The Key

The Best key has no shoulder. Instead, the tip is flat-faced to act as a stop. A high tolerance is maintained between tumbler and root, because both are flat as opposed to the curved valleys and tumblers found in most locks.

22_1.8.2 Security Issues

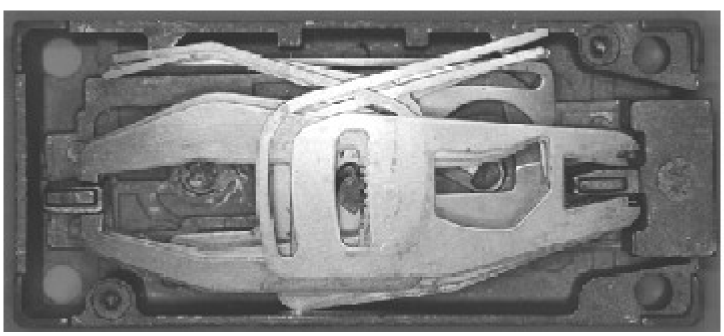
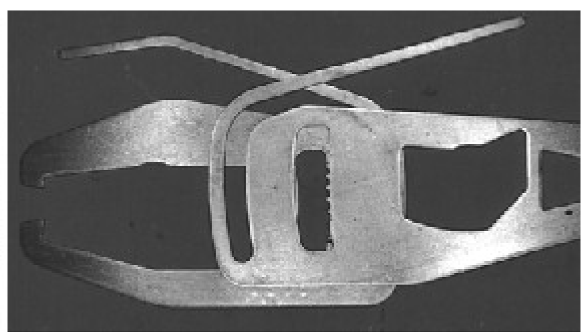
Removable or interchangeable core systems are especially vulnerable to compromise and sabotage if the code for the control key is improperly obtained. This is because in most systems the control key will work on many if not all of the locks. Convenience and necessity can pose serious security risks. If the control key is lost or falls into unauthorized hands, the entire system can be compromised. Accordingly, the control key should be

considered as a great grand master. With its possession, one can simply remove any core and open the lock.

Sabotage is another significant threat. Possession of a control key allows an exchange of cores, resulting in a lockout condition. In high-security installations, groups of locks should have their own control keys so that system compromise can be localized.

22_1.9 LeFebure Lever Locks and Decoder

The LeFebure seven-lever dual-control lock is utilized in safe-deposit vaults. The bitting combination for both the renter's key and guard key can be changed without disassembling the mechanism. A decoding/impressioning tool for the 7700 series lock was introduced in 1997 by Lock Defeat Technology. The system allows almost instant bypass of the renter's lever pack, and will produce an impression on a brass blank that can be decoded. Individual levers in each lever pack are identical in design with regard to the spatial relationship between gate and belly. Differs are created by physically placing a lever in a different position as to its gate.

Decoding and impressioning this lock is extremely simple, because the location of each gate directly correlates with the position of the lever and its belly. In many respects, the design of this lock is identical to a conventional wafer mechanism. In both instances, the active locking components are offset by the precise distance to the gate or shear line.

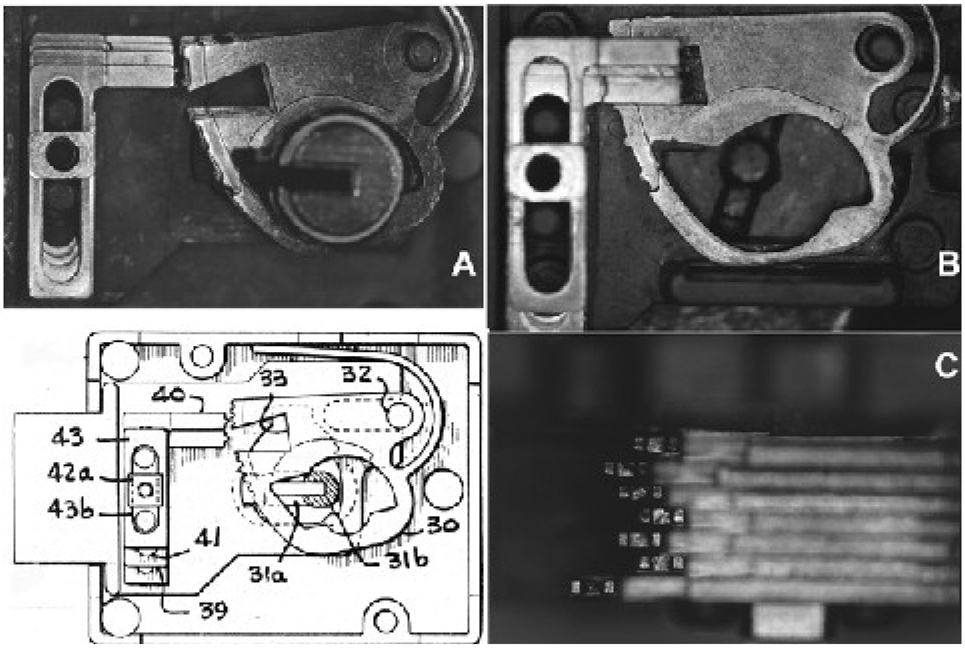
The impressioning and decoding process resembles the use of plasticine and yields almost identical results. In practice, a special brass strip is inserted into the lock alongside a guide that is used to actuate the bolt. The strip is forced against the lever pack until stopped, resulting in a precise impression

of the **relative** position of each lever. A guide key, in concert with the impressioned brass strip, is turned until the levers are raised to clear the fence. Because the strip mirrors the relative height of each lever at the drop in point, all that is required is that the strip be rotated to the correct position. The impression strip can then be decoded, if the amount of rotation required to bring all gates to the fence can be ascertained.

22_1.10 S&G 4110 and 6805 Changeable Lever Locks

In 1982, S&G patented a changeable safe-deposit lock having a single or double-key configuration (**4462230(224)**). These devices have one or two stacks of vertically slideable adjustable fences, that are carried on a bolt. They are held in an adjusted position by a clamping assembly that utilizes a changing screw that is accessible from the rear of the lock.

The S&G 4110 and 6805 were designed around the 1982 patent and have a changeable fence that allows instant programming to fit any key. The 4110 is a single-key, seven-lever lock and is used in safe-deposit boxes and other applications. The 6805 also has seven levers and is used in high-security containers. Within the 4110 and 6805, all of the levers have their gating in the exact same position. All tumblers are identical and can be interchanged. There is an individual fence for each lever gate, the position of which is altered based upon the key bittings. After insertion and rotation of the key for which the lock is presently set, the screw that holds the fence stack is loosened and a new key inserted. The position of each fence is changed to fit the new key.



Exploded views 1, 2, 3, 4, 5, 6..

The 6805 is UL listed and has the added security feature of a closed sweep and serrations for pick resistance. A moveable bolt actuator must be rotated past a certain point in order for the bolt to move, once all of the levers are aligned to their gates. The levers can be "read" in this lock with a borescope in order to determine markings that correlate to the depth of each cut. See Chapter 31 for a discussion of decoding.

22_1.11 Instakey Programmable Lock

Instakey (Smith) received a patent for a programmable lock in 1988 (4741188). The company has become a leader in supplying changeable systems, especially for retail, government, and educational facilities that require the capability to instantly change keying combinations without removing a core. The system is cost effective in comparison with removable core systems, or when the services of a locksmith are required to recombinate a cylinder. An employee can be easily trained to change combinations for any one cylinder, or a group of cylinders.

Instakey technology can be applied to a variety of hardware configurations, including small format interchangeable core cylinders, and Medeco Bi-axial. Instakey has agreements to supply cylinders for Best, Falcon, Medeco, Corbin-Russwin, Cisa, and

Pfaffenhain. Keyway groups have been assigned by these manufacturers for use by Instakey customers on an exclusive basis. In most instances, both the OEM and Instakey name will appear on the face of the cylinder to indicate its functionality.

22_1.11.1 Overview of the System





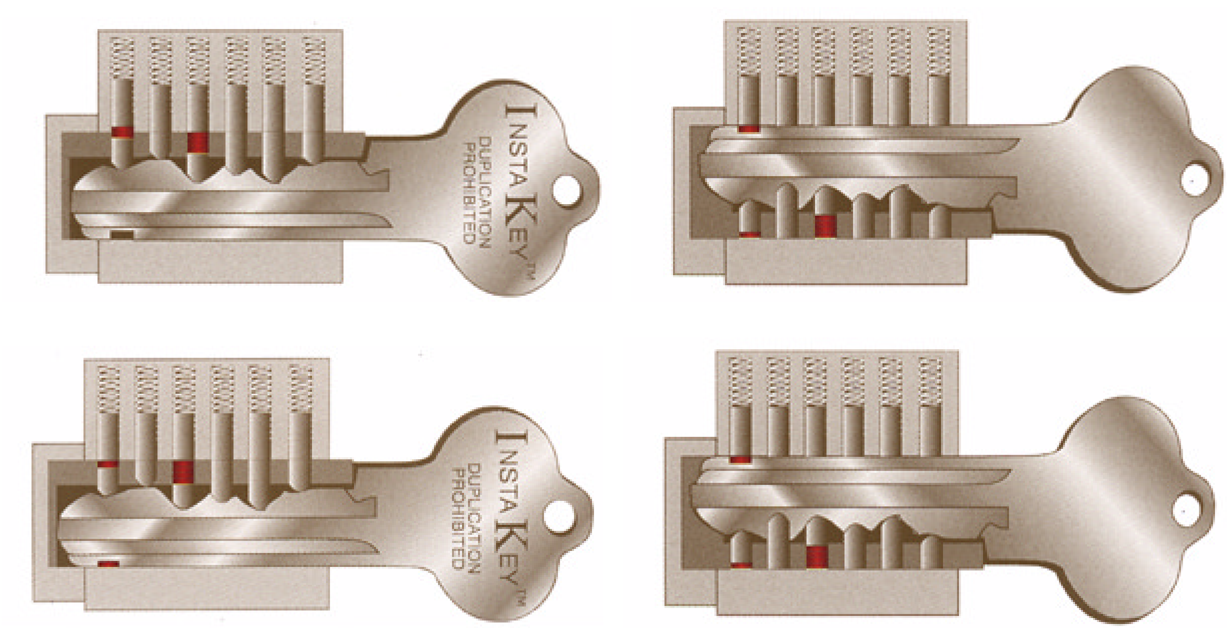


Figure LSS+2201 The Instakey cylinder has a wider than normal base at the bottom of the keyway. This allows room for the tumbler segment that has been

sliced during reprogramming to be removed from the lock. A slot that corresponds with the chamber position that is being programmed allows the transport of the wafer from shear line to the base of the plug. The slot in the programming key is slightly deeper than the depth increment of the tumbler.

An Instakey cylinder utilizes programmable pin stacks to allow for instant reprogramming. Special pins are available for many different manufacturers as well as the Instakey brand. The normal depth increment for Instakey SFIC is .0125". Master keying and programming utilize a two-step progression; thus, .025" is the minimum depth for each pin segment. Pin stacks are available in .025" (1 depth) .050" (2 depths) .075" (3 depths) and .100" (4 depths). The specially glued pin arrays can be placed in three different chambers, which are normally the fifth, sixth, and seventh position (measured from the tip).

Instakey normally supplies a programming "kit" that contains one or two new keys that can be utilized in the event that a lock requires reprogramming. The lock can be programmed a total of twelve times before it must be exchanged. All change keys are usually not supplied to the end user. The company maintains a sophisticated on-line tracking system for each of its customers so that Instakey and the specific location always know the programming sequence for any given lock and inventory.

Combinations can be changed at the change key, master key, and control key levels. To change the bitting combination for a given cylinder, the next step-programming key (with a slot at the base of the blade) is inserted and rotated a full revolution. This action will slice the next section in the programmable pin stack and park it above shear line. As the plug rotates, the pin segment is picked up by the slot in the key. When the key is returned to "home" position, the pin is carried out of the plug as part of the key. The combination has now been changed, and the last step-key will no longer function. In the case of change key reprogramming, it can be seen that the overall pin stack height for the master key or control key will not be affected because each programming step of two depth increments is added to the new key that operates the lock. That is, the code sequence for a given chamber always runs from the deepest cut to the shallowest. Increments for the Instakey SFIC cylinder are measured from 0-9, where 0 is the shallowest depth.

INSTAKEY SFIC(225)

Depth	Space	Increment
0		.0319
1	.086	.0306
2	.236	.0294
3	.386	.0281
4	.536	.0269
5	.686	.0256
6	.836	.0244
7	.986	.0231
8		.0219
9		.0206

Figure LSS+2202 Table showing depth and spacing for Instakey small format interchangeable core system.

Code progression for a sample lock is shown below.

INSTAKEY PROGRAMMABLE LOCK SAMPLE SYSTEM CODE PROGRESSION		
SEQUENCE	CHANGE KEY	PROGRAMMING KEY
1	3250989	
2	3250789	3250789
3	3250589	3250589
4	3250389	3250389
5	3250189	3250189
6	3250169	3250169
7	3250149	3250149
8	3250129	3250129
9	3250109	3250109
10	3250107	3250107
11	3250105	3250105
12	3250103	3250103
13	3250101	3250101

Figure LSS+2203 Table showing the progression of step keys for a reprogrammable Instakey lock.

22_1.11.2 Detailed System Operation

A customer will be supplied with a system that is programmed for the first step. In the progression table above, the sequence begins with the bitting code of 3250989. The customer would usually be supplied with the next step-programming key and change key, which have the same value of 3250789. We note the following characteristics of the system from the progression table:

- **Chambers 5-6-7 are utilized for programming;**
- **The key is coded from tip to bow;**
- **There are programmable pin segments in all three chambers;**
- **Any chamber can be utilized for programming, but only three chambers are ever utilized for this purpose;**
- **Each programmable pin segment measures .100", which is equal to eight depth increments. Because this is a two-step system, each removable pin segment is equal to .025";**
There are a total of ten depths for this specific lock, each with a depth increment of .0125";
- **Each time the cylinder is reprogrammed, the pin stack in only one chamber is acted upon;**
- **When the cylinder is reprogrammed, the special tumbler for a specific chamber is raised two depth increments (one pin segment) above shear line, sliced and removed;**
- **A cylinder can only be reprogrammed with the use of a special key that contains a slot at the base of the blade, corresponding with the location of the programming pin;**
- **Each time the lock is reprogrammed (up to twelve times), one segment is removed from the plug. When this occurs, the previous step key will not function, as its bitting value will be two depth increments below shear line;**
- **Programming pins can be sliced with a regular change key. However, the segment cannot be removed from the plug. This has significant implications with regard to the security of the lock, and is discussed in a later section, and in Chapter 31 with regard to the extrapolation of the top level master key;**
- **Reprogramming of the lock is done in sequence, beginning from chamber 5, then 6, then 7;**
- **As the length of the pin stack is shortened by the removal of a**

pin segment, so the length of the bitting value of the key is correspondingly increased. That is, every time a pin segment of two depth increments is removed from the plug, the value of the next change key is increased (the bitting is shallower) by two depth increments;

- **Each programmable pin segment can contain one, two, three, or four segments, each of which are equal to two depth increments;**
- **The change key, master key level, or control key (in removable core locks) can be altered independently;**
- **In the removable core lock, the control lug is only acted upon by the first four chambers;**
- **Unless specifically programmed, the value of the control key will never be affected by reprogramming;**
- **The base of the keyway has been specifically widened to allow for the removal of the programmable pin segments. Generally, this modification is performed by the original equipment manufacturer for Instakey;**
- **Restricted blanks can be replicated on the Easy entrie profile milling machine;**
- **If the customer is provided with more than one programming step key, and the wrong key is utilized for reprogramming, confusion can result because the lock will be out of sequence with the information retained by Instakey;**
- **If the customer is provided with all twelve step keys, each can be made to open the lock, creating a serious security problem, detailed below.**

In the diagram below, the programming progression is graphically illustrated for four cylinders in the system shown in figure LSS+2203, above. The system is very basic, and does not take into account either master key or control key. The diagrams show the bitting of each step key #1-4 (green). Note that the "0" cut in chamber four shows as only one pin length. The bottom pins in chambers five and seven are shown in blue. Although a "0" value pin also appears in chamber six, it is not shown, other than as the bitting height of the key. The red segments indicate programmable pins that are raised by the action of each sequential step key and removed from the plug. The actual depth code values are shown in yellow. The depth increments are shown in tan, to the right of the diagrams. An overlay of the actual photograph of the third step key is shown for combination 3250589.

The pinning values for this lock are shown in the table below.

INSTAKEY PINNING CHART FOR SAMPLE SYSTEM FOR STEP #1 3250989							
SHEAR LINE	3	2	5	0	9	8	9
PROGRAMMING PINS, FOUR SEGMENTS, EIGHT DEPTH INCREMENTS					2		
					2		
					2		
					2		
BOTTOM PIN	3	2	5	0	1	0	1

Figure LSS+2204 Pinning chart for Instakey sample lock.

INSTAKEY PROGRAMMING PROGRESSION FOR FOUR CYLINDERS

STEP #1 BITTING VALUE = 3250989
STEP #2 PROGRAMMING KEY BITTING VALUE = 3250789
STEP #3 PROGRAMMING KEY BITTING VALUE = 3250589
STEP #4 PROGRAMMING KEY BITTING VALUE = 3250389

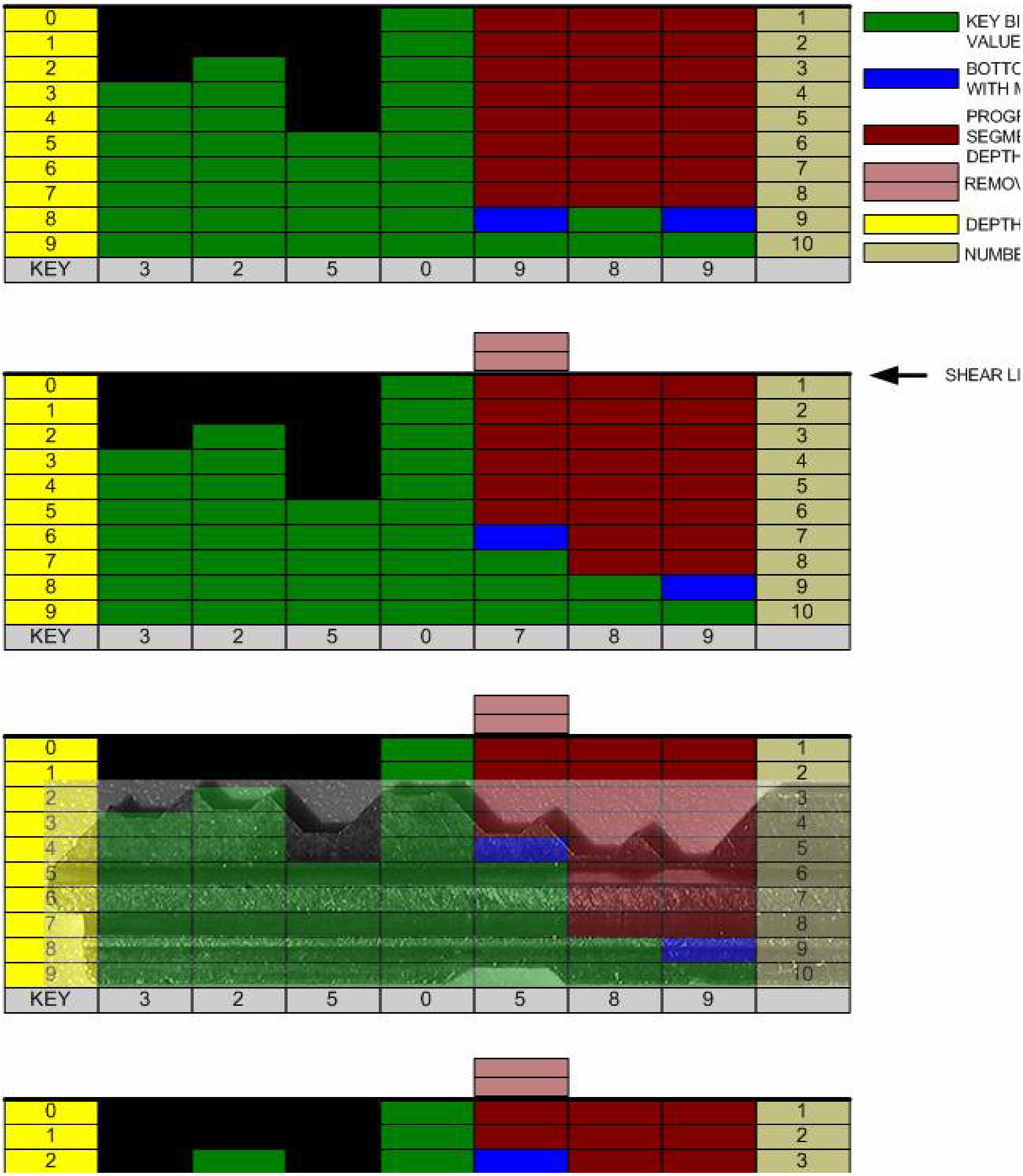


Figure LSS+2205 Programming progression diagram for four Instakey cylinders

22_1.11.3 Security Issues

There are a number of real and potential security considerations and issues involving the use and reprogramming of any lock that utilizes the Instakey technology.

Programmable chamber identification: Although the factory routinely utilizes chambers 5-6-7 for programming, this is not a required constant, and can be modified. If an employee or other individual has access to more than one step key, it may be relatively easy to determine which chambers are utilized for reprogramming.

Torque: The amount of torque that is required to sever a pin is minimal. In fact, the manufacturer only utilized a glue bond between programmable pin segments to make the lock more resistant to picking. If more than one programming step key is obtained and inserted into the lock, multiple pin segments can be severed. This will result in significant key interchange issues, creation of incidental master keys, and reduction in pick resistance.

Key Interchange: If multiple pin segments are sliced but not removed from the lock, then serious key interchange will result, as well as the creation of incidental master keys and cross keys. It may be impossible to determine if programmable pin segments remain in the lock after being severed.

Sabotage potential: A system may be sabotaged by being reprogrammed by an unauthorized individual. This could occur if a change key was modified by adding two depth increments to one of the chambers utilized for programming, and a slot cut in at the base of the key to correspond with one or more chambers.

Extrapolation of the top level master key: If an Instakey lock is probed, as described in chapter 31, then multiple pin segments may be severed without knowledge, creating key interchange and incidental master keys. It will also cause confusion to a covert entry team attempting to decode the TMK, because multiple shear lines are created as pins are severed.

Pick Resistance: The pick resistance of a cylinder will be reduced if pin segments are sliced but not removed.

22_2.0 Changeable Combination Padlocks

Many changeable key and combination padlocks have been designed during the past 150 years. These are configured as removable core, rotating thumbwheel, pin tumbler, axial pin tumbler, and combination lock. The Corbin Sessamee and equivalent Master Lock design (**5109684(226), 3983724(227)**) utilize a programmable thumbwheel and gear arrangement to alter the relationship between a number on a thumbwheel and fixed detent within a padlock. Tension is released from the two components to change their relative indexing and four digit combination. See **Chapter 23.**

Harry Miller was granted several patents for high-security combination padlocks that were produced by Sargent & Greenleaf (**2852928(228)**, 2831447, **3533253(229)**) beginning in the 1950s. Produced primarily for government use, these locks offer a high level of resistance to surreptitious and covert entry. See also (2673457) (**2814940(230)**) (**2830447(231)**) (3024640) (**4404823(232)**). The combination is reset by the introduction of a special change key at the back of the lock. The relationship between each gate and spindle can be changed while maintaining security against manipulation. They are described in **Chapter 23.**

22_3.0 Survey of Other Programmable Locks

Many other locks that are capable of being programmed have been invented. These include a battery-operated access control device using a keypad for entry of the combination (**5083122(233)**) an axial lock (**3868838(234), 3330141(235), 3572070**) changeable keys for combination locks (**1899739(236)**) safe-deposit locks (**1863525(237)**) and a key-operated combination lock with programmable gated tumblers (**4375159(238)**).

BOOK TWO: ENTRY

Methods of Entry

PART I: INVESTIGATION

PART II: GENERAL INTRODUCTION TO BYPASS: SILENT NON-DESTRUCTIVE ENTRY

PART III: DESTRUCTIVE ENTRY

Book II is divided into three parts, within which an analysis of destructive and non-destructive methods of entry is presented. The material explores how locks and locking systems can be bypassed and compromised using surreptitious techniques, as well as by force.

Part A, INVESTIGATION, has four chapters (chapters 24-27), that provide detailed information about the analysis of locks and keys, from the perspective of the criminal investigator and the forensic criminalist.

The emphasis is on **Non-Destructive Entry**, first offering an extensive checklist to determine, document, and establish whether a crime has been committed, and possibly by what means.

Although it is recognized that almost all intrusions are by force, the most serious offenses involve an aspect of covert entry. Common burglars do not pick locks or manipulate safes. However, in the realm of compromise of data, internal thefts, acts of espionage and sabotage, surreptitious entry becomes a critical factor.

Part B, GENERAL INTRODUCTION TO BYPASS, provides extremely detailed information regarding surreptitious methods of entry, such as picking and impressioning. Chapter 28 provides an overview of the primary techniques employed in opening locks, with the focus placed upon picking and impressioning. In Chapters 29-31, specific information is provided regarding each primary classification of lock and how they can be opened. For the crime lab technician and criminal investigator, this material will provide a thorough understanding of the techniques utilized in bypass. This information should be equally useful to the intelligence officer and technical support specialist. They have the responsibility to effect surreptitious and undetected entry for the purpose of court- ordered electronic surveillance, execution of search warrants, intelligence gathering and other operations.

Part C, DESTRUCTIVE ENTRY, contains one chapter, Chapter 32. It examines the tools and techniques utilized in the forced-entry of locks and enclosures. A brief discussion of forensic examination, in the context of forced-entry of safes and vaults, is also presented in Chapter 35.

PART A: Investigation

Locks, Safes and Security

CHAPTER TWENTY-FOUR: INVESTIGATION

Investigation and Evidence Involving Locks and Keys

Master Exhibit Summary

A forensic investigation involving the theft of a BMW automobile. Courtesy Hans Mejlshede.

Doing research on different bypass techniques is important for the forensic investigator. Courtesy of Don Shiles.

Analysis of a case involving forensics. Courtesy of Don Shiles.

Case example, burglary investigation. Courtesy of Don Shiles

Case example of hotel lock bypass. Courtesy of Don Shiles.

Case example, Courtesy of Hans Mejlshede.

Analysis of a case involving forensic locksmithing. Courtesy of Don Shiles.

Mail slot bypass device. Courtesy of Hans Mejlshede.

Keys can be copied by taking a 1:1 image using a copier machine. Courtesy of Hans Mejlshede.

Master key records. Courtesy of Hans Mejlshede.

Investigative clues that develop during a case. Courtesy Jim Bickers.

Pickability or ease with which a lock can be picked. Courtesy of Hans Mejlshede.

24_1.0 Introduction

This chapter will provide a comprehensive checklist for the criminalist and investigator about the methods of surreptitious or covert (non-destructive) entry and bypass of locks and locking systems. The primary focus is upon locks that utilize keys. Later chapters will offer specific information about bypass of each generic type of lock.

Doing research on different bypass techniques is important for the forensic investigator. Courtesy of Don Shiles.

We will examine circumstances where locks are bypassed through manipulation of their components in a non-destructive manner that neither leaves obvious physical evidence or affects the operation of the lock subsequently. Then, the analysis of internal and external components for signs for surreptitious entry will be presented. Examination of locks that have been the subject of forced-entry is covered in **Chapters 26**, **27**, and **32**.

Locks and locking systems are examined at crime scenes and in secure areas suspected of being compromised for many reasons. Keys, specialty tools, lock-picking tools, key blanks, code books, and other indicia of criminal activity may also be relevant and are analyzed to determine:

- **Evidence of entry;**
- **Was a lock picked or otherwise bypassed;**
- **Prove or disprove unlawful entry;**
- **Identification of perpetrator;**
- **Identification of methods of entry;**
- **Develop investigative leads;**
- **Link individuals with prior criminal activity;**
- **Link associates through a terrorist and criminal association file.**

Locks are examined, either before or after an incident has occurred, concerning the following:

- **Criminal investigation;**
- **Civil insurance claim;**
- **Security investigation regarding breach, espionage, sabotage, or terrorist activity;**
- **Prevention of loss;**
- **Safety of life or property;**
- **Collateral issues involving liability and insurability.**

Often, the criminalist is asked to determine whether a lock has been bypassed, opened with keys, or by other means. Bypass techniques will include but not be limited to:

- **Decoding and key generation or simulation;**
- **Top level master key decoding and extrapolation;**
- **Picking;**
- **Impressioning;**
- **999 rapping;**
- **Other forms of manipulation;**
- **Drilling and repair;**
- **Drilling and replacing the entire lock;**
- **Altering the pin-stack prior to entry;**
- **Using an unauthorized key;**
- **Prior replacement of one or more locks.**

Techniques for bypassing locking systems can take many forms: some simple, and some very complex. Although in the vast majority of burglaries entry is accomplished by force, there are serious instances of covert entry. Internal theft, sabotage, espionage, and other crimes generally rely upon such techniques.

Many variables can affect the ability to compromise a locking system. Thus, the detection of the method of entry may be quite difficult. In many instances, such evidence may only be gathered through the logical inference of facts, for there is often no physical evidence from which to draw such conclusions.

The analysis of a crime scene to determine methods of covert entry is quite complex and often inconclusive. Most crime laboratories throughout the world do not conduct such inquiries on a routine basis. The examinations can be quite difficult, time consuming, and require expertise not ordinarily available or possessed by the criminalist.

The forensic investigator must be concerned with what the evidence both proves and does not prove. This is extremely important, because erroneous conclusions can easily be drawn from physical evidence. Such conclusions would be subject to rigorous cross-examination.

Analysis of a case involving forensic locksmithing. Courtesy of Don Shiles.

For example, marks may be found on internal locking components that may have been caused by picking. Such marks may just as easily have occurred during normal use.

In the view of the author, this chapter is one of the most important in this text. The preceding 23 chapters all have provided the foundation and theory to support the data presented in this and the following eleven chapters. The information provided here will sensitize the criminalist and investigator to the many possible means that may have been employed to effect entry or compromise a locking system. Those responsible for providing a solution to a given set of facts that are encountered or developed at a crime scene must be able to ask many probing questions. The importance of this material is to raise the threshold of awareness of relevant issues that must be factored into an analysis of any suspected bypass.

The chapters are organized to provide a basis for the evaluation of the potential for bypass and a determination of the most likely methods of entry. Information will also be provided to indicate situations where indications of entry have been fabricated by alleged victims.

In some cases, investigators may first have to conduct a lengthy inquiry to determine one or more ways to bypass a lock or locking mechanism in order to reach a conclusion as to probable entry methods. Most often, a manufacturer will not provide any relevant information regarding its bypass. In fact, they will generally state that the lock is secure against attack, and will rarely admit or be aware of design defects or methods of compromise.

Locks can be analyzed both in the field and in the laboratory, thus allowing two distinct inquiries to be pursued with some overlap. Special care must be taken at the scene to insure that the laboratory examination is not compromised due to improper techniques.

In order to competently investigate covert entry, a thorough understanding of the following topics (covered in Chapters 1-23) by both the investigator and criminalist is essential:

- **Anti-picking features**
- **Bypass capability and methods of entry**
- **Bypass techniques**
- **Code cutting of keys**
- **Cross-keying**
- **Databases and reference materials for locks**
- **Decoding of locks**
- **Differs and depth coding: theory and reality**
- **Disassembly of locks**
- **Evidence of bypass**
- **Forensic analysis of locks**
- **Forensic disassembly of locks**
- **Identification of locks, keys, and components**
- **Impressioning**
- **Key-duplication procedures**
- **Keying of locks**
- **Keying systems, including master keying**
- **Keyways and restrictions**
- **Locking hardware**
- **Locks and theory of operation of each type of mechanism**
- **Manufacturing specifications for locks and keys**
- **Metals and Metallurgy**
- **Methods of forced-entry**
- **Picking**
- **Safes: construction, locks, and methods of entry**
- **Security systems and access control**
- **Specifications for key machines**
- **Tolerance specifications**

- **Tools utilized in bypass**

24_1.1 Case Examples

The following simple factual situations encountered during the course of investigations conducted by the author illustrate the variety of issues that can confront the investigator or criminalist. Hopefully, the material presented will provide many potential avenues of inquiry. These cases will be revisited at the end of **Part A.** Also included are summaries of cases that have been worked by Hans Mejlshede, Don Shiles, and other forensic locksmiths.

A forensic investigation involving the theft of a BMW automobile. Courtesy Hans Mejlshede.

Analysis of a case involving forensics. Courtesy of Don Shiles.

Case example, burglary investigation. Courtesy of Don Shiles

Case example of hotel lock bypass. Courtesy of Don Shiles.

Case example, Courtesy of Hans Mejlshede.

Investigative clues that develop during a case. Courtesy Jim Bickers.

Case #1: Money is missing from an inner locked drawer that is contained within a safe. There are no signs of forced-entry.

Case #2: An apartment has been broken into. Property, including jewelry, is missing. There is a large insurance claim based upon the loss. There are tool marks on the face of the lock and within the keyway.

Case #3: A lock shop has been burglarized. The insurance company believes that the burglary report is false; that the owner setup the loss, because the high-security locks cannot be bypassed.

Case #4: Property is missing from an office. All employees have been polygraphed with negative results.

Case #5: Confidential information has been compromised from a computer. The keyboard is always locked at night or when not in use. An employee is suspected.

Case #6: Upon opening the store on Monday morning after a three-day holiday, there is money missing from the safe. There is no sign of forced-entry. The theft obviously occurred over the weekend; the manager is the prime suspect because he was the only individual having the combination. The lock is a Sargent & Greenleaf 6730, 3 combination, with 1,000,000 permutations.

Case #7: A theft of jewelry occurred in a hotel room safe, at a very exclusive resort. There are no signs of forced-entry, either in the safe or door lock. The guest has been polygraphed with negative results.

Each of these cases should immediately cause certain initial questions to be raised. The purpose of this chapter is to sharply define issues in order to make a case solution possible. The following discussion is concerned with any crime, suspected crime, compromise of a secure area, or other incident where the critical element, as a condition of entry, is bypass of a locking system or component.

A comprehensive checklist is presented in order that a possible determination can be made as to methods of entry or compromise and the resulting development of investigative leads. This outline will also provide the information necessary for a thorough analysis of the locks, keys, locking systems, and access control for a given area.

It is the author's intent to provide a road map for the criminalist and investigator, which explores the intricacies of locks and how they can be compromised.

24_2.0 Preliminary Field Investigation Checklist

Before beginning an examination in the field or crime lab, it is important that the criminalist and investigators focus upon exactly what information is being sought. Initially, and depending upon who is conducting the inquiry, one must consider precisely what data is required if the investigation is to be successful. Simply stated, what do you need to know at the conclusion of the examination in order to identify perpetrators, produce investigative leads, or reconstruct events? The following **Preliminary Field Investigative Checklist** can provide

many avenues of inquiry at the crime scene or remote physical location to help answer that threshold question.

The checklist will focus on **locks, keys, and locking systems** that are examined at the scene, rather than in the crime laboratory. A preliminary and cursory forensic inquiry and examination in the field can yield valuable information and provide investigators with relevant leads, often quickly. The material is organized under two main headings: **Bypass of the Components of the Lock;** and **Keys. Components** encompass internal and external parts, and secondary-locking mechanisms including strikes, bolts, and cylinder-securing devices. **Keys** involve key system analysis and key control. Under each category, both summary information and relevant areas of inquiry are presented.

The starting point for any inquiry is to determine how entry was accomplished: was it by forced or surreptitious means, and if a lock was operated, opened, or bypassed in the process? In other words, are there visible signs of entry.

24_2.1 Actual Method of entry:

Preliminary questions that must be addressed prior to a forensic analysis and evaluation of lock sub-systems will include:

- **Was a lock opened, operated, or used to gain entry;**
- **Are there obvious methods of entry available. What are they;**
- **Could there have been an open window or door or a lock left unlocked;**
- **Is the apparent method of entry consistent with operating the lock;**
- **Was entry in fact accomplished;**
- **If entry was not completed, why not;**
- **If surreptitious entry is suspected, was a key possibly involved;**
- **Is the suspect lock presently working, and, if so, does it operate normally;**
- **What actually unlocked the mechanism;**
- **Is the physical evidence consistent with what was required to open the door or lock:**
- **Physically, what tools were required to effect entry;**

- **How much time was required to effect entry;**
- **How much noise or attention would be expected during entry;**
- **Was any property damaged during the entry process;**
- **Was any trace evidence left at the scene, or taken from the scene;**
- **Was any tool mark evidence left at the scene;**
- **Were any implements of the crime left at the scene such as tools indicating interruption of the entry process. This information may provide further evidence of the skill level of the perpetrator;**
- **Were any dangerous conditions created as the result of entry, i.e., explosives, loose debris or other items, weakened items, poisonous or toxic gasses or substances, or other hazardous materials;**
- **If the motive for entry was burglary, analyze what was taken. Does the value of the goods and method of attack seem consistent. If it appears that entry is connected with an insurable loss or the theft of records that might provide evidence of a crime, the likelihood of simulated surreptitious entry must be even more closely examined;**
- **Were standard universally coded keys utilized to gain access. This would include elevator keys, power panels, telephone panels, lockers, gates, alarm panels, and other access control devices that are keyed alike throughout a geographic area or industry. An excellent example are the elevators in New York state and New York city. Ordinances require that all elevators within the five boroughs of New York be keyed alike for fireman access. Likewise, a state law requires all elevators anywhere in New York be keyed alike (other than New York City).**

If one or more employees could have caused the loss, either intentionally or through negligence, then consideration of the level of employee compensation versus the potential for compromise must be evaluated. That is, an overall security rating of the system must be undertaken and compared to the likelihood that an employee was responsible.

- **Could an employee have left duplicate keys in a desk drawer or other unsecured location that would allow**

access;

- **Although an employee states that it is certain that he or she locked a specific mechanism, is there a possibility that in fact the employee forgot or intentionally caused the lock to remain open. This is especially relevant if insurance coverage is based upon the affected area being secured;**

The burden of proof in any given loss should also be considered. Does the insurance company require that "approved" locks be utilized in order for coverage to be in effect? If so, are such locks in use?

- **Was the suspect mechanism locked or unlocked when the intrusion was discovered. If the lock was picked, generally it will remain in the unlocked position, especially in higher security devices. It is the author's experience that most intruders will not take the time to repick a lock to the original position. However, this is by no means a certainty, especially if the thief is attempting to shift blame to others or conceal the fact altogether;**
- **How often is the lock operated each day. This will provide information for the forensic examiner regarding internal tool marks;**
- **Has anyone inserted a key into the lock since the suspected entry;**

It is extremely important to determine if anyone else has used the lock since entry occurred. This is critical when looking for tool marks, metal fragments, and debris that may have been transferred from the user of the key to internal components.

24_2.2 Purchase, Installation, and Service

- **Where and when were locks purchased;**
- **Were they factory or locally keyed;**
- **Who installed the locks;**
- **Is there any coincidence between recent burglaries and the use of a common locksmith;**
- **Who maintains the locks;**
- **Are lock service records kept that include system coding data;**

- **How are records stored and at what location;**
- **If kept on computer, are files secure;**
- **Were locks originally registered with the factory. If so, have there been any recent additional key requests of the manufacturer or local locksmith.**

24_2.3 Security Rating of the Lock and Lock System

- **Are high-security locks installed. Does the lock carry a UL 437 or equivalent EC rating;**
- **What is the tumbler orientation of the lock (vertical or horizontal) and how does this affect pick resistance;**
- **Are security pins (serrated, mushroom, spool) employed. Are telescoping pins present for extra security;**
- **Does the lock utilize a paracentric keyway for added pick resistance;**
- **Has special pick or decoding tools or procedures been developed for this type of lock. Are there known picking or bypass techniques;**
- **What is the pick resistance or ease with which the lock can be bypassed;**

Pickability or ease with which a lock can be picked. Courtesy of Hans Mejlshede.

- **Do locks utilize high-tolerance components, factory original keys, and incorporate anti-pick features;**

24_3.0 Bypass and Compromise of Locks: Internal and External Components

Locks may be surreptitiously bypassed through external means such as picking and impressioning or by internal manipulation or alteration of components.

24_3.1 Internal Bypass

This requires that the lock be taken apart, altered, and reassembled without any visible outward signs. Locks may be

internally bypassed by:

- **Altering the pin-stack prior to entry:**
  - **removing one or more tumblers to reduce pick resistance;**
  - **adding one or more tumblers to create multiple shear lines;**
- **Manipulation of lock mechanism;**
- **Removal of retaining screws from cylinder;**
- **Disassembled, decoded, and reassembled;**
- **Drilling and repair not visible to naked eye.**

24_3.1.1 Altering the Pin-Stack Prior to Entry

The pin-stack may have been altered for several reasons, all of which may reduce security. Alterations include:

- **Removal of security tumblers;**
- **Addition of pins to increase the number of shear lines (and reduce pick resistance);**
- **Placement of extra master pins within the lock to allow a different key (cross-key) to open the lock.**

The addition of master pins will allow an individual to be in possession of a key for a given lock that does not match the change key. Thus, a defendant might claim that he had no knowledge that the key would open a lock, and in fact the key should not have worked but for the addition of pins.

24_3.1.1.1 Removal of One or More Tumblers to Reduce Pick Resistance

One or more sets of tumblers may be removed from a lock to reduce pick resistance. Security tumblers may likewise be replaced with standard lower or upper pins.

24_3.1.1.2 Adding One or More Tumblers to Create Multiple Shear Lines

Master pins may be added to individual pin stacks to increase the number of shear lines (and cross-keying combinations). This will reduce pick resistance.

24_3.1.2 Manipulation of Lock Mechanism

Locks may be manipulated in a variety of ways to accomplish opening. Picking, impressioning, 999 rapping, visual decoding, use of a blank key, specialized decoding and other forms may all be employed. In one instance, a European lock manufacturer assembled pin tumbler locks at two different facilities, which resulted in the use of slightly different pin diameters for top and bottom pins, allowing the lock to be easily opened with a blank key. As described in chapter 29, a blank may also be utilized to pick the lock.

24_3.1.3 Removal of Retaining Screws from Cylinder

The setscrews may be removed or loosened from a cylinder, permitting release or rotation to actuate secondary locking mechanisms.

24_3.1.4 Disassembled, Decoded, and Reassembled

Locks may be disassembled, decoded, and then reassembled in order to derive change keys or master keys.

24_3.1.5 Drilling and Repair Not Visible to Naked Eye

Locks may be drilled, opened, and repaired without leaving any visible trace. This is especially true in the case of combination locks used in safes. Such techniques may also be employed in penetrating high-security locks.

24_3.2 External Bypass

External bypass encompasses any action done to the lock through external manipulation or usage that does not require disassembly or modification of internal components. Locks may be externally bypassed through:

- **Use of a key;**
- **Decoding (visual, use of shim wire, extrapolation of top level master key, or special tool);**
- **Manipulation;**
- **Bypass of secondary locking bolt or locking**

mechanism;
- **Drilling and replacing the entire lock;**
- **Using an unauthorized key;**
- **Prior replacement of one or more locks.**

The following discussion summarizes external methods of bypass and associated issues.

24_3.2.1 Use of a Key

Obviously, the simplest way to open a lock is by a key. The many ways to obtain keys are described in later sections.

24_3.2.2 Decoding

Decoding procedures take many forms. Information, however derived, is used to produce a working key. Decoding may require that the lock be disassembled, although there are some sophisticated methods that will leave no trace. These methods include:

- **Visual observation of wafers, levers, or tumblers;**
- **Use of a borescope inserted into the keyway;**
- **Use of special plastics and metals to sense tumbler position;**
- **Use of shim wire decoders, either through the pin chambers or around the plug;**
- **Use of pressure-sensitive materials.**

24_3.2.3 Manipulation

A lock may be opened through many forms of manipulation that include picking, impressioning, 999 rapping, and decoding. Detailed information regarding each of these procedures is presented in other chapters of this text. A summary will be provided here.

24_3.2.3.1 Picking

This process involves the insertion of specialized tools into a lock in order that the tumblers can be moved to shear line to allow rotation of the plug. As shown in **Chapter 29**, there are many different types of picks, depending upon the technique applied and the preference of the user. Locks may be picked

using conventional techniques with a pick gun or snap tool, by special pick tools, or by an electric impact pick. Generally, picking will leave internal marks, discussed more fully in later chapters. It is not, however, axiomatic that tool marks will remain. Depending upon the skill of the operative, the type of picks employed, and the composition of the pin-stack, marks may or may not be visible.

Picking is accomplished by moving individually or in concert each tumbler, disc, wafer, lever, or ward to its shear line position. The concept is very simple. In practice, of course, many factors affect the ability to pick a given lock.

24_3.2.3.2 Impressioning

This technique allows keys to be produced for locks without requiring disassembly. There are several different methods, depending upon the mechanism and personal deference. These include:

- **Standard techniques;**
- **Use of foil in dimple locks;**
- **Use of a special brass, lead, latex key, or hybrid key surface.**

Impressioning will generally leave internal tool marks. See **Chapter 30.**

24_3.2.3.3 999 Rapping

This is a procedure to open pin tumbler locks. It requires that a specially cut blank be inserted and “rapped” in order to create shock waves so that tumblers might be bounced above shear line. The technique is essentially identical in theory to the use of a pick gun.

24_3.2.4 Bypass of Secondary Locking Bolt or Locking Mechanism

Depending upon the design of the lock and its interface with the bolt works, strike, and other components, bypass of such systems can be quite simple. For example, a piece of spring steel may be inserted through the keyway and can then be used to rotate the cam in order to engage the strike release.

24_3.2.5 Drilling and Replacing the Entire Lock

If the original lock has been drilled, removed, and replaced, added difficulty might be encountered in detection.

24_3.2.6 Prior Replacement of One or More Locks

Locks may have been removed and replaced without the necessity of drilling as described above. For example, the author has encountered many cylinders that have loose or missing setscrews in metal door frames. These locks can be easily removed, decoded, or replaced.

24_3.2.7 Using an Unauthorized Key

If an unauthorized copy of a key has been utilized, it may be very difficult to detect and prove. There are certain methods, however, that may be employed. See the section on Keys in **Chapter 27**.

24_3.3 Queries Regarding External and Internal Bypass

- **Could simple tools have been utilized to externally manipulate locking mechanisms? For example, could an opening tool have been inserted into a mail slot in the door in order to gain access to the bolt works. Specially designed tools slip under the door, climb vertically on the locked side, and grip the handle to allow opening. A search for tool marks should be made if such access is suspected or possible;**

Mail slot bypass device. Courtesy of Hans Mejlshede.

- **Does examination of the strike and lock case indicate that they are functioning properly, correctly installed, and fitted;**
- **Are there any missing components;**
- **Are there any other obvious possible methods of entry;**
- **Could the hinge pins have been removed and replaced;**
- **Is the lock, or any component, missing;**
- **Is the cylinder loose, indicating possible**

manipulation;

- **Determine if there is access to setscrews for mortise cylinders. Can the entire cylinder be rotated, to allow the bolt to be withdrawn or removed. Have retaining screws or pins been loosened or removed in order to facilitate rotation;**
- **Check the threads on any mortise locks for wear. Look for scoring on the grooves that would indicate that the lock was forcibly spun against the setscrews. Feel whether the cylinder is loose or can be rotated;**
- **Check for marks on the side of cylinders and guard rings, indicating that tools were used to forcibly rotate the lock. Look in the side channel of the cylinder, for scratches, indicating forced rotation. Also, look for a broken setscrew tip in the door frame. The screw may have been sheared through torque and then replaced;**

Tools can be made to wrench the guard ring free. A piece of pipe that fits over the guard ring and cylinder, with a bolt through it to allow tightening and a rod for torque, works quite effectively.

- **Check for color differences in the metal of the lock and housing caused by rust or corrosion. This could indicate that the lock has been moved after being in place for a long time. Then, check maintenance records to see if the cylinder has been repaired recently;**
- **Check the surface of the cam that faces the inside of the keyway. Bypass can be accomplished using a piece of spring steel with a sharpened end, by forcing it to the back of the lock, then rotating the mechanism;**
- **Was the plug found in a picked position. In the case of a removable core lock, is the plug picked to the control shear line;**
- **Can the plug be rotated using a screwdriver, knife, or similar object, without inserting a key. If so, this would indicate that most if not all tumblers have been removed, possibly for maison keying;**
- **Does the system rely upon direct or indirect locking**

action, making manipulation more difficult;

- **Is the pin-stack correct. Do all keys fit the lock. Are there any extra pins. Have pins been removed. Are security pins, bearings, or special tumblers used in the target lock in the same proportion or configuration as in other similar locks within the facility;**
- **Are there any fingerprints on the exterior surfaces of the lock or on internal components. Are there any handprints or palm prints present on any surface affecting entry;**
- **Do the physical characteristics of the suspect lock match all other locks within the facility that were installed at the same time;**
- **Do pins appear to be more or less worn than in similar locks at the location;**
- **Is there any corrosion on the suspect lock. If so, is it consistent with other locks in the facility.**

24_3.4 Bypass and Compromise of Locks: Using Keys

There are many ways that a lock can be bypassed; one of the simplest means is to use a key. This is perhaps the most important threshold question to resolve. If it appears that a key was used to gain access, as opposed to other means of surreptitious entry, then the inquiry must focus on whether the key was intentionally or accidentally acquired.

Keys (and their coding information) may be obtained through a variety of schemes. Any inquiry involving the possible use or compromise of keys will of necessity require an analysis of the key system in place for a given lock, as well as a consideration of many interrelated factors.

Master key records. Courtesy of Hans Mejlshede.

24_3.4.1 Queries Regarding Use of Keys

- **Could keys have been lost, left in a desk or other area, or misplaced that were later found, used, and then returned. Are keys missing or stolen;**
- **Are there any key control procedures to determine:**

- **Who has keys for which locks;**
- **Accountability for all duplicate keys;**
- **Accountability for all blanks;**
- **Accountability for all old keys that are presently out of service. This is especially important in the case of restricted keyways, because keys can be cut down or built up to create a different bitting pattern;**

- **What is the procedure relating to former employees;**
- **Are duplicates kept for all locks, and if so in how many different locations;**
- **When were specific locks last rekeyed;**
- **How many keys are in inventory for any specific lock;**
- **Is a record of loaned keys maintained;**
- **Is there an access log to key cabinets and areas where keys are maintained and duplicated or locks serviced;**
- **Could someone have let an unauthorized individual into a secure area. Is contract maintenance, cleaning, or work staff utilized;**
- **Could change keys or master keys have been loaned, even briefly, to open a door. This is especially important in hotel thefts where guests often approach staff, claiming that they lost or forgot their key or left it in the room. Possession of a key, even for a few seconds, can yield code numbers and allow an individual to visually decode the key or make an impression;**
- **Are there secondary access keys for emergency use or for lock bypass. For example, many hotel card locks also have bypass keys for maintenance and security staff;**
- **Does the lock incorporate special mechanisms, such as the Corbin split ring, to prevent cross-keying;**
- **Are restricted keyways employed;**
- **Does the facility utilize a complex and integrated lock design, incorporating electronic + mechanical, or mechanical + magnetic, sidebar, or similar hybrid systems;**
- **How complex and secure is the master keying system.**

Is cross-keying prevented. How many keying levels are present;

- **Is there one top level master key for all cylinders within the system? What locks are master keyed? Can the decoding and extrapolation procedures explained in chapter 31 regarding the use of a change key to decode the TMK have been utilized;**
- **What master key scheme is employed within the facility: total position progression, rotating constant, Page, or was a non-standard system used to generate differs;**
- **Are there more than two bottom pins in any chamber, indicating that a non-standard master keying scheme was employed;**
- **Do locks have instant rekey capabilities that may in fact lower the security rating and subject them to bypass;**

24_3.5 Keying System Analysis

Keying system analysis requires an evaluation of keys in terms of keying differs, master keying, key control, codes, and storage of system data. Tracing the origin of keys back to a specific lock is also possible and is covered under **Forensic Analysis of Locks: Keys.**

The following material examines significant factors relating to keys within a keying system and specific issues that must be considered.

24_3.5.1 Keying System

- **Has the lock been keyed individually, or is it part of a complex keying system. If complex, is there the potential of cross-keying;**
- **How many levels of master keying are employed, and does the system employ recognized keying schemes to limit the number of cross-key combinations;**
- **Is a maison keying system in place. If so, locks are generally quite easy to pick; their security is very low. In some maison systems, almost any key can be inserted, jiggled, and made to turn the plug;**
- **Are removable or interchangeable core systems in**

use. Are there any missing cores. Could the control key have been compromised.

24_3.5.1.1 Master Key Levels

- **How many keying levels are present within the suspect lock;**
- **Was the system devised using an industry-recognized program following accepted keying standards. Are standard code depths utilized;**
- **How many sectional keyways are employed within the system;**
- **How many master keys are unaccounted for;**
- **Who has been issued master keys;**
- **How difficult are the keys to decode, especially the top level. What is the code for the master key;**
- **How easy would the lock be to pick or bypass;**
- **How long has the present master key system been in use;**
- **When was the change key last altered;**
- **Are any locks capable of instant rekey or reprogramming;**
- **How many locks are keyed alike;**
- **Have all individuals having keys that would fit the suspect lock been identified;**
- **Are the same keyways and combinations used in different locations, either by design or by accident;**

The system must be examined to determine if there are duplicate keys used in different areas within a large facility or complex by more than one individual working for the same entity. It may also be possible that an individual with no connection whatsoever to the subject location will have had a key that opened a specific lock by accident.

24_3.5.1.2 Number of Differs

The differs for a given lock should be calculated from the number of tumblers, depth, and spacing. This will provide an index as to apparent security. Knowledge of whether a maison keying system is used will also indicate the level of security. The

number of differs or tumbler combinations and the probability of a random opening must be considered. The use of the same keyway, the length of time that a given keyway has been in use for a given area, and cross-keying potential must all be factored into the evaluation.

24_3.5.1.3 Cross-Keying Potential and the Number of Incidental Master Keys

An analysis of the keying system will reveal whether an established scheme was utilized to reduce or eliminate cross-keying.

- **Is there any protective hardware to prevent cross-keying;**
- **What is the potential that a key not associated with the specific system will open the lock. This will require a complete examination of the keying scheme to determine all possible cross-keying combinations;**
- **How many incidental master keys will open a specific cylinder.**

24_3.5.1.4 Duplicate Keys

- **How long has the same key been used in a given lock;**
- **When was the last time the lock was rekeyed;**
- **Have keys been lost;**
- **How many keys may be in circulation for the lock. In Denmark, for example, if it can be proven that over ten keys are unaccounted for, then no insurance coverage will be in effect.**

24_3.5.1.5 Age of Lock

- **What is the vintage of the lock and keyway. When was it first introduced. This may give an indication of the number of keys in existence on a global basis.**

24_3.5.2 Codes and Code Numbers

Keys can be produced by number. Direct or indirect code numbers stamped on keys or cylinders, as well as internal identification

numbers, can allow the generation of factory original keys. Key codes can be found on a system list, can be derived by decoding the key or the lock, or can be obtained from the manufacturer. Locks may be compromised by obtaining their direct coding information. This will allow keys to be surreptitiously created. Data for a given lock may be obtained by various means, including:

- **Gaining physical possession of the key and copying it;**
- **Visually decoding the bitting, then utilizing that code for creation of a duplicate key at a later time;**
- **Viewing code numbers stamped on the key;**
- **Obtaining codes from an internal system list, from the locksmith who installed the system, or from the manufacturer;**
- **By impressioning;**
- **By use of a borescope to read the wafers, levers, or tumblers;**
- **By visual external decoding of the tumblers;**
- **By disassembling the lock;**
- **By shim wire decoding.**

24_3.5.2.1 Sources for Codes

Codes may also be determined by taking the lock apart and measuring tumblers, or by the use of special decoding tools that use shim wires as manufactured by Falle-Safe and others. Keys can be visually decoded, especially if there are distinct depth levels. In this connection, the number of depths utilized by the manufacturer should be considered.

- **Determine if the keyway for a particular lock is listed on the standard HPC, Silca, or other manufacturer key reference used in conjunction with code- cutting machines. The HPC HKD-75 handheld decoder, for example, has data for all standard keyways to allow rapid decoding.**
- **Was the lock removed, either in the process of gaining entry or prior to entry, to obtain coding information or to produce keys for later entry;**
- **Was the original lock removed and replaced by a**

different cylinder;

- **Is there a possibility that more than one lock has been removed or tampered with, either in the same or different areas of the facility;**
- **Could locks have been removed or stolen on prior occasions, in contemplation of the present incident;**
- **Is it possible to disassemble one lock and derive the master key coding for the entire facility, including the suspect lock. It is generally impossible to decode one lock and successfully produce a master key in a conventional system. This is because there may be more than one chamber containing master pins or more than one master pin for each chamber.**

Depending upon the construction of the lock and the requirements of the keying system, a lock may have several different shear lines. In that event, many combinations may be generated before the proper system master code could be determined. To work on a cylinder that is master keyed, both the change key and master key are required. However, it is possible to decode certain **positional** master key systems with only one lock. See **Chapter 11.**

24_3.5.3 Key Duplication and Generation

Keys can be produced using many different processes of duplication and generation techniques.

24_3.5.3.1 Could Keys have been Copied Surreptitiously

Keys can be copied by physical duplication through the use of a key machine, by code, by visual decoding, by silicone, wax or clay impression, by photograph, by tracing, or by the use of a copy machine. See **Chapter 8** for a detailed discussion of copying techniques.

Keys can be copied by taking a 1:1 image using a copier machine. Courtesy of Hans Mejlshede.

24_3.5.3.2 Can Keys be Easily Duplicated by Machine

It is imperative to determine the availability of blanks. It may also be prudent to check with the local distributor of the type of lock under examination in order to determine if there are many other customers in a given area using the same keyway.

- **Do locks utilize a standard or restricted keyway. If restricted, what is the security level of restriction, and what does the term "restricted" really mean;**
- **If restricted keyways are used, can blanks be milled or simulated using a similar blank;**
- **If sectional keyways are utilized within a large system, how easy is it to modify one section for use in another. If this is possible, examine other sections for the same or similar key code;**
- **Are restricted keyways in use by other non-related lock owners;**
- **Does the manufacturer maintain key code control and coordination with all customers in the area;**
- **Can the manufacturer trace keys to an owner through registration;**
- **Who stocks or sells blanks for locks that have been compromised;**
- **Are blanks maintained on premises. Can they be obtained at the local hardware store or locksmith;**
- **Is there anything special about the keyway.**

24_3.5.3.3 Missing Keys used to Produce Different Keys

- **Are there any keys that are missing. If so, could these have been utilized to produce a key for the suspect lock.**

24_3.5.3.4 Special Key Cutting Machine

- **Was a special cutting machine required to produce keys to a given lock. If so, who manufacturers such a machine. Who has one in the local area. The EVVA 3KS system, for example, requires a machine costing in excess of $150,000 to duplicate its**

complex laser-track keys. The likelihood of conventional duplication is virtually nonexistent. However, a simple clay impression is easy to accomplish.

24_3.5.3.5 Could Keys have been Borrowed and Copied

- **Was a copy or extra key made recently. If so, at what location. Could the operator have made a duplicate key without the knowledge of the customer;**
- **Can an examination be made of source keys in an attempt to determine if copies were made. For example, the author reviewed evidence of key copying from a rental car company where Mercedes-Benz automobiles were stolen in Germany. It was determined that there were distortions in the guide pin of the key cutter that were reproduced on the copied keys, thus proving that copies were made from originals. See subsequent material regarding forensic analysis of keys.**

24_3.5.3.6 Suspect Having Access to Keys

- **Who had access to keys that may have been copied or duplicated. Are extra keys kept in a secure area or in a locked key case. If keys are kept in such a key caddy, how difficult is the lock to pick. Generally, most key containers utilize wafer or tubular cam locks that are easily bypassed;**

- **Did the perpetrator have access to blank keys, out-of-service or old keys, or missing keys with the same keyway that could have been used to produce a key for the lock.**

24_3.5.3.7 Key Control for a Specific Lock

Each manufacturer establishes and implements certain key control guidelines, criteria, and technical standards for a lock. This is to protect their legal standing to restrict the sale and distribution of keys, key codes, blanks, and key duplicating machines. If no patent or copyright protection is in force, then

lock and key manufacturers have no proprietary or intellectual property rights that would prevent others from making facsimile products. Key control is a significant component of any investigation involving the surreptitious bypass of a lock. The following issues must be pursued:

- **Is patent or copyright protection for the keyway and keys in effect. Such protection will restrict the availability of and trafficking in blank keys through unauthorized channels because of the heavy penalties associated with infringement;**
- **Are knockoff or facsimile blanks available in the area where the suspect lock is installed;**
- **Are proprietary and unique key sections available for complex installations. This would include related master key sections.**

24_3.5.3.8 Does the Lock Mechanism Employ Secure Keying Techniques

- **Can an individual with limited access to other similar keys modify them to operate more locks than intended**

24_3.5.3.9 Does the Lock have a High Key Differing Potential

Often, the blade depths for any bitting surface is divided into ten steps of approximately .015″ each. When the tolerance at shear line exceeds .005″, a bitting step of .015″ is too small to offer any real security. Bitting steps of less than .060″ invite cross-keying problems. If a master key system is in place, then several million theoretical key differs must be available to yield only a few thousand non-interchangeable keys, especially in many of the high-security locks.

24_3.5.3.10 Is the Lock Recognized as a High-Security Device

Is there universal government acceptance of the lock for high-security applications. As detailed in **Chapter 10**, the prime criteria for a security rating, especially UL 437, includes pick resistance, key control, and resistance to penetrating tools.

CHAPTER TWENTY-FIVE: LOCKS AND FORENSICS

Forensic Examination: Specifications, Operation, and Security

Master Exhibit Summary

Figure 25-1 Partially picked axial pin tumbler lock
Figure LSS+2501 Forensic investigation forms
Figure LSS+2502 Forensic evidence log-in report by Hans Mejlshede
Figure LSS+2503 Sample forensic analysis form by Hans Mejlshede

Art Paholke is the father of modern forensic locksmithing. Courtesy of Hans Mejlshede.

Many car thefts are simulated for insurance claims. Courtesy of Hans Mejlshede.

It is essential to save the pins from a lock that has been the subject of a burglary attack. Courtesy of Hans Mejlshede.

Pressure will often be applied to the forensic locksmith during the course of an investigation to change the results of a report. Courtesy of Hans Mejlshede.

A clean work area for the forensic locksmith is a necessity. Courtesy of Hans Mejlshede.

Care must be exercised in cleaning of components. Courtesy of Hans Mejlshede.

The Forensic locksmith is often called upon to investigative covert entry. Courtesy of Hans Mejlshede.

The forensic investigator must prepare detailed reports. Courtesy of Hans Mejlshede.

Evidence in car theft investigations. Courtesy of Don Shiles.

Analysis of vehicle locks. Courtesy of Hans Mejlshede.

Analysis of vehicle theft cases. Courtesy of Hans Mejlshede.

Simulation of vehicle theft. Comments on investigation. Courtesy of Hans Mejlshede.

Investigations involving vehicle fires. Courtesy of Hans Mejlshede.

Analysis of marks produced by a slimjim bypass tool. Courtesy of Hans Mejlshede.

Use of rubber or silicone-coated tweezers. Courtesy of Hans Mejlshede.

Discussion regarding microscopes for use in forensic analysis. Courtesy of Hans Mejlshede.

Issues regarding crime scene sketches. Courtesy of Don Shiles.

Evidence handling techniques. Courtesy of Don Shiles.

Methods of forensic analysis. Courtesy of Don Shiles.

The investigative locksmith as a witness. Courtesy of Don Shiles.

Required background of the forensic locksmith and investigator. Courtesy of Don Shiles.

Definition of a forensic locksmith.

Use of photograph. Courtesy of Don Shiles

What is an investigative locksmith? Courtesy of Don Shiles.

An introduction and summary of forensic locksmithing. Courtesy of Hans Mejlshede.

Forensic locksmithing history and the role of Art Paholke. Courtesy of Hans Mejlshede.

Was the lock picked? Courtesy of Don Shiles.

Macro lens, Courtesy of Hans Mejlshede.

Data back for documentation of images. Courtesy of Hans Mejlshede.

Photographic equipment requirements. Courtesy of Hans Mejlshede.

Ring strobe is a necessity for forensic photography. Courtesy of Hans Mejlshede.

Use of plastic tweezers. Courtesy of Hans Mejlshede.

Recovering stamped numbers from keys and locks. Courtesy of Hans Mejlshede.

Opinions of examiner, and certainty of their opinions. Courtesy of Hans Mejlshede.

Logging receipt of evidence. Courtesy of Hans Mejlshede.

Issuers regarding investigative reports. Courtesy of Hans Mejlshede.

It is difficult to bypass laser track locks through the use of jiggle keys. Courtesy of Hans Mejlshede.

Definition of an Investigative locksmith. Courtesy of Don Shiles.

Forensic marks and their observation with proper lighting. Courtesy of Don Shiles.

The investigative locksmith gets involved in insurance fraud cases. Courtesy of Hans Mejlshede.

Marks on the back of the lock from bypass. Courtesy of Hans Mejlshede.

Use of WD-40 to clean and lubricate. Courtesy of Hans Mejlshede.

Oxidation and dating of marks in a forensic examination. Courtesy of Don Shiles.

Forensic implications of using a shim to open a lock prior to analysis. Courtesy of Hans Mejlshede.

An attempt may be made to mask pick marks so that the perpetrator is not identified. Courtesy of Hans Mejlshede.

Obtaining all keys that fit a particular cylinder. Courtesy of Hans Mejlshede.

Removal of cylinder and its analysis must be done correctly. Courtesy of Hans Mejlshede.

Changing or removal of top pins. Courtesy of Hans Mejlshede.

Preliminary issues in the examination of a lock. Courtesy of Don Shiles.

Examination of a lock and disassembly. Courtesy of Don Shiles.

Examination of a lock and marks that are visible. Courtesy of Don Shiles.

Information during a forensic investigation. Courtesy of Don Shiles.

Opening a lock using a blank key and a shim. Courtesy of Don Shiles.

LSS202: Forensic investigation and the locksmith, by Don Shiles

25_1.0 Forensic Analysis of Locks and Keys

Methods of forensic analysis. Courtesy of Don Shiles.

Information during a forensic investigation. Courtesy of Don Shiles.

Chapters 25-26-27 deal with the forensic examination of locks and keys in the laboratory. We begin with a summary of precautions and procedures designed to safeguard evidence that is to be evaluated and to preserve vital information about such evidence. Data is then presented regarding the individual lock components to be examined and each specific type of forensic examination to be performed. The author is indebted to Hans Mejlshede for his assistance in research for much of the material in this chapter. Many of the graphics and audio segments that have been included within Chapter 24-27 were prepared by Mr. Mejlshede.

Chapter 25 will also provide information regarding the preliminary analysis of a lock to determine its operation, specifications, and security.

Chapter 26 will detail the techniques and analytical criteria for developing tool mark and trace evidence left in a lock. **Chapter 27** will look at keys from the perspective of identification of suspects, locations, and property. Generally, disassembly of the lock will be conducted in a laboratory environment. See **Chapter 16** for detailed disassembly procedures. The analysis of locks for possible covert entry is one of the primary functions of the forensic examination.

Opening a lock using a blank key and a shim. Courtesy of Don Shiles.

The Forensic locksmith is often called upon to investigative covert entry. Courtesy of Hans Mejlshede.

25_1.1 Preliminary Considerations and Precautions

If a forensic examination is to be performed, additional precautions need to be taken both at the scene and in the laboratory. It is important that all evidence be preserved from the crime scene. Forensic locksmiths should be cautioned that if cylinders have been attacked, they should be replaced, and the suspect components preserved and transmitted to the laboratory for further analysis.

It is essential to save the pins from a lock that has been the subject of a burglary attack. Courtesy of Hans Mejlshede.

Preliminary issues in the examination of a lock. Courtesy of Don Shiles.

25_1.1.1 Precautions and Procedures at the Scene Prior to Laboratory Examination

- **Be certain to log which way the cylinder plug must be rotated to open while in the door. Log this information and draw an arrow on the face of the lock or on the evidence tag;**
- **Seal both ends of the cylinder with tape so that no material can leave or enter the lock;**
- **Identify each lock to its source location;**
- **Photograph each lock taken from the scene prior to disassembly;**
- **If electronic locks are involved in the investigation, be certain to download the contents of memory to preserve audit trails of entry/exit history. Determine if external electrical supplies provide power to run computers within locks; the removal of such power may erase volatile memory. Determine if there are onboard backup batteries such as lithium cells, prior to disconnection of any power source;**
- **All telephones associated with locked areas should be checked for redial,**

stored number, and last number dialed capabilities. If the telephone is so equipped, this information should be captured and downloaded prior to using the telephone or removing power from the instrument;

- **Be certain to document whether cylinders have been repaired after a burglary or loss. In such cases, new cylinders should be installed, and the original mechanism retained as evidence;**
- **Draw an arrow on the cylinder to indicate which way the plug was turned to open the lock;**

Removal of cylinder and its analysis must be done correctly. Courtesy of Hans Mejlshede.

25_1.1.2 Precautions and Procedures in the Laboratory

The following checklist provides minimum guidelines as to required documentation prior to conducting a forensic analysis of any lock. There may be some overlap in procedures between examinations.

- **Be certain that the work area is clean and devoid of other lock components or contaminants. If the examination is being conducted by a forensic locksmith, it is recommended that the normal work area not be utilized;**
- **If the components of the lock are to be cleaned, be certain to inspect them first. There may be valuable evidence in the appearance of grease or other lubricants that may be lost in the cleaning process.**

Care must be exercised in cleaning of components. Courtesy of Hans Mejlshede.

Use of WD-40 to clean and lubricate. Courtesy of Hans Mejlshede.

A clean work area for the forensic locksmith is a necessity. Courtesy of Hans Mejlshede.

- **Verification that the lock can be destroyed, if necessary, in order to empty chambers and to examine**

interior portions of the plug. This may be especially important in the case of padlocks if they cannot be disassembled;

- **All observed marks and tracks, regardless of origin:**
  - **Any marks caused to be made by the examiner upon any internal or external component of the lock;**
  - **The presence of marks on each pin;**
- **All foreign materials in the plug, including metal fragments, grease, oil, graphite, paper, glue, foreign metal;**
- **Identification of each pin within each pin-stack, noting the order and sequence within the plug;**
- **For each pin:**
  - **the diameter;**
  - **the color;**
  - **the design of the bottom and top (square, rounded, chamfered, pointed);**
  - **the type of pin (driver, wafer, bottom, security);**
  - **the presence of ball bearings;**
- **Documentation of all steps performed in the examination process;**
- **Mark the side of the plug to denote case information;**
- **Note and document the proper cam orientation. In most cylinders, the screw holes are countersunk from the outside;**
- **Verification that the lock was sealed when received;**
- **Upon receipt of sample, with cover letter requesting specific examinations, documentation of all identifying data regarding the lock, including:**
  - **Manufacturer;**
  - **Model and any numbers stamped on the side of the cylinder;**
  - **Year when model discontinued, if applicable;**
  - **Generic type of lock: warded, lever, wafer, pin**

tumbler, combination, electronic, hybrid, instant rekey;

- **Code numbers stamped on the lock;**
- **Keyway identification;**
- **Lock shell material;**
- **Plug material;**
- **Pin tumbler, lever, or wafer material;**
- **Security rating of lock;**
- **Estimated age of the lock;**

- **Is the lock new or worn, and degree of use, expressed on a 1-6 scale:**

1	***new, no visible wear***
2	***very little use, high tolerances***
3	***average wear***
4	***heavy use, high wear***
5	***old, low tolerance***
6	***unreliable erratic operation***

- **All components should be photographed. Frame sequence numbers should be logged with a description. All photographs should be made in the same manner to allow an accurate comparison;**

- **Photograph of:**

  - **all items received with cover letter;**
  - **cylinder, front view;**
  - **cylinder, side view;**
  - **bitting of key to allow decoding from photograph, if necessary;**
  - **all internal and external parts, both prior to removal from the lock and upon examination;**

- **Sequentially numbered negatives or frames for all photographs. Use one film roll for each case, or imprint case number and sequence number on each photograph;**
- **Utilize a databack or other time-date generator on the camera that will produce the time, date, and frame or case number. Be**

certain not to utilize an orange or red background when using time-date backs, due to the imprint color utilized;

- **Choose a high f-stop for better depth of field when shooting microphotographs.**
  F22 will yield significantly better photographs when shooting marks on pins.

- **Color coding of each tumbler, if relevant, to document position in plug or shell. Often, pins are also factory color-coded by length. This information needs to be recorded. The author may also color-code individual pins, by position within the plug, irrespective of the factory-coding scheme. From the front of the plug, pin 1=brown; pin 2=red; pin 3=orange; pin 4=yellow; pin 5=blue; pin 6=green; pin 7=violet; pin 8=grey; pin 9=white;**

- **Pin-stack length and diameter for each chamber, and insure that top and bottom pins have the same diameter;**
- **All pin-stack permutations in order to determine every depth combination that will open the lock. This will include all change keys, master keying levels, and cross-keying possibilities;**
- **The surface design of the lower tumbler that contacts the bitting surface (rounded, chamfered, pointed, square, steel bearing);**
- **Inventory of all components that have been examined and which are contained within the lock. An inventory should include the physical number of parts for each category listed below, as well as identification of the part itself, and notation of any missing parts. The parts list should include:**

- **Springs;**
- **Plug and plug cover;**
- **Wafers, levers, tumblers (including upper, lower, and master pins);**
- **Secondary pins;**
- **Ball bearings;**
- **Keyway guides;**

- **Spring-retaining cover;**
- **Setscrews for chamber sealing;**
- **Tailpiece and screws;**
- **Anti-drill pins;**
- **Sidebar and springs;**
- **Shell.**

- **Documentation regarding the orientation of sidebar inserts (such as in ASSA locks);**
- **Check for foreign object at the front of the keyway, placed to delay entry of authorized individuals in order to give illegal entrants notice and time to flee;**
- **Setup a similar cylinder pinned to same combination. This cylinder may also be utilized as a control for picking;**
- **Setup similar cylinder, pinned to same combination,and picked using 999 keys;**
- **Availability and use of modeling clay to hold components for examination and photography.**

25_1.1.3 Special Precautions in the Laboratory

The criminalist must be certain that the following procedures are followed to insure valid results, protect against the destruction or contamination of evidence, and to thwart defense objections:

- **If analyzing electronic locks such as utilized in hotels, be certain to verify whether the lock maintains an audit trail of transactions. If so, download all information prior to disassembly;**

- **Determine how many pin chambers the lock contains and if there is a pin-stack for every chamber. This is very important to learn prior to disassembly, because the lock may be a six tumbler mechanism but only loaded for five pins;**

- **If the plug is improperly withdrawn from the shell (removed without rotating at least 30º from shear line) then a top pin can drop into an empty bottom chamber. This will generally destroy a spring, make**

removal difficult, and mark internal surfaces;

- **Use extreme caution when taking a cylinder apart not to disturb the rotational position of pins. Although this may not be relevant in some investigations, the orientation of pins can be extremely important to document certain types of picking techniques. Thoroughness also dictates the practice;**

Forensic implications of using a shim to open a lock prior to analysis. Courtesy of Hans Mejlshede.

- **If a dimple lock is to be taken apart, check to be certain that all pins are in pin chambers prior to disassembly. In certain instances, if a lock has been picked and the plug remains in that state, drivers can drop out of their chambers. Likewise, if the plug is rotated in a profile cylinder to what would normally be the position where springs and drivers would be ejected, pins can fall into the open area;**
- **Pin-stack combinations must remain intact. A mix-up in the order of pins can be disastrous. This is especially true in the case of master pins;**

- **If the lock is to be cleaned prior to disassembly, be certain to keep the wash that was utilized. This will retain any foreign materials that are present. The author does not believe that washing should be done;**
- **Use nylon, plastic, or wooden tweezers or tongs. Standard tweezers may also be coated with Plasti-Dip or other silicone-based materials;**

Use of plastic tweezers. Courtesy of Hans Mejlshede.

Use of rubber or silicone-coated tweezers. Courtesy of Hans Mejlshede.

- **Use setup tray to maintain the integrity of tumblers;**
- **Prior to disassembly, be certain to examine the plug for brass debris;**

- **Setup the identical lock body (duplicate) with the same springs and drivers using new pins to test tension, metal loss, and marking.**

25_1.2 Forensic Examination of Locks: Specific Components to be Evaluated

Examination of a lock and disassembly. Courtesy of Don Shiles.

The following items, parts, and components must be closely examined and inventoried anytime a thorough forensic examination for physical evidence of bypass and operational characteristics is to be conducted:

- **Cylinder (internal and external);**
- **Plug;**
- **Pins, wafers, levers, discs;**
- **Springs;**
- **Plug and Cylinder (together);**
- **Key, plug, and pins (together);**
- **Pins and shell (together);**
- **Brass spring retainer;**
- **Plug-securing means: screws, arc ring, cam.**

25_1.2.1 Examination to be Conducted

Six primary forensic examinations and evaluations may be conducted, depending upon the evidence sought. They are:

- **Lock specifications and data;**
- **Operation of the lock;**
- **Security of the lock;**
- **Indication of manipulation and bypass: tool marks;**
- **Material transfer;**
- **Keys.**

Was the lock picked? Courtesy of Don Shiles.

Within the category of **Indication of manipulation and bypass,**

there are four subcategories:

- **Method of entry and whether destructive or non-destructive;**
- **Presence of tool marks and how they were created;**
- **Type of tools used to effect bypass;**
- **Skill of the perpetrator.**

The remainder of this chapter will examine and evaluate the operation, specification, and security of a lock with an emphasis upon underlying theories and procedures. The reader will recognize that some material has been repeated in slightly different form from earlier portions of **chapter 24** based upon the specific emphasis of each section. Some material will overlap between areas of inquiry. This is especially true in the case of tool mark examinations. Information presented in each of the areas of examination can and often will relate to the presence or absence of marks.

The author has attempted to organize the data in the most relevant and coherent form. However, the reader must consider all information in the examination process, in order to look at the lock as a composite of its individual components. Finally, it will be noted that details of dissecting the plug have been placed in the section dealing with tool marks rather than in the preceding text, because the procedure is germane to that specific topic.

25_1.2.2 Queries During Analysis of Locks and Keys

Examination of a lock and marks that are visible. Courtesy of Don Shiles.

The examiner will be concerned with the following issues during the analysis of a lock, keys, and associated hardware:

- **Construction of pins;**
- **Trace pick gun marks from the tip of the gun to the depressions on the pin;**
- **Match striae created by the pick upon the pin or chamber;**
- **Analysis of the area of marking on the pin, which may**

indicate the bypass technique;

- Angle of attack of bypass tool and location of the lock as to the type an depth of the marks that have been created;
- Which direction does the lock open;
- How often is the lock used on a daily basis;
- Type of metal and hardness and oxidation potential;
- Number of individual marks on each pin;
- Relationship between marks on each pin;
- Has the cylinder been replaced;
- If a 999 key was utilized, where should marks appear within the keyway;
- Have retaining screws been removed from the back of the cam, indicating service or replacement;
- Has lacquer on the cylinder been disturbed from the factory original condition;
- Is the cylinder factory OEM;
- Have the top pins been replaced. Do they conform to factory original specifications;

Changing or removal of top pins. Courtesy of Hans Mejlshede.

- Does the lock utilize balanced drivers to prevent the use of a comb;
- What is the length of the lower pins, and would their length require the use of a specific tension wrench, or placement of that wrench at a certain point in the keyway;
- Are there excessive markings for the method of bypass, indicating that an attempt has been made to simulate such marks in order to mask a crime, or mask a modus operandi;

An attempt may be made to mask pick marks so that the perpetrator is not identified. Courtesy of Hans Mejlshede.

Many car thefts are simulated for insurance claims. Courtesy of Hans Mejlshede.

- Are there markings only on the first two or three pins, indicating an attempt to mask criminal activity;
- If the investigation involves an insurable loss, has there ever been any history of late payment of premiums;
- If a burglary, is the item or items of such value as they would be stolen in the manner indicated;
- All keys for a specific lock should be inspected for irregularities;

Obtaining all keys that fit a particular cylinder. Courtesy of Hans Mejlshede.

- **The security of a lock and the difficulty of bypass will directly correlate to the number of markings on the pins and chambers;**
- **Is the lock master keyed;**
- **Is there any metal residue on the floor under the lock, caused by picking or drilling;**
- **Is there a different level or wear on different locking components, such as latches and bolts, indicating that certain parts have been replaced as part of a false insurance claim or other ruse;**
- **Is the method of entry or bypass different than the "usual" technique in such cases;**
- **Are there marks on the back of the cylinder or cam;**

Marks on the back of the lock from bypass. Courtesy of Hans Mejlshede.

- **Analysis of wear patterns on pins;**
- **Does it appear that a pick gun has been utilized, based upon rotation patterns on the pins;**
- **Is there evidence of a pick gun being inserted into the keyway;**
- **Determination of when pick marks were made, based upon surface oxidation;**

Oxidation and dating of marks in a forensic examination. Courtesy of Don Shiles.

- **Could marks on pin have been caused by the use of steel keys with rough cuts, produced by inexpensive cutters. In such cases, the bitting surface can act as a saw;**
- **If there is forced entry, compare the apparent method of bypass and the presence of pick marks to determine if there is an attempt to mask the real method of entry in order to hide the identity of the perpetrator;**
- **If the investigation involves a lever lock, there may be more evidence of bypass due to the inherent difficulty in manipulating this mechanism. Lever locks are typically mortised into the door, which makes them more secure than exposed cylinders. Marks will also be present on the bellies of the levers;**
- **If the use of a 999 key is suspected, be certain to inspect**

the keyway for markings, as well as pins;

25_1.3 Possible Defense Theories or Contraindications

It is never too early to consider potential defense arguments to conclusions drawn by the criminalist, as a lock is analyzed. In fact, the conduct of any forensic investigation into bypass requires that **all** possibilities be considered, especially where there appears to be physical evidence to support a theory of surreptitious entry. Conflicting indications of bypass can be found in many locks. Often, marks are produced from normal wear, service, age, or other external non-related causes. These must be distinguished from actual evidence of bypass. The following possibilities must be considered in any inquiry where physical marks or trace evidence is identified within a lock. Factors that may affect the production of marks and which should be analyzed will include:

- **Spring tension on each tumbler;**
- **Hardness of tumblers;**
- **Bearings;**
- **Design of key and sharpness of ramp angles;**
- **Driver and lower pin length as it affects compression of springs.**

25_1.3.1 Earlier Picking Attempts

- **Could there have been an earlier attempt to pick the lock;**
- **Could someone have previously attempted to claim surreptitious entry to collect insurance which caused marks to be made;**
- **Could a locksmith have made the marks in an attempt to open the lock;**

25_1.3.2 Normal Use

- **Could marks have been caused by normal use of the lock. For example, could an improperly cut key have scored the pins or shell.**

25_1.3.3 Tool Marks

- **When were the marks created. Can they be dated with any reliability;**
- **Does corrosion exist around the marks. Is such corrosion consistent with other corrosion in or around the cylinder;**
- **Could the marks be interpreted to have been present for quite some time. Can it be proven that the marks were made within the time frame of the incident or event under investigation;**
- **With respect to markings on pins, are there inconsistent marks or marks only on one or two pins. This might indicate that these were produced from a jagged key angle and not from a pick. Do not be fooled by marks on only one pin: locks are not picked in that fashion unless the perpetrator was interrupted almost immediately or did not understand how to rake a lock;**

- **Could the marks be false and have been created by a screwdriver, ice pick, or other sharp implement to simulate surreptitious entry;**
- **Are the marks consistent with lock-picking or impressioning techniques. Why and how would the marks have been made;**
- **Could a locksmith have previously worked on the lock and allowed a top pin to drop into the plug, catching a spring between the plug and shell. The subsequent use of excessive force to rotate the plug would result in markings being produced;**

- **Has the lock been disassembled previously for maintenance, repinning, or keying;**
- **Are there spots on the bottom of tumblers indicating improper fitting keys, worn keys, or errors in spacing that requires the key to be lifted or retracted slightly in order to raise tumblers to shear line;**
- **Is there scoring in the upper surface of the shell which intersects the top chambers and appears to**

follow the rotation of the plug. If so, it is generally due to keys that raise lower tumblers slightly higher than shear line;

- **Are there marks on all top surfaces of the lower pins, or scoring of the cylinder walls. This may indicate a loose plug caused by cam-retaining screws that do not hold the plug firmly. Try inserting and removing the correct key. If it is difficult to withdraw, this may be the cause of such marking;**
- **Could keys have been duplicated on inferior knockoff blanks that were too wide for a particular keyway, thereby removing metal upon insertion;**
- **Could internal wear be based upon the way in which keys were originally cut, excessive spring tension, or the age of the lock;**
- **If striations are found on the side of the keyway, can they be correlated to the pressure required to turn the lock mechanism and matching striations on key blanks.**

25_1.3.4 Keys

If keys are found on suspects or seized during search warrants or inventories, careful consideration must be given to the following issues:

- **Does the key fit the suspect lock properly or is the fit loose, tight, or in other respects not correct. Perhaps the wrong blank was used in the duplication process or the key was designed to fit another lock and has nothing to do with the one being examined. There are many similar keyways throughout the world. Some are interchangeable. Just because a key fits a particular lock does not mean that it was cut for that lock;**

- **The internal components are so worn that many keys, if jiggled, will open the lock. This is especially true in the case of car locks: tryout keys work on this principle. To disprove, take 25 random keys and attempt to open by manipulation. Determine the tolerance of lock parts by micrometer measurement.**

This will allow an extrapolation of the potential number of keys that will open the lock;

It is difficult to bypass laser track locks through the use of jiggle keys. Courtesy of Hans Mejlshede.

The reverse of this argument is also true. Keys found on a suspect may not properly fit a lock, but that does not necessarily mean that they will not open it. If the key is close to that which would open the mechanism, then careful attention should be paid to the suspect key to determine if in fact if was **intended** to open the lock.

- **A suspect lock may have been altered with added pins in order to allow keys to fit that are not listed in the master system layout. In some cases this has been done intentionally so that possession of a key may not constitute a crime, or evidence;**

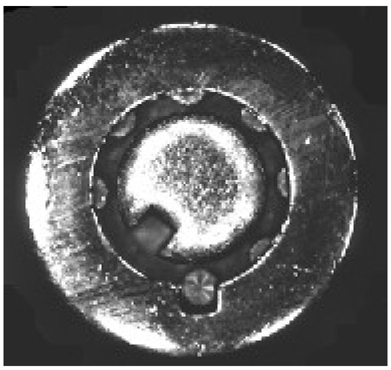
- **The absence of tool marks within a suspect lock may be relied upon or introduced by insurance companies or defendants as evidence that the lock was not picked or that there was no surreptitious entry. That conclusion does not automatically follow.**

There may be several explanations for a lack of marking. If picking was accomplished with a rake using very light tension or pins were picked in the conventional manner (one at a time), no indication may be left. If the lock utilizes nickel silver pins or plug, this metal will be much more resistant to scoring. If a key was run through the lock several times after picking, such may obscure any trace.

- **Indentations on the face of a plug can be construed to mean that 999 rapping was employed. However, it may also indicate heavy use of the lock. Follow-up examination of the pins is required in this event;**
- **Scratches on the sides and bottoms of the pins can show that a 999 rapping technique was applied or that there was too steep a ramp angle on the key and it was forced into the lock. The insertion of a poorly designed or improperly cut key can definitely cause marking on the sides of tumblers. This possibility must be carefully considered.**

25_1.3.5 Picked Tubular Locks or Cylinders

Sometimes, an axial pin tumbler lock or other cylinder is found with the plug rotated to a partially picked position. This will generally indicate that bypass has been attempted or accomplished and that the perpetrator was trying to return the plug to the locked position. However, it is possible to create this condition by cutting the guide pin off any tubular key and moving the plug to a partially rotated position.




It is not conclusive that the lock was picked or otherwise bypassed just because the plug is rotated. It may be possible in rare instances that the key's top guide pin has been worn away or removed for some legitimate purpose. If this occurs, then the lock may be left in what appears to be a picked condition although that was not the intent. Placing an axial lock in a partially rotated state can be done for security reasons. Locks may be set to this position in order to prevent unauthorized keys from being inserted. Sabotage may also be a factor.

25_2.1 Lock Specifications and Data

The lock as an entity should be examined both externally and as to each component to determine if there are discrepancies or differences between the target and factory original.

25_2.1.1 Queries Regarding Lock Specifications and Manufacturing Data

- **What is the length of each pin-stack, in order to assess the potential for bypass by a comb pick. This condition is referred to as balanced drivers,**

meaning that the overall length of the bottom and top pins is constant.

The length of the upper and lower pins, including all master pins for each cut, must be calculated and compared to the length of each upper chamber. If the length of the chamber is greater than the total length of all pins and spring for that chamber, then a comb pick may be utilized.

- **Does the lock have all original factory components;**
- **Examine the way the lock has been assembled, and determine if there is any deviation from factory standards;**
- **Is it possible that the lock was recombinated and that driver pins were not changed at the same time or that previously used lower pins were inserted;**
- **Are components missing;**
- **Have non-original components been substituted, such as pins, springs, cam, or plug;**
- **Are pins color coded from the factory;**
- **Has the spring-retaining tab been removed, replaced, or altered;**
- **Is the lock keyed to the original combination;**
- **Does the pin-stack match codes stamped on factory original keys with respect to depth of bitting;**
- **Can all pins (within a chamber) be forced into the upper chamber above shear line;**
- **Does there appear to be any damage to any lock component;**
- **Is the diameter of the plug equal to factory specifications;**
- **Is the design of the plug-shear line interface round or flat? A higher tolerance is achieved with a round plug;**
- **Are bottom tumblers round, pointed, or flat;**
- **Are steel bearings used by the factory. If so, are they present in the target lock;**
- **Have springs of the proper tension, length, and diameter been installed;**
- **Does the plug rotate freely in the lock with the proper key inserted;**

- **Do tumblers catch or hang, either in the shell or plug;**
- **Must keys be jiggled in order for the lock to work;**
- **Is there any distortion of the plug or shell, indicating that excessive torque has been applied;**
- **Are cam-retaining screws tight;**
- **Does the manufacturer use security tumblers? If so, are they present in the lock;**
- **What is the security rating of the lock;**
- **Does the lock carry a UL 437 or equivalent EC rating;**
- **Are there any obvious defects or problems with the operation of the lock.**

25_2.2 Operation of the Lock

Analyzing the operation of the lock can yield valuable information about its condition, age, wear, formation of internal markings, and (of equal importance) missing, replaced, non-standard or out-of-place components. The criminalist will be concerned with each internal and external component and their interaction.

A decision must be made by the criminalist as to whether to conduct a cursory review to determine if the lock is functioning properly prior to a detailed forensic examination.

If there is a possibility of the destruction or alteration of internal markings, then great care must be used. This is especially true if keys are inserted and removed from a working lock. Depending upon the bitting surface, side-milling, and tolerances, unwanted marks or artifacts may be created in the examination process. Alternatively, if the lock is disassembled and the plug dissected then a proper determination of operation cannot be made following the evaluation criteria in this chapter. If a lock is to be first evaluated to determine its operational characteristics, all of the components must be examined, cataloged, and checked. Special attention must be paid to those items detailed below.

25_2.2.1 Summary Mechanical Evaluation

Proper operation of the lock must be determined prior to dissection, assuming the lock has not been damaged during entry.

At this point, observations must be made regarding operational characteristics. The reader will note some duplication of information in subsequent sections. This section describes gross distortions or irregularities regarding the operation of the lock and its components. In **Chapter 26** specific indicia will be examined with respect to the presence of tool marks.

25_2.2.2 Queries Regarding Mechanical Operation

- **After examination of the entire length of the keyway, are there any broken key parts or foreign materials present. If so, is there a possibility of a match between a broken key and the hey head;**
- **Is there a stuck key lodged in the plug. If so, is it back cut, indicating that an amateur produced it or that impressioning was attempted;**
- **Does the proper key fit and open the lock;**
- **Is the key properly matched to the keyway;**
- **Is the cam tight or loose. If the cam is loose (retaining screws allow movement of the cam when the proper key is inserted and removed), then excessive and unexplained marking may appear;**

- **Does the lock exhibit smooth or rough operation: do the pins bind, or must the key be lifted to work;**
- **Do all keys work;**
- **Are all springs intact, and do they have the proper length and tension;**
- **Is the plug correct for the given lock;**
- **Is the spring-retaining clip secure. Has it been removed and replaced;**
- **Is the plug rotated to a picked position;**

- **Is there visual evidence of bypass, including tool marks, metal fragments or filings, distortion of the plug, broken keys in the plug, or other marks;**
- **Is there any foreign material in the plug, including Freon residue;**
- **Are there any metal scrapings within the lock, in the keyway, or chambers;**
- **Does it appear that excessive pressure was applied to the plug, causing marks to be made between the**

plug and shell;
- **Are there marks that appear to have been caused by picking or other forms of manipulation. If such marks were from picking, how old are they. When were they made. Could normal operation of the lock cause the questioned marks.**

25_2.3 Chambers, Plugs, Pins, and Springs

25_2.3.1 Chambers

Chambers must be examined for deformation and obvious scoring that may have been caused by improperly cut keys that did not raise all tumblers precisely to shear line. In addition, gross evidence of impressioning may be present. Attention must also be paid to the potential of drilling that can be evident in the plug and/or shell.

25_2.3.2 Plugs

A complete examination of the exterior and interior segments of the plug must be conducted. Depending upon whether dissection is performed, the plug may be examined with a microscope, borescope, or ophthalmoscope.

25_2.3.2.1 Queries Regarding Plugs

- **Is there evidence of external scoring around the circumference;**
- **Has the top of the plug at shear line been filed;**
- **Is there warping, bending, flattening, or distortion of the wards in the keyway;**
- **Are there unexplained marks, spots, dents, scratches, tracks, or other indicia of bypass.**

25_2.3.3 Pins

Pins can provide valuable information regarding disassembly, alteration, and replacement of the lock.

25_2.3.3.1 Queries Regarding Pins

- **How many chambers are in the plug, and is there a**

tumbler set (lower pin, upper pin, master pin in the case of complex systems, and spring) for each chamber;

- **Is the correct diameter pin present within each chamber;**
- **Is there a great deal of play between the chamber and pin;**

If low tolerance exists between the pin and its chamber, the lock may be easy to decode by using the Falle-Safe decoder. This sophisticated instrument allows a shim wire to enter between the lower pin and chamber to decode each tumbler. It is described in **Chapter 31.**

- **Are driver pins too long or too short for a given depth of bitting. If so, can a comb pick force all lower pins into the shell to create another shear line. Long drivers may also indicate that the lock has recently been rekeyed by an amateur;**

If springs are compressed into the shell, the overall length of the pin-stack should be measured. There may be a defect in the design of the lock or in factory pinning. Compressed springs will cause marks to be produced on the tops of driver pins.

- **Do the pins appear to be factory original, or have they been replaced. Do they appear old or new;**
- **Have the tops of the pins been filed;**
- **Have lower pins been loaded upside down as drivers, indicating an amateur was working on the lock;**
- **Is there correct driver and lower pin orientation;**
- **Does it appear that the lock has been rekeyed improperly;**
- **Has the combination been altered. Does it appear that pins have been added or removed to make picking easier, to allow the use of cross-keys, or other unauthorized keys;**
- **Have old pins from other locks been used, indicating that an amateur may have done the work;**
- **Does the manufacturer use color coded pins on this series of lock. Are the pins in fact color-coded. If not, should they be. Have colored and non-coded pins been mixed;**

- **Is the lock pinned with mushroom, spool, or other forms of security tumbler. If so, is the correct number present. What is the factory original standard with respect to the number of security pins, their position, and design. Generally, up to three security tumblers will be utilized;**
- **Are there any master pins. If so, their position and precise length must be documented with extreme caution;**
- **Have master pins been used that are too thin, causing operational problems. Jammed wafers could indicate that tumblers had been added, the lock was not keyed to industry standards, or was worked on by an amateur;**
- **Have only some of the chambers been loaded with pins. Although this may seem unusual, each lock must be evaluated on a case-by-case basis. The author has investigated many system where six-pin locks are keyed with five tumblers;**
- **Would the tumbler combination allow the removal of a key when the plug is normally locked. This may give a false indication of picking because some keys are improperly cut or designed and may be withdrawn in a rotated (non-vertical) position;**

If the key design is in an ascending stair-step pattern with the deepest cuts at the tip, it may be possible to withdraw the key from the lock while the plug is rotated. Example: a bitting pattern of 765432 (from the tip), with "7" being the deepest cut, can quite possibly be removed without engaging the tumblers during withdrawal.

25_2.3.4 Springs

Springs can also provide valuable information. Evidence from springs can indicate if the lock has been worked on recently, whether it has been taken apart by an amateur or by one in a hurry, and whether comb picking has been attempted.

25_2.3.4.1 Queries Regarding Springs

- **Are all springs worn to the same degree. Are some more worn than others;**

- **Are springs missing;**
- **Are springs compressed;**
- **Are some springs very old, while some appear new;**
- **Are some springs crushed or broken;**
- **Are all springs in place. Is there a spring in every chamber, and are they the correct length and tension;**
- **Are the springs operational, compressed, extended, or broken;**

> **If springs appear to be compressed, this may indicate improper driver length for a given chamber. This can demonstrate that the lock was not keyed by the factory as original or was rekeyed by an experienced locksmith.**

- **Have any of the springs been sheared. This would indicate that the lock may have been disassembled by an amateur, having caught a spring in an empty chamber. Are there fragments of springs that would indicate the same condition.**
- **Are any of the springs noticeably weak or not functional which may indicate age or use; Are the springs the correct diameter for the given chamber. If not, this may indicate replacement by an amateur;**
- **Are the springs all the same color. If not, this can indicate that the lock has been worked on, perhaps recently. If that might be the case, could the lock have been disassembled prior to its bypass to compromise its security, either intentionally or through amateur workmanship;**
- **Will the springs compress if there is a high cut on the key bitting. This may indicate that drivers are too long for a given depth tumbler position, possibly pointing to rekeying of the lock.**

25_2.4 Security of the Lock

Whenever a lock is to be subjected to forensic examination, an assessment must be made as to the ease with which it may be bypassed. This evaluation will often yield valuable leads as to perpetrators, possible physical evidence that may be recovered

from the lock, and specific types of tests that may be performed. The reader is directed to **Chapter 10** for evaluation criteria of high-security locks.

As was pointed out earlier, a security rating can be rather elusive in terms of what it defines. Although specific industry standards have been developed in the United States (UL 437), England (BSI ratings) and Europe (EC ratings), such security ratings are not absolute. In terms of surreptitious entry, the target and the lock protecting it may attract perpetrators and tools equal to the task, and potentially not contemplated or understood by the standards rating organization.

Manufacturers of some of the highest security locks in the world, such as Medeco (U.S.), Chubb (UK), Keso (Swiss), Mul-T-Lock (Israel), Abloy (Finland), and Abus (Germany) often claim that their locks are impervious or highly resistant to bypass. The author, from personal experience, can attest that locks produced by each of these companies can be defeated and opened. The author has utilized extremely sophisticated bypass tools to subvert mechanisms developed by each of these (and other) manufacturers of the highest security mechanisms. The description and use of such tools is covered in depth in the video supplement to **LSS+**.

An example illustrates the point. A Chubb Isolator safe that is equipped with a high-security eight-lever lock (such as the 6K174) has apparently has been compromised. The manufacturer advises that this lock is virtually impossible to pick or manipulate. This information should not automatically lead an investigator or criminalist to conclude that it was an inside job. Quite the contrary. The author has utilized tools that can penetrate this lock without leaving a trace in as little as fifteen minutes.

Although the Isolator is one of the finest high-security safes offered by Chubb, the lock still provides the primary defense against entry. In reality, the safe simply protects the lock from attack. The lever lock, regardless of design, is still a lever lock. Inherent to its basic design is the capability of compromise. There is little that a manufacturer can do, given the sophistication of tools and techniques, to absolutely prevent against bypass.

The most important fact for a criminalist to remember is that almost any lever, disc, or pin tumbler lock can be compromised, given the proper tools and expertise. These tools, and

individuals capable of operating them, do exist. In any major investigation, one should never lose sight of the fact that covert bypass may be entirely possible. In the civil legal arena, it should also be remembered that insurance companies generally do not define what constitutes a "secure lock," although they often require them to be installed in order to extend coverage. This problem within the insurance industry is going to have to be addressed.

This section shall summarize, in the form of questions, the basic criteria with which to assess the security of a lock in terms of the following:

- **Resistance to physical attack;**
- **Difficulty and likelihood of covert methods of bypass;**
- **Likelihood of random opening, rather than premeditated attack.**

In the beginning of **Chapter 24**, a number of questions were raised regarding locks and locking systems as part of an initial survey that would be made at the outset of an investigation. Those questions were general in nature. In assessing the security of a lock that may have been compromised, the following additional, specific questions and related issues must be considered.

25_2.4.1 Queries Regarding Security

- **What is the estimate of the security rating of the mechanism:**

1. **NO SECURITY**
2. **LOW SKILL TO BYPASS**
3. **MODERATE TO MEDIUM SKILL REQUIRED**
4. **ADVANCED SKILL REQUIRED, TIME CONSUMING**
5. **VERY DIFFICULT, TIME CONSUMING, SPECIAL TOOLS AND EXPERTISE REQUIRED, OR NOT REALISTIC TO PICK THE LOCK IN THE AVAILABLE TIME. SEE UL STANDARDS**

- **What type of mechanism is employed;**
- **Can the secondary locking system be bypassed;**
- **Does the mechanism meet high-tolerance standards;**
- **Does the mechanism utilize dual-locking systems, such as pin tumbler + sidebar;**

- **Is it easy or difficult to move a pick in the keyway;**
- **Are there any secondary locking pins which restrict the plug from turning, such as in the DOM dimple lock;**
- **Are there deep cuts next to shallow ones, making picking difficult;**
- **Are there anti-pick mechanisms, such as detectors, floating levers, sidebars, or special locking components that will engage if picking occurs, such as in the EVVA DPX sidebar lock;**
- **Was the plug found in a picked position;**
- **How difficult is picking;**
- **Can the lock be easily impressioned;**
- **Can the lock be 999 rapped;**
- **Can the lock be decoded;**
- **Are cylinder-retaining screws loose;**
- **What lock profile is used: .S. cylinder, European;**
- **Can the locking mechanism be bypassed through sophisticated means as described in LSS+/X CD/ROM;**
- **Is it classed as a high-security mechanism;**
- **Does it have a UL 437 rating;**
- **Are all chambers active and pinned;**
- **Are all components working;**
- **Are security pins installed;**
- **What is the design of the keyway? Will it frustrate picking;• Are there known ways to bypass the lock;**
- **Are there anti-drill pins;**
- **Has the plug been drilled at shear line;• Has the lock been modified in any way from factory standard;**
- **Are there special decoding tools available for this lock;**
- **Has the lock been tampered with;**
- **Has the lock been worked on by an amateur locksmith. For example, has the top of the plug at shear line been filed flat;**
- **Have pins, wafers, or levers been filed;**
- **Can the plug be turned with a screwdriver;**
- **How many tumblers must be manipulated to open the**

lock;

- **Were Maximum Adjacent Cut Standards (MACS) followed when the particular cylinder was keyed;**
- **How many total pin tumblers, levers, or wafers are present;**
- **What is the basic type of locking mechanism;**
- **Can the lock be decoded rather than picked; then a key produced from the decoding process;**
- **Is the pin-stack configuration or combination extremely conducive to picking. Are all tumbler positions close to the same depth, or in a stair-step pattern;**
- **Is maison keying in effect. How many tumblers are present;**
- **Is complex master keying employed. How many levels. Are there many cross-combinations available;• Are there any wards or obstructions in the keyway;**
- **Is the tolerance between plug and shell quite sloppy, either due to poor manufacturing controls or because the top of the plug was filed by an amateur locksmith;**
- **Is the horizontal center-point alignment between chambers erratic, allowing ease of picking;**
- **Is the suspect lock inherently easy to pick due to its design (especially if a wafer mechanism);**
- **Can the lock be opened by inserting a pocket knife to lift all tumblers because the length of the pins are quite similar;**
- **Is the lock combinated so that rocker picks could easily simulate the depth pattern;**
- **Were standard pins and depths utilized during keying;**
- **Every manufacturer has different standards for bitting. These apply to depth and spacing and determine differs and thus security. Failure to adhere to such standards will diminish the security of the lock. Representations by manufacturers as to the actual number of differs may not be accurate. See LSS+/X CD/ROM for a description of the Medeco Biaxial lock, for example.**

25_3.0 Forensic Experts in Locks and Keys

What is an investigative locksmith? Courtesy of Don Shiles.

An introduction and summary of forensic locksmithing. Courtesy of Hans Mejlshede.

Definition of an Investigative locksmithing. Courtesy of Don Shiles.

Purpose of investigative locksmithing. Courtesy of Don Shiles.

LSS202: Forensic investigation and the locksmith, by Don Shiles

The **International Association of Investigative Locksmiths (IAIL)(239)** has been organized to train and certify professional locksmiths that conduct forensic examinations involving locks, keys, keying systems, security containers, arson investigations, compromise of security systems, and the investigation of crimes relating to motor vehicles. The association has developed job specifications, procedures, and analytical techniques for examining locks, keys, and vehicles for evidence of bypass, tampering, or fraud. Training is also provided with regard to evidence collection and preservation, and presentation of findings in court. I.A.I.L. is the most recognized private association relating to the forensic examination of locks.

Forensic locksmithing history and the role of Art Paholke. Courtesy of Hans Mejlshede.

Forensic locksmiths may be called upon by insurance companies, criminal investigators, security management, and crime laboratories to conduct primary analysis, or to aid other specialists in the investigation of cases involving potential bypass or forced entry of locks and safes, and cases involving fraud where locks, keys, or keying systems may have played a role.

The investigative locksmith gets involved in insurance fraud cases. Courtesy of Hans Mejlshede.

These experts often have experience and insight that may be lacking in other disciplines due to their daily contact with locks, safes, and security issues. Assuming that they have the requisite background and qualifications, they can be invaluable

in certain investigations. Unfortunately, most law enforcement agencies do not have the in-house expertise to properly evaluate locks and related systems.

Required background of the forensic locksmith and investigator. Courtesy of Don Shiles.

The beginnings of the forensic investigation of locks and keys began with the Chicago Police Department sometime around 1970, when Art Paholke, a police officer assigned to the criminalistics laboratory, began developing techniques for the examination of locks, safes, keys, and keying systems. Although he has long since retired, he is credited with developing many of the techniques and procedures that are utilized today.

Art Paholke is the father of modern forensic locksmithing. Courtesy of Hans Mejlshede.

It is critical the competent experts be utilized in cases involving the potential compromise of security systems. Throughout the Forensic Section (Chapters 24-27) reference is made to defense theories and evidence that may be presented to dispute, discredit, or disqualify the admission of physical evidence or expert testimony. It is therefore of vital important that evidence be identified, gathered, preserved, and analyzed correctly in order to assure a valid case resolution.

There are many integrated disciplines and areas of knowledge and expertise that must be mastered in order for the forensic locksmith to competently perform his job. These include:

- **Crime Scene Processing:**
  Making an assessment as to whether a lock, key, keying system, or security system has been or is at risk of compromise;
  Securing a crime scene;
  Physical examination of a crime scene;
  Collection and storage of evidence;

- **Tool Marks:**
  Identification of tool marks; Performing basic tool mark classifications;
  Evidence from tool marks;
  Submission of tool mark evidence to laboratory;

Casting and Impressioning;

- **Forensic Photography:**

Forensic photography. Courtesy of Don Shiles

Macro lens, Courtesy of Hans Mejlshede.

Data back for documentation of images. Courtesy of Hans Mejlshede.

Photographic equipment requirements. Courtesy of Hans Mejlshede.

Ring strobe is a necessity for forensic photography. Courtesy of Hans Mejlshede.

- **Admission of Evidence:**
  Chain of Custody; Depositions and courtroom testimony;
  Rules of Evidence;Qualifications for Forensic Locksmiths;

- **Specialized Forensic Investigations:**
  Compromise involving security containers;
  Restoration of obliterated tool marks;
  Automobile Theft investigations;
  Arson investigations;

- **Forms and Reports:**
  Specimen Report;
  Forensic Inspection Report;
  Case Report;

- **Reference Files:**

This section shall provide an outline of the criteria and general duties of a forensic locksmith, as well as the legal requirements and guidelines that must be adhered to in order for evidence to be legally competent. For a more detailed discussion regarding specific processes and procedures, the reader may wish to obtain the I.A.I.L. Forensic Locksmithing Manual. Appreciation is expressed to James Glazier, President of I.A.I.L. for assistance in developing certain multimedia segments contained within this section.

25_3.1 I.A.I.L. General Qualifications for Forensic Locksmith

The International Association of Investigative Locksmiths has developed general standards for their members to define basic qualifications for a forensic locksmith. These are reproduced below.

Definition of a forensic locksmith.

Professional Qualification Standards for Certified Forensic Locksmiths

Chapter 1. General:

1-1 Scope. This standard identifies the professional level of performance required for a Certified Forensic Locksmith and specifically identifies the job performance requirements necessary to perform as a Certified Forensic Locksmith.

1-2 Purpose. The purpose of this set of standards is to specify the minimum job performance requirements for service as a Certified Forensic Locksmith in both the private and public sectors. It is not the intent of these standards to restrict any jurisdiction from exceeding these minimum requirements. Job performance requirements describe the performance required for a specific job. The complete list of requirements for each duty describes the tasks an individual must be able to perform in order to successfully carry out that duty; however, they are not intended to measure a level of knowledge. Together, the duties and job performance requirements define the parameters of the position of Forensic Locksmith.

1-3 General

1-3-1. The Certified Forensic Locksmith shall be at least twenty?one (21) years of age.

1-3-2. The Certified Forensic Locksmith shall have a high school diploma or a state recognized equivalent.

1-3-3. The International Association of Investigative Locksmiths, Inc. (I.A.I.L.) shall conduct a thorough background and character investigation prior to accepting an individual as a candidate for certification as a Forensic Locksmith,

1-3 4. The job performance requirements for the Certified Forensic Locksmith shall be completed in accordance with recognized practices and procedures or as they are defined by law or by the International Association of Investigative Locksmiths, Inc.

1-3-5. The job performance requirements defined in these standards

need not be mastered in the order in which they appear. Training agencies or other authorities may establish programs that prepare individuals to meet the requirements defined in these standards.

1-3-6. Evaluation of job performance shall be by individuals approved by the International Association of Investigative Locksmiths, Inc. The evaluator shall be qualified to conduct the evaluation of a Forensic Locksmith and make appropriate recommendations in relation to their certification as a Forensic Locksmith.

1-3-7. The Certified Forensic Locksmith shall remain current with investigation methodology, locksmith technology, and current requirements through attendance at workshops, seminars, classes and/or through professional publications and journals. The Certification Board of the International Association of Investigative Locksmiths, Inc. on a tri-annual basis shall evaluate this. The Certified Forensic Locksmith shall certify to their attendance and study during the prior three-year period.

1-3-8. The Certified Forensic Locksmith shall commit to the Code of Ethics of the International Association of Investigative Locksmiths, Inc.

Additional performance requirements are defined in Chapter 3 of the I.A.I.L. Professional Qualifications and Standards.

3-1-1. The Certified Forensic Locksmith shall meet the job performance requirements defined in Sections 3-2 through 3-7.

3-1-2. Because Certified Forensic Locksmiths are often required to perform activities under adverse conditions, all regional and national safety standards must be adhered to in all situations.

3-1-3. The Certified Forensic Locksmith should maintain appropriate liaison with other professionals.

3-1-4. The Certified Forensic Locksmith shall ensure that due process of law is served.

25_3.2 Crime Scene Processing

Crime scene processing involves a number of critical steps to insure the proper discovery, development, integrity, and admissibility of the evidence. Although criminalists and government investigators receive extensive training with regard to the proper techniques for processing evidence, the fundamentals are summarized below for the benefit of the forensic locksmith.

Evidence handling techniques. Courtesy of Don Shiles.

I.A.I.L. has detailed the general requirements for the correct handling of a crime scene and any evidence that it may yield where there is suspected criminal activity involving keys, locks, containers, or security systems. These procedures may slightly vary from "typical" crime scene processing.

There are five critical stages in this process:

- **Secure, survey, and examine a suspected crime scene**
- **Document the scene with photographs, video, and notes**
- **Document specific items of evidence**
- **Collect and preserve evidence**
- **Presentation of Evidence**

25_3.2.1 Securing and Examining the Crime Scene

Whenever there is an area that is thought to be a crime scene, the appropriate law enforcement jurisdiction has the responsibility of securing and protecting the area and its contents from accidental or intentional contamination or disturbance. Any witnesses or individuals with knowledge regarding the connected criminal activity must be identified and interviewed as soon after the event as possible in order to preserve the value of their information.

Each law enforcement agency develops its own procedures and protocol for processing a crime scene. However, every forensic examination of the scene of a crime involves the following steps:

- **Protect the scene;**
- **Conduct a preliminary survey of the crime scene;**
- **Physical examination of the crime scene;**
    - **Document the scene by:**
    - **written narrative or recorded statement**
    - **drawings**
    - **photographs**
    - **video**
- **Collect and temporarily store evidence;**
- **Preserve and package the evidence for transport;**

The I.A.I.L. has defined the following responsibilities for a forensic locksmith:

3-2 Scene Examination. Duties shall include inspecting and evaluating the scene so as to determine the method of access, area of access, method of defeating or bypassing the locking mechanism(s).

3-2-1. Secure the suspected area of access, locksets or access devices, doors, door frames, steering column, ignition lock assembly, and any other device or area involved using any special tools, tape or marking devices, so that unauthorized persons can recognize the perimeters of the investigative scene and are kept from restricted areas. Protect all evidence or potential evidence from tampering, damage or destruction.

(a) Requisite Knowledge: Types of evidence and the importance of security, evidence preservation, issues relating to spoliation and chain of custody.

(b) Requisite Skills: Ability to deal effectively with people in a friendly yet authoritative manner.

3-2-2. Conduct a survey of the alleged scene of forced entrance or surreptitious entry, given standard equipment and tools, so that evidence is preserved, alleged access damage is interpreted, and with relationship to property, all potential means of ingress and egress are discovered. With relationship to possible automobile theft, examine all exterior surfaces of the vehicle, wherever feasible, with regard to the use of access tools (Slim Jim and other "in-door" tools), force or other means of questioned access.

3-2-3. Conduct an interior survey, given standard equipment and tools, so that areas of potential evidentiary value requiring further examination are identified, photographed and preserved, the evidentiary value of contents is determined, and alleged methods of bypass are identified and protected.

(a) Requisite Knowledge: Knowledge of the types of locks, access control, and other security devices. Steering columns, ignition switch assemblies, ignition lock assemblies, anti-theft devices, alarm and security devices, effects of bypass methods, various methods of access and bypass and general locksmith skills.

(a) Requisite Skills: Locksmith skills including lock device installation, servicing and repairs in automotive work. Ignition lock removal and replacement, steering column service and repair, and service and repair of anti-theft devices. Photography, identification and preservation of evidence are crucial in all investigations.

3-2-4. In the event of an automobile theft or arson, examine, photograph and remove fire debris given standard equipment and tools, so that all fire debris is checked, including the ignition switch assembly, ignition lock assembly, steering column parts, steering wheel locking parts, and other components. This investigation should be coordinated with any SIU or other fire investigator with a relationship to the preservation of evidence potentially relating to cause and origin of the vehicle fire. Special attention should be paid to the relationship of all evidence recovered with the levels of evidence in the fire debris.

3-2-5. Wherever feasible, inspect the performance of the lock or access device or security system within a building or the steering column lock, ignition switch assembly, ignition lock assembly, anti-theft devices, given standard and special equipment and tools, so that a determination can be made as to the need for expert resources so that the defeated systems and the method of defeat are identified.

25_3.2.2 Documentation

Issues regarding keeping of records. Courtesy of Hans Mejlshede.

3-3. Documentation of the Scene. Duties shall include diagramming the scene, photographing, and taking field notes to be used to compile a final report.

3-3-1. Diagram the scene, given standard tools and equipment, so that the scene is accurately represented to insure that evidence, pertinent objects, significant marks and areas of damage or potential evidence are identified and accurately represented.

(a) Requisite Knowledge: Commonly used symbols and legends that clarify the diagram, types of evidence that need to be documented, and formats for documenting the scene.

(b) Requisite Skills: Ability to sketch the scene, basic drawing skills, and evidence recognition and observational skills,

Issues regarding crime scene sketches. Courtesy of Don Shiles.

3-3-2. Photographically document the scene, given standard tools and equipment, so that the scene is accurately depicted and the photographs appropriately support scene findings. It is recommended that video be used during the examination, disassembly and removal of any lock cylinder, security device, locking mechanism or automotive steering column, ignition switch assembly or ignition lock assembly. If not practical then 35mm or similar photographs must be made of each step in the removal of the aforementioned assemblies.

(a) Requisite Knowledge: Working knowledge of a 35mm or other camera and flash mechanism, types of 35mm or other cameras and lens, types of film and flash available and suitable for such tasks, as well as the strengths and limitations of each. Working knowledge of video cameras and lighting.

(b) Requisite Skills: Ability to use a 35mm or other camera, flash and other appropriate lighting. Ability to use video cameras and lighting.

3-3-3. Construct investigative notes, available documents, and interview information so that the notes are accurate, provide further documentation of the scene, and represent complete documentation of the scene findings.

(a) Requisite Knowledge: Relationship between notes, diagrams, and photos, how to reduce scene information into concise notes, and the use of notes during report writing and legal proceedings.

Issues regarding investigative reports. Courtesy of Hans Mejlshede.

(b) Requisite Skills: Data-reduction skills, note taking skills and observational and correlating skills.

25_3.2.3 Collection and Preservation of Evidence

3-4. Evidence Collection/Preservation. Duties shall include using proper physical and legal procedures to retain and preserve evidence required within the investigation.

3-4-1. Utilize proper procedures in managing facilities (buildings and vehicles), given a protocol and appropriate personnel, so that all evidence is discovered and preserved and the protocol is followed.

(a) Requisite Knowledge: Types of evidence associated with surreptitious entry, forced entry, and auto theft and evidence preservation methods.

(b) Requisite Skills: Observational skills and the ability to apply protocols to a given situation.

3-4-2. Locate, collect, and package evidence, given standard or special tools and equipment and evidence collection materials, so that evidence is collected, identified, preserved and packaged to avoid contamination and investigator-inflicted damage. Establish and maintain the chain of custody.

(a) Requisite Knowledge: Types of evidence (exclusionary or theft-supportive evidence), types, capabilities and limitations of standard and special tools used to locate evidence, types of laboratory tests available, packaging techniques and materials, and the impact of evidence collection on the investigation.

(b) Requisite Skills: Ability to recognize different types of evidence and determines evidence critical to the investigation.

3-4-3. Select appropriate evidence for analysis, given information from the investigative file, so those samples forwarded for analysis support specific investigative needs.

(a) Requisite Knowledge: Purpose for submitting evidence for examination, types of analytical services available, and capabilities and limitations of the services performing the analysis.

(b) Requisite Skills: Evaluate the alleged scene of entry or theft to determine forensic engineering or laboratory needs.

3-4-4. Maintain a chain of custody, given standard investigative tools, marking tools and evidence tags and/or logs, so that written documentation exists for each piece of evidence and maintain security of all evidence.

(a) Requisite Knowledge: Rules of custody and transfer procedures for evidence, types of evidence (e.g., physical evidence obtained

at the scene, photos and documents), and methods of recording the chain of custody.

(b) Requisite Skills: Ability to execute the chain of custody procedures and accurately complete the necessary documentation.

3-5. Interview of Individuals with Relevant Information and Examination of Exhibits. Duties shall include obtaining information regarding the overall forensic lock examination from others through verbal and written communications.

3-5-1. The Certified Forensic Locksmith shall develop a plan to obtain reports as may have been prepared or submitted by other forensic scientists relating to locks and their components. The examiner shall be familiar with documents relating to tool mark examination, testing, comparison, and any other related subjects.

The forensic investigator must prepare detailed reports. Courtesy of Hans Mejlshede.

3-5-2. The Certified Forensic Locksmith shall develop a plan of testing all evidence materials. That plan shall be subject to peer review and shall include the steps for comparison of evidence marks with test marks, preparation of error rate charts, preparation of photomicrographs to illustrate all findings, and maintain a testable method of obtaining results and references to all documents and exhibits that are utilized to support the findings of the examiner.

Opinions of examiner, and certainty of their opinions. Courtesy of Hans Mejlshede.

(a) The examiner shall meet the following tests with regard to preparation of his/her opinions and reports:

1. Whether the technique or theory has been a subject of peer review or publication in a recognized media;

2. Whether the technique or theory used may be tested or refuted;

3. The known or potential rate of error of a particular scientific technique; and

4. The degree of acceptance of a theory or technique within the relevant scientific community.

NOTE: The Court has provided a rather broad definition of the word "scientific", as referred to in Rule 702; "a grounding in the methods and procedures of science". The Court additionally stated that a scientific expert's "knowledge" means "more than subjective belief or unsupported speculation".

25_3.2.4 Presentation of Findings

3-6. Presentations. Duties shall include the ability to present findings to those individuals not involved in the actual examination and investigation.

3-6-1. Formulate an opinion as to the condition of the evidence examined (wafers, pins, springs, and other lock components as well as related items such as strike plates, door frames, etc.), so that the opinion regarding the status of the evidence examined is supported by records, reports, documents, photographs and photomicrographs.

(a) Requisite Knowledge: Analytical methods and procedures, photographic and microscope procedures, tool mark comparison techniques, locksmith procedures and technical knowledge of the profession.

(b) Requisite Skills: Analytical skills, tool mark examination and locksmith skills.

3-6-2. Prepare a written investigation report, given investigative findings, documentation and a specific audience, so that the report accurately reflects the investigative findings, is concise, expresses the examiner's opinion and is appropriate for the intended audience(s).

(a) Requisite Knowledge: Elements of writing, typical components of a written report, and types of audiences and their respective abilities and needs.

(b) Requisite Skills: Writing skills, ability to analyze information, and the ability to determine the reader's abilities and needs.

3-6-3. Testify during legal proceedings, give investigative findings, contents of reports, and consultation with legal counsel, so that all pertinent examiner's information and evidence is presented clearly and accurately, and the examiner's demeanor and attire are appropriate to the proceedings.

(a) Requisite Knowledge: Types of investigative findings, understanding of the types of legal proceedings, appropriate demeanor for each, and an understanding of legal proceedings.

(b) Requisite Skills: Communication and listening skills, ability to differentiate facts from opinions and the ability to determine appropriate procedures, practices and etiquette during legal proceedings.

3-7. Expert Testimony

3-7-1. General Witness. A Certified Forensic Locksmith will often be called to give testimony before courts, administrative bodies, regulatory agencies, and related entities. In addition to giving factual testimony, the examiner may be called to give conclusions or opinions regarding a lock or lock components or other evidentiary materials. In such instances, all testimony will be based upon the examiner's experience or lack thereof.

3-7-2. Litigation or Expert Witness. For purposes of litigation, only expert witnesses are allowed to offer opinion testimony at the discretion of the court. An expert witness is generally defined as someone with sufficient skill, knowledge, or experience in a given field so as to be capable of drawing inferences or reaching conclusions or opinions that an average person would not be competent to reach. The expert's opinion testimony should aid the judge or jury in their understanding of the fact at issue and thereby aid in the search for truth.

The opinion or conclusion of the examiner testifying as an expert witness is of no greater value in ascertaining the truth of the matter than that warranted by the soundness of the examiner's underlying reasons and facts. The evidence that forms the basis of any opinion or conclusion should be relevant, reliable and therefore admissible. The proper conduct of an examination will ensure that these indices of reliability and credibility are met. Refer to 3-5-2 and NOTE.

There may be times when the forensic investigator is pressured into altering his findings or report to suite a client, an insurance company, or law enforcement agency. It is imperative that the conclusions of the investigator be accurate, and that the results are not modified to suit anyone.

Pressure will often be applied to the forensic locksmith during the course of an investigation to change the results of a report. Courtesy of Hans Mejlshede.

25_3.2.5 U.S. Department of Justice Handbook of Forensic Science

The forensic locksmith and evidence technician may be called upon to assist with investigations involving locks, keys, and locking systems in a myriad of situations and crime scenes. For that reason, relevant sections of the FBI Handbook of Forensic Science has been reproduced here. Basic information regarding evidence collection and processing, protection of personnel from hazards including explosives, dangerous chemicals, enclosed spaces, toxic substances and general guidelines for identifying and preserving relevant evidence is presented. Although the reader may question the inclusion of certain sections, it is the author's experience that the forensic investigator may be summoned to locations where he would never expect to be called, and to analyze locks in circumstances that would be highly unlikely.

Basic Safety Guidelines for Crime Scene Investigation and Evidence Collection

Laboratory examiners, photographers, evidence team members, evidence technicians, fingerprint specialists, and others are often called upon to conduct crime scene searches and to identify bodies in mass disasters. Because of the inherent risk of exposure to human blood and other potentially infectious materials, as well as the various physical hazards present at the crime scene, the health and safety of these individuals may be compromised. For protection, it is essential that they develop and maintain am acute awareness of the hazards present in their work environment and take the necessary precautions and measures to protect themselves and their coworkers.

The purpose of this section is to identify general safety guidelines and personal protective measures that should be followed when handling potentially hazardous evidentiary materials or when exposed to hazardous environmental conditions. These recommendations are not all inclusive and should serve only as a guide and/or supplement for personal training and growth in safety awareness. The basic safety guidelines for crime scene investigation and evidence collection are intended to serve only as a starting point for good safety practices. Personnel involved

in crime scene investigations and evidence collection and handling should consult pertinent local, state, and federal laws concerning specific safely requirements and standards.

ROUTES OF EXPOSURE

Inhalation

Inhalation is the most likely route of entry for chemicals as well as some infectious agents (e.g., tuberculosis). Chemical or biological contaminants present in inhaled air can easily enter the lungs and bloodstream where they can circulate throughout the system, causing damage to target organs such as the liver and kidney. Inhaled substances can be in the form of dusts, mists (aerosols), smoke, vapors, gases, or fumes. Proper work practices, engineering controls (e.g., ventilation) and, when necessary, the use of respirators minimize inhalation of air contaminants.

Ingestion

Ingestion is a less common route of exposure for both chemical and biological contaminants. Ingestion of a corrosive material can cause damage to the mouth, throat, and digestive tract. When swallowed, toxic chemicals may be absorbed by the body through the stomach and intestines. To prevent entry of toxic chemicals or biological hazards into the mouth, always wash your hands before eating, smoking, or applying cosmetics. Also, avoid bringing food, drink, and cigarettes into areas where contamination can occur.

Skin, Eye, and Mucous Membrane Contact

Contact of chemicals or infectious materials with the skin, eye, or mucous membranes is a frequent route of entry. Chemical contact with those surfaces could result in local damage and subsequent absorption into the bloodstream, thereby causing other effects throughout the body. The effect of eye contact with a chemical can range from irritation to permanent blindness. Chemical exposure can be avoided by use of appropriate protective equipment such as gloves, safety glasses, goggles, and/or face mask.

Injection

Injection of foreign materials (chemical or biological) can cause

a serious health hazard because the material can be delivered directly to the bloodstream or become embedded in tissues. Exposure to toxic chemicals, human blood or other potentially infectious materials can inadvertently occur through mechanical injury from contaminated glass, metal, needles/syringes, or other objects. Therefore, extreme caution should be exercised when handling these or similar objects.

Crime Scene/Mass Disaster

General Precautions

No one should enter the crime scene/mass disaster without the proper safety and personal protective equipment. (See Personal Protective Equipment later in this manual.)

Individuals should not be permitted to eat, drink, smoke, or apply makeup at the crime scene/mass disaster.

The crime scene/mass disaster may be a source of contamination from a variety of sources including human blood and body fluids (both liquid and dried), human tissues and other remains.

Treat all human body fluids as potentially infectious and use Universal Precautions under Bloodborne Pathogen Safety, discussed subsequently.

In addition to the biological hazards, consideration must be given to the variety of chemical, environmental, and/or mechanical hazards that may be present at the crime scene/ mass disaster.

Always be on the alert for sharp objects such as hypodermic needles, knives, razors, broken glass, nails, and exposed or cut metals.

Broken glass which may be contaminated should never be picked up directly with the hands. It should be collected using mechanical means, such as a brush and dust pan, tongs, or forceps.

Ensure that the crime scene/mass disaster is properly ventilated.

Mirrors and flashlights should be used when looking in confined

spaces such as under car seats, beds, etc., prior to reaching into those areas with the hands.

Use a wooden paint stirrer, or other similar item, to search narrow and confined spaces, such as those found between car seats and chairs, before the hands are used.

Never recap hypodermic needles or place covers, such as pencil erasers, on the end of the needles. Place all syringes, needles, and other sharp objects in puncture?resistant containers.

Refer to Bloodborne Pathogen Chemical Safety, for specific safety procedures.

Access Control

Provide a means of controlled entry and exit for personnel and equipment entering or leaving the crime scene/mass disaster.

Provide a system for centralized decontamination of personnel and equipment and the collection of infectious waste (gloves, coveralls, etc.) to prevent transfer of potentially infectious material to noncontaminated areas such as the worker's office, car, or residence. Procedures should be established for the proper disposal of all contaminated waste.

Violent Crimes

Violent crimes pose a greater potential for contact with infectious material.

All human blood, body fluids, and tissues, from both living and deceased individuals, must be handled as being potentially infectious for hepatitis and HIV (human immunodeficiency virus).

Avoid direct contact with all human blood, body fluids, and tissues. Personal protective equipment must be readily available and used. (See Universal Precautions under Bloodborne Pathogen Safety)

Surgical caps, fluid?resistant protective clothing, face masks/shields, eye protection, shoe covers and boots should be worn in instances when gross contamination can be reasonably anticipated (e.g., autopsies, crime scenes, mass disasters).

Bombings

If a bombing incident occurs, investigative personnel should ensure that the following precautions are taken before entering the scene:

Ensure that all utilities (electric, gas, and water) are turned off. Contact local utilities or power company for assistance.

A bomb technician should first check the damaged area for unexploded bomb(s).

The structure should then be checked by engineers for hazardous structural conditions.

Do not touch or move any suspected explosive device at the crime scene until it has been rendered safe by a public safety bomb squad or military Explosive Ordnance Disposal (EOD) Unit.

Initial entry personnel should carry at least one radiation extremity monitoring alarming dosimeter/rate meter in order to identify any potential radiation hazard.

Use proper personal protective equipment such as hard hats, safety goggles, gloves, foul weather clothing, waterproof and puncture-resistant coveralls, steel/toe steel shank workboot, respirator, reflective tape for clothing, and any other protective item. (See Personal Protective Equipment).

All bombing or explosive?related evidence which consists of substances of unknown composition, such as powders or liquids, must be assumed to be extremely sensitive and capable of initiation or detonation.

Unknown substances in these matters should be examined by a bomb technician or a forensic chemist before collection.

Prior to packaging for shipment, call the FBI Laboratory, Explosives Unit at (202) 324?2696 to ascertain the quantity needed for analysis, the packaging method to be used, and the proper shipping method. Also, call for questions regarding handling of these types of substances.

All unknown substances should be labeled:

Use caution when handling. Substance is possibly flammable or explosive.

All evidence collected at the crime scene which has been examined by a forensic specialist (bomb technician or chemist) and found to be safe and nonhazardous should be clearly labeled as such. The label should be clearly visible and include the name, agency, and phone number of the forensic expert who examined the material and made the determination that it was safe.

Clandestine Drug Laboratories

Clandestine drug laboratories may present extremely dangerous situations to untrained personnel. These laboratories often contain extremely dangerous chemicals, which may be intentionally mislabeled, as well as "booby trapped," to prevent entry. They should only be searched, cleared, and decontaminated by the Drug Enforcement Administration (DEA) personnel who are trained and certified for this type of work.

When dealing with clandestine drug laboratories evacuate the scene, secure the area, and contact the nearest office of the DEA.

Removal of Hazardous Materials from the Crime Scene/Mass Disaster

All hazardous materials should be properly labeled, stating the type of hazard and any special handling procedures before being removed from the crime scene/mass disaster.

All hazardous material labels should be dearly visible and include the agency, name, and phone number of the forensic expert who examined the material.

Title 49 of the Code of Federal Regulations lists specific requirements that must be observed in preparing hazardous materials for shipment by air, highway, rail, water, or any combination thereof.

Title 49 of the Code of Federal Regulations, part 172.101 (49 C.F.R. 172.101), provides a Hazardous Materials Table which identifies those items considered hazardous for the purpose of transportation, special provisions, hazardous materials

communications, emergency response information, and training requirements.

Exposure to Critical (Traumatic) Incidents

Shootings, drownings, accidents, sexual assault and child abuse are only a few examples of critical (traumatic) incidents that law enforcement personnel are exposed to which may produce significant emotional responses. These responses may include any of the following:

Alcohol/substance abuse
Anger
Anxiety
Crying/depression
Fatigue
Flashbacks and intrusive thoughts
Guilt
Heightened sense of danger
isolation/withdrawal
Marital problems
Nightmares
Numbness
Perceptions of going insane
Startle reactions (e.g., difficulty sleeping, headaches, muscle aches, stomachaches, high blood pressure, etc.)
Trouble remembering/concentrating

For additional information or assistance concerning critical (traumatic) incidents, contact:

The International Critical Incident Stress Foundation, Baltimore, Maryland, (410) 730 4311. If emergency assistance is needed, contact the 24 hour Critical Incident Stress Debriefing (CISD) Hotline, (410) 313 2473.

Safety

Bloodborne Pathogen Safety

On December 6,1991, the Occupational Safety and Health Administration (OSHA) issued the regulation called "Occupational Exposure to Bloodborne Pathogens (BBP)," found in Title 29, Section 1910.1030 (29 C.F.R. 1910.1030) of the Code of Federal Regulations. The standard covers those occupations having a high

potential for exposure to bloodborne pathogens, including law enforcement, emergency response, and crime laboratory personnel.

Individuals covered by this standard should observe Universal Precautions to prevent contact with human blood, body fluids, tissues and other potentially infectious materials.

Universal Precautions require that employees treat au human blood, body fluids, or other potentially infectious materials to be infectious for hepatitis B virus (HBV), human immunodeficiency virus (HIV), and other bloodborne pathogens. Appropriate protective measures to be taken to avoid direct contact with these materials include:

Use barrier protection at all times;

Prohibit eating, drinking, smoking, or applying makeup at the crime scene/mass disaster;

Use gloves when there may be hand contact with blood or other potentially infectious materials. Gloves should always be worn as if there are cuts, scratches, or other breaks in the skin. In some instances where there is heavily contaminated material, the use of double gloves is advisable for additional protection;

Change gloves when contaminated or as soon as feasible if torn, punctured, or when their ability to function as a barrier is compromised;

Always wash hands after removal of gloves or other personal protective equipment (PPE). The removal of gloves and other PPE should be performed in a manner which will not result in the contamination of unprotected skin or clothing;

Wear safety goggles, protective face masks or shields, or glasses with side shields to protect from splashes, sprays, spatters, or droplets of blood or other potentially infectious materials. These same precautions must be taken when collecting dried stains for laboratory analysis;

Use disposable items, such as gloves, coveralls, shoe covers, etc. when potentially infectious materials are present;

Place contaminated sharps (e.g., broken glass, needles, knives,

etc.,) in appropriate leakproof, closable, puncture?resistant containers when these sharps are to be discarded, transported, or shipped. If transported or shipped, containers should be appropriately labeled;

Do not bend, recap, remove, or otherwise handle contaminated needles or other sharps;

Use a protective device, such as a CAR mask, when performing mouth?to?mouth resuscitation;

Decontaminate all equipment after use with a solution of household bleach (diluted 1:10, 70% isopropyl alcohol, or other appropriate disinfectants;

After all evidence e has been collected and the crime scene has been released, the owner or occupants of the affected property should be made aware of the potential risks from bloodborne pathogens;

Evidence containing blood or other body fluids should be completely dried before it is packaged and shipped to the laboratory for analysis. Appropriate biohazard warning labels must be affixed to the evidence container indicating that a potentially infectious material may be present;

To avoid direct contact and exposure to potentially infectious evidentiary materials in the courtroom, evidence contaminated with human blood or other potentially infectious materials should be placed in a sealed, transparent package and labeled with the appropriate biohazard warning label.

Additional Precautions

In addition to Universal Precautions, there are certain requirements in the OSHA BBP standard that pertain to collection, handling, storage, transport, and shipping of blood and other potentially infectious material.

Evidence specimens contaminated with wet blood or other potentially infectious materials must be placed in a closable, leakproof container (i.e., heavy?duty plastic bag) when transported from the crime scene to the drying location. After drying, the evidence must be placed in a suitable and properly labeled container before being transported to the crime

laboratory. (Note: Plastic bags used to transport evidence contaminated with wet blood or other fluids should be retained as evidence.)

OSHA's BBP standard 29 CFR 1910.1030 (g)(l)(i), requires that evidence specimens, such as liquid blood (vacutainer tubes) or other potentially infectious materials, must be placed in a closable, leakproof container and labeled (see above) or color?coded prior to being stored or transported.

Engineering and work practice controls are used to eliminate or minimize employee exposure to hazardous materials. Engineering controls (e.g., puncture?resistant containers for contaminated sharps, paint stirrers, and adjustable mirrors for locating evidence in confined/hidden spaces) isolate or remove the hazard, whether bloodborne or chemical, from the workplace. Workplace controls (e.g., hand washing facilities, wearing personal protective equipment) reduce the likelihood of exposure by altering the manner in which a task is performed.

For additional information on proper protection against blood and other potentially infectious materials, refer to "Personal Protective Equipment."

Decontamination of Nondisposable Clothing

These recommendations apply only to nondisposable clothing and not to clothing that is part of the personal protective equipment according to OSHA 29 CFR 1910.1030.

Protect hands with disposable gloves;

Remove contaminated garment carefully; protect skin and mucosal surfaces during removal, e.g., cover face and eyes with mask and goggles or face shield when removing garment over head;

Fill a sink, bucket, or deep tray with cold water and soak contaminated part of garment to remove blood or other material. Using gloves, squeeze out water from garment; dispose of water into sewer, toilet, or dirty sink; rinse sink and container with plenty of water; disinfect container if needed;

Store garment in plastic bag prior to being laundered, or place garment into tray and cover contaminated area with one of the following disinfectants:

1:20 dilution fresh chlorine bleach for fabrics that tolerate bleaching such as white coats or uniforms;

70% alcohol (ethanol or isopropyl) for delicate fabrics;

Let soak for 10 minutes, remove, rinse with water, and dry. The disinfected garment can be laundered or dry cleaned.

Chemical Safety

Depending on the type of material encountered, a variety of health or safety hazards may exist. Some of those hazards are identified by the following categories:

Flammable or combustible materials (e.g., gasoline, acetone, ether) ignite easily when exposed to both air and an ignition source such as a spark or flame;

Explosive materials (e.g., dynamite, CA, TNT, etc.) are chemically unstable. Instability determines the sensitivity (i.e., the amount of energy required to initiate a reaction). Explosives containing nitroglycerine require a minimal amount of shock to be initiated. Heat, friction, and fire are also means for initiation;

Pyrophoric material is any liquid or solid igniting spontaneously in air at or below 130° F (54° C) Examples include phosphorus, sodium, and barium;

Oxidizers are a class of chemical compounds that can react violently with flammable and combustible materials. Some common types of oxidizers include chlorates, nitrates, hydrogen peroxide, perchloric acid, and sulfuric acid. Avoid storage with incompatible materials that could react with the oxidizer or catalyze its decomposition;

Corrosive materials are those substances which can cause injury to body tissue or be corrosive to metal. Corrosive injury may be to a minor degree (irritation) or actual physical destruction of body tissues. Corrosive chemicals act on body tissues through direct contact with the skin or eyes, inhalation, or ingestion;

The key to working safely with chemicals is knowledge of their

hazardous properties, proper training in handling and disposal techniques, and emergency preparedness.

For proper protection against Chemicals Hazards, see "Personal Protective Equipment."

Latent Fingerprint Safety

Refer to Bloodborne Pathogen Safety, when dealing with any human tissue or body fluid from a living or deceased individual.

When latent print evidence is contaminated by human biological material, appropriate personal protective equipment and engineering controls must be used during the examination.

Light Source Safety

The use of ultraviolet (UV) lights, lasers, and other alternative light sources are increasing in use not only in the latent fingerprint field, but in forensic science in general. While these tools are of great value to the forensic scientist, they also create some potentially hazardous conditions, especially when the user is untrained or unaware of the hazards associated with their use. The operator of any light source must be properly trained in the use and safety of these instruments. Regardless of the light source being used, it is absolutely essential that appropriate eye wear be worn by the user and by all personnel in the vicinity of the device.

When using UV light sources, it is essential that an individual's eyes be protected from direct exposure and that prolonged exposure to the skin be avoided.

Because some lasers create an apparent point source of light which may not be visible to the viewer, there exists an enormous radiant energy which has the potential to cause irreversible damage to the retinal tissues of the eye, from both direct and/or reflected beams.

Personal protection for the eyes requires goggles which have sufficient protective material and which are fitted so that stray light cannot enter from any angle. All laser protective eye wear should be clearly labeled with the optical density and wavelength for which protection is afforded.

Avoid both direct and indirect (reflected from a polished

surface) eye and skin contact with a collimated laser beam. Eye wear, worn while conducting examinations using high?powered lasers should be approved by the American National Standards Institute (ANSI), and have an optical density of five or greater at the maximum operating wavelength.

Adequate ventilation should be provided with all lasers.

Lasers can present a shock hazard both indoors and outdoors in a wet environment.

Keep the exit port of the light source at a sufficient distance from surfaces to prevent overheating and combustion.

Firearms Safely

Weapons should never be shipped or stored in a loaded condition;

Remove all ammunition from firearms and follow the regulations for transportation;

For submission of live ammunition, bullets, and/or guns, follow approved procedures specified by the FBI or local crime laboratory.

Confined Space Safety

A confined space is an enclosed space large enough for an individual to bodily enter and perform assigned work. It has limited or constricted means of entry or exit and is not designed for continuous occupancy.

Entry into confined spaces may expose the individual to a variety of hazards, including toxic gases, explosive atmospheres, oxygen deficiency, and electrical hazards.

Conditions in a confined space must be considered immediately dangerous to life and health unless shown otherwise.

Some safety tips for working in confined spaces include:

Never enter a confined space before all hazards (atmospheric, engulfment, and mechanical) have been identified and procedures have been developed to deal with them;

Always isolate the confined space from all unwanted energy

sources or hazardous substances;

Always maintain proper mechanical ventilation in a confined space and make sure ventilation equipment does not interfere with entry, exit, and rescue procedures;

Never introduce hazards such as welding, cleaning solvents, etc., in a confined space without first making provisions for these hazards;

Always monitor for atmospheric hazards (oxygen, combustibles, toxins) prior to and during entry;

Always provide barriers, as necessary, to warn unauthorized personnel and to keep entrants safe from external hazards;

Always provide constant communications between entrants and outside attendants, and remember to have backup communications if using two?way radios;

Always wear appropriate personal protective equipment: be familiar with the use and limitations of that equipment; and be sure it is properly maintained;

Never attempt rescue in a confined space unless you are part of a designated rescue team and have the proper knowledge, skills, and equipment to effect a safe rescue;

Use of safety belts and harnesses is mandatory.

For additional information, refer to the OSHA standard for permit?required confined spaces, 29 CFR 1910.146.

Personal Protective Equipment Hand Protection

Hand protection should be selected on the basis of the material being handled and the particular hazard (biological or chemical) involved. For chemical resistance, select the glove material that offers the best level of protection for the chemicals handled. The following are some glove material types and their functions:

Nitrile (NOR) provides protection from acids, alkaline solutions, hydraulic fluid, photo solutions, fuels, lubricants, aromatic, petroleum, and chlorinated solvents. It also offers excellent resistance to punctures, cuts, and snags.

Neoprene offers resistance to oil, grease, acids, solvents, alkalies, bases, and most refrigerants.

Polyvinyl chloride (PVC) is chemically?resistant to alkalies, oils, limited concentrations of nitric and chromic acids. This material can be worn by most workers who are allergic to natural rubber.

Natural Rubber (Latex) resists mild acids, caustics, detergents, germicides and ketonic solutions, but it will swell and degrade if exposed to gasoline and kerosene. Because gloves made from natural rubber (latex) are adversely affected by exposure to high temperatures and direct sunlight, they should not be stored for an extended period of time in the passenger area or trunk of a car.

Have readily accessible hypoallergenic gloves, glove liners, powderless gloves, and other similar alternatives for those allergic to the normally provided gloves.

Check the gloves to be used for holes, punctures, and tears and remove rings or other sharp objects which may cause punctures.

Wear heavy (8?10 mil thick) latex gloves or a double layer of gloves when working with items heavily contaminated with blood or other human biological material.

Remove gloves carefully by grasping the cuffs and pulling them off inside out, starting at the wrist and working toward the fingers.

Discard disposable gloves in designated containers. Do not reuse.

Eye Protection

Eye protection is an important consideration when working at a crime scene or when handling potentially hazardous materials. Appropriate eye protection (face shields, goggles and safety glasses) should be worn when handling any of the following materials:

Biohazards
Caustics, corrosives, or irritants
Explosives
Flammable materials

Lasers radioactive materials
UV light

Types of Eye Protection

Refer to American National Standard Practice for Occupational and Educational Eye and Face Protection, American National Standards Institute, ANSI Z87.1?1989 (or latest revision) for additional information.

Safety Glasses

At the crime scene, you are likely to encounter both biological and chemical hazards. There always exists the potential for splashing biological fluids or chemicals. In addition, flying objects may enter the eyes if not properly protected. Safety glasses should be worn at all times in the presence of these hazards. In most instances, safety glasses with side shields are adequate. Where there is danger of splashing of biological fluids, chemicals, or flying particles, goggles and/or full face shields will give more protection.

Contact Lenses

Contact lenses are not to be used as eye protection. In the event of a chemical splash into the eye, it is often extremely difficult to remove the contact lens to irrigate the eye. Gases and vapors can be concentrated under such lenses and cause injury or permanent eye damage.

Prescription Safety Glasses

Crime scene personnel whose vision requires the use of corrective lenses should wear safety eye protection of one of the following types:

Prescription safety glasses with protective lenses. Safety eye wear that can be worn over prescription glasses without disturbing the adjustment of the glasses.

Safety Goggles

Goggles are not intended for general use. They are intended for wear when there is danger of splashing chemicals or flying particles.

Face Masks/Shields

Full?face masks/shields that protect the face and throat should always be worn when maximum protection from flying particles and harmful liquids (biological or chemical) is needed.

Foot Protection

Shoes that completely cover and protect the foot are recommended. Shoes that expose the foot in any way should not be worn. In addition, fabric shoes, such as tennis shoes, should not be worn as they may readily absorb liquid. Certain hazardous situations may require footwear that has conductive soles, insulated soles, steel toe and shank, and is chemical resistant.

Respiratory Protection

Certain crime scenes, such as bombings and clandestine laboratories, may produce noxious fumes and other airborne contaminants which require respiratory protection.

Safety supply companies carry many types of respirators ranging from a disposable dust mask to a self?contained breathing apparatus. Selection should be made according to the guidelines in the American National Standard Practices for Respiratory Protection Z88.2?1992, after consultation with health and safety professionals.

The critical elements for the successful use of a respirator include training, motivation, medical evaluation, fit testing, and a respirator maintenance program. Without a complete respiratory protection program, personnel will not receive the degree of protection anticipated from a respirator, even if it is a correct choice for the situation. As a minimum, compliance with Title 29 CFR 1910.134 is mandatory whenever respirators are used by personnel, whether on a required or voluntary basis.

Head Protection

Elimination or control of hazards leading to an accident should be given first consideration, but many accidents causing head injuries are difficult to anticipate and control. Where these conditions exist, appropriate head protection must be provided to eliminate injury.

Head protection, in the form of protective hats, must resist

penetration and absorb the impact. In certain situations, such as bombings which can cause structural damage to a scene, additional head protection may be necessary. Heavy?duty fireman?type hats provide added protection to the ears and posterior neck. Protective helmets also protect against electrical shock.

The standard recognized by OSHA for protective hats is contained in ANSI Requirements for Industrial Head Protection, Z89.1?1986. This standard should be consulted for further details.

Bibliography

Reference materials(240) are available for the preceding sections.

The Crime Scene

The physical evidence recovered during investigations of crime scenes is one of the critical areas in contemporary law enforcement. Often, the facts and tangible items of evidence derived from these investigations make the difference between success and failure when a case is brought to trial. With the evolution of the scientific aspects of forensic science, more attention must be awarded at crime scenes to recovering and maintaining the integrity of evidence which will be eventually examined by specialists in the crime laboratory.

One important consideration, bearing on the modern view of forensic science is that this field is sometimes associated only with work accomplished in the crime laboratory. This consideration, however, is in actuality a very limited perspective on the overall area of forensic science. It is obvious that the ability of the laboratory to provide scientific interpretations is dependent to a great extent on the recognition, recovery and documentation of evidence at the crime scene. In essence, then, the field investigator or crime scene technician is as much a part of forensic science as the highly skilled laboratory examiner. If the evidence from a scene is not properly handled, the work of the crime laboratory can be hindered to a great extent.

Therefore, it is suggested the discipline of forensic science be regarded as a multifaceted one. Each level of evidence involvement must be planned, organized, and performed with a central issue in mind: effective use of the physical evidence to its greatest potential.

It should be ensured that the crime scene searches are conducted in a systematic and methodical fashion. Numerous suggestions are presented in terms of practical aspects of day-to-day search operations.

Due to the myriad situations which can occur, it would be virtually impossible to cover all conceivable possibilities. Nonetheless, the material contained herein brings out significant concerns common to almost all agencies. Additionally, these points should serve as catalysts for the reader to generate other important items based on specific agency needs.

Practical Suggestions Regarding Crime Scene Administration and Management

Preparation

Accumulate packaging and collection of materials necessary for typical search circumstances;

Prepare the preliminary format for the paperwork needed to document the conducting of the search;

Ensure that all specialists are aware of the overall forms of evidence usually encountered as well as the proper handling of these materials;

Evaluate the current legal ramifications of crime scene searches (e.g., obtaining of search warrants);

Discuss the search with involved personnel before arrival at scene, if possible;

Identify, when feasible, a person?in?charge prior to arrival at scene;

Make preliminary personnel assignments before arrival at scene, if practicable;

Consider the safety and comfort of search personnel. When encountering a potentially dangerous scene or inclement weather, be prepared with:

· **clothing**

- **communication**
- **lighting assistance**
- **shelter**
- **transportation**
- **food**
- **medical assistance**
- **scene security**
- **equipment**

Assess the personnel assignments normally required to successfully process a crime scene.

The following information is provided as an example of the personnel responsibilities. (Depending on circumstances and personnel availability, it may not be feasible to have one person assigned to each duty. It is relatively common for one individual to accomplish two or more responsibilities.

Person-In-Charge
- **administrative log**
- **narrative description**
- **preliminary survey**
- **scene security**
- **final decision making**

Photographer
- **photographs**
- **photographic log**

Sketch Preparer
- **sketch**
- **documentation of items on sketch**

Evidence Recorder
- **evidence log**
- **evidence custodian**

In instances of prolonged search efforts, consider the use of shifts using two or more teams. Transfer paperwork and responsibility in a preplanned manner from one team to the next.

Organize communication with services of any ancillary nature (e.g., medical examiner, prosecutive attorney) in order that questions which surface during crime scene search may be resolved. Take steps to organize a command post headquarters for

communication, decision making, etc., in major or complicated crime scene investigations.

The possibility of coordinating multijurisdiction scene investigations should be explored. It is advantageous to have working agreements that are mutually acceptable to potentially involved agencies. These agreements should be made before confusion occurs in an actual multijurisdiction case, rather than as a later crisis response.

Approach Scene

Be alert for discarded evidence;

Make pertinent notes;

Establish frame of mind to take control of scene regardless of circumstances observed on arrival;

Consider personal safety.

Secure and Protect Scene

Take control on arrival;

Determine extent to which scene has thus far been protected;

Check for adequate scene security even if advised that it has been protected prior to arrival;

Obtain information from logical personnel who have entered scene and have knowledge relative to its original conditions;

Identify one individual who is designated as the person?in?charge for final decision making and problem resolution;

Take notes: do not rely on memory;

Keep out unauthorized personnel: begin recording who enters and leaves;

Evaluate Physical Evidence Possibilities;

Initiate Preliminary Survey

The survey is an organizational stage to plan for the entire search'

Cautiously, walk through the scene;

Maintain definite administrative and emotional control (usually the person?in?charge);

Select appropriate narrative description technique;

Acquire preliminary photographs;

Delineate extent of the search area: usually expand initial perimeter;

Organize methods and procedures needed: recognize special problem areas;

Determine manpower and equipment needs make specific assignments;

Identify and protect transient physical evidence, e.g., evidence that can be lost such as hairs, fibers, dust, etc.;

Develop a general theory of the crime;

Make extensive notes to document the scene's physical and environmental conditions, assignments, movement of personnel, etc.;

Evaluate Physical Evidence Possibilities

This evaluation begins upon arrival at scene and becomes detailed in the preliminary survey stage. Based on the preliminary survey, establish evidence types most likely to be encountered.

Ensure collection and packaging equipment is sufficient for task at hand: given scene may require special techniques not normally used.

Focus first on evidence that could be lost (e.g., detached from garment) and leave the least transient forms of evidence to be last;

Ensure all personnel consider the great variety of possible evidence, not only evidence within the scope of their respective specialties;

Focus first on the easily accessible areas in open view and progress eventually to possible out?of?view locations: look for purposely hidden items;

Consider whether the evidence appears to have been moved inadvertently;

Evaluate whether or not the scene and evidence appear intentionally contrived;

Prepare Narrative Description

The narrative is a running, written description of the condition of the crime scene in general terms.

Represent the scene in a general to specific reference scheme;

Use photographs to supplement narrative description;

Use a systematic approach in recording the narrative; no item is too insignificant to record if it catches one's attention;

Do not permit the narrative effort to degenerate into a sporadic and unorganized attempt to recover physical evidence. It is recommended that evidence not be collected at this point, under most circumstances;

Methods of narrative include: written, audio, and video (sight/sound or sight only).

Depict Scene Photographically

Begin photography as soon as possible: plan before photographing;

Document the photographic effort with a photographic log;

Ensure that a progression of overall, medium, and close?up views of the scene is established;

Use a recognized scale device for size determination when

applicable;

When a scale device is used, first take a photograph without the inclusion of this device;

Photograph the evidence in place before collecting and packaging;

Be observant of and photograph areas adjacent to the crime scene, points of entry, exits, windows attics, etc.;

Consider the feasibility of aerial photography;

Photograph items, places, etc., to corroborate the statements of witnesses, victims, and suspects;

Take photographs from eye level, when feasible, to represent the scene as would be observed by normal view;

Points to Consider

Use two-dimensional photographs supplemented by diagrams and sketches;

Do not hesitate to photograph something which has no apparent significance. Film is relatively cheap compared to the importance of providing evidence to the investigator;

Prepare Diagram and Sketch of Scene

The diagram establishes a permanent record of items, conditions and distance-size relationships: diagrams supplement photographs;

Draw a rough sketch at the scene, which is normally not drawn to scale;

Typical material on the rough sketch:

specific location
date
time
case identifier
preparer/assistants
weather conditions
lighting conditions
scale or scale disclaimer

compass orientation
evidence
measurements
key or legend

Number designations on the sketch may be coordinated with same number designations on the evidence log in many instances.

This sketch should contain sufficient measurements and details to be used as a model for a drawn?to?scale diagram, if necessary.

Be sure to select the sketch technique before beginning the sketch. Ensure that enough room is allowed to include all pertinent information and measurements.

General progression of sketches:

· lay out the basic perimeter;
· set forth fixed objects, furniture, etc.;
· insert evidence as it is recovered;
· record appropriate measurements;
· set forth the key/legend, compass orientation, etc.

Conduct Detailed Search/Record and Collect Physical Evidence

Accomplish the search based on a previous evaluation of evidence possibilities.

Conduct search from general to specific, regarding evidence items.

Use specialized search patterns when possible, (e.g., strip, grid, spiral, quadrant or zone).

Mark evidence locations on the diagram/sketch.

Complete the evidence log with appropriate notations for each item of evidence.

Have at least two persons:
· see evidence in place before collection;
· observe it being recovered;
· mark evidence (mark item itself whenever feasible);
· place identifying marks on evidence containers.

If feasible, have one person as an evidence custodian especially

in relatively complicated crime scenes involving large amounts of evidence.

Do not excessively handle the evidence after recovery.

Seal all evidence containers at the crime scene.

Do not guess on packaging requirements: different types of evidence may necessitate different containers.

Photograph all items before collection and enter notations in the photographic log (remember to use a scale device when necessary).

Do not forget entrance and exit areas at the scene for potential evidence.

Be sure to obtain appropriate known standards (e.g., fiber samples from a
known carpet).

Always make a complete evaluation of the crime scene. Do not rely on the results of Laboratory tests only.

Constantly check paperwork, packaging notations, and other pertinent recordings of information for possible errors which may cause confusion or problems at a later time.

Four Basic Premises to Consider

The best search options are often the most difficult and time consuming.

You cannot over?document the physical evidence.

There is only one chance to perform the job properly.

There are two basic search approaches, in this order:

1. A cautious search of visible areas, taking steps to avoid evidence loss or contamination;
2. After the cautious search, a vigorous search for hidden or concealed areas.

Conduct Final Survey

This survey is a critical review of all aspects of the search.

Discuss the search jointly with all personnel for completeness.

Double?check documentation to detect inadvertent errors.

Ensure that photographs are taken of scene showing the final condition after completion of the search.

Check to ensure all evidence is accounted for before departing the scene.

Ensure all equipment used in the search is gathered.

Make sure possible hiding places or difficult access areas have not been overlooked in a detailed search.

Critical issues:

Have you gone far enough in the search for evidence, documented all essential things, and made no assumptions which may prove to be incorrect in the future?

Release Crime Scene

Release the crime scene only after completion of the final survey.

At minimum, documentation should be made of:
· time/date of release.
· to whom released.
· by whom released.

Ensure that the evidence found at the crime scene is gathered according to legal requirements, is documented, and is appropriately marked for future reference.

Once the scene has been formally released, reentry may require a warrant.

Only the person?in-charge should have the authority to release the scene.

Ensure that all personnel follow this rule.

Release the scene with the notion that there is only one chance to perform the job correctly and completely. Release then occurs

once personnel are satisfied this is the situation.

Consider the need for experts (e.g.,blood pattern analyst, medical examiner) to observe the scene before it is release
.

Examinations of Explosives

The Explosives Unit conducts examinations of Improvised Explosive Device (IED) remains, commercial explosives, blasting accessories, military explosives, ordnance items, including toolmark and bomb components. The Explosives Unit may assist in processing bombing crime scenes and handling of explosives. To request assistance or information, call the FBI Laboratory, Explosives Unit at (202) 324?2696. Send correspondence, evidence, or samples to:

Director
Federal Bureau of Investigation
Attn.: FBI Laboratory, Explosives Unit
lOth Street and Pennsylvania Avenue, N.W.
Washington,D.C. 20535

Examinations of Bomb Remains

Bomb remains are examined to identify bomb components such as switches, batteries, detonators, tape, wire and timing mechanisms. Also identified are fabrication techniques, unconsumed explosives, and overall construction of the bomb. Instrumental examination of explosives and explosive residues are carried out by the Materials Analysis Unit in conjunction with bomb component examinations.

Toolmark Examinations

All bomb components are examined for toolmarks, where possible. Tools utilized in the construction of the bomb are identified for investigative purposes.

Reference Files

The Explosives Unit also maintains extensive reference files on commercial explosives, blasting accessories, and bomb components. These files contain technical data that include known standards of military and commercial explosives, time fuses, detonators, batteries, tape, switches, and radio control systems.

Handling Explosives

Explosive devices or bombs should be handled only by qualified police or military bomb disposal personnel.

Shipping Explosives

Explosives are classified as hazardous materials. Special packaging is required, and the amount to be shipped is regulated. Call the Explosives Unit each and every time an explosive is to be shipped for examination. The shipping instructions furnished must be strictly adhered to for meaningful forensic examination as well as safety.

Examinations of Explosives by the Materials Analysis Unit

Examinations in cases involving IEDs are performed by the Materials Analysis Unit to assist the Explosives Unit in the determination of:

· Whether unknown substances are high explosive, low explosive, or incendiary in nature.

· Whether recovered explosives are consistent with known explosive products by compositional analysis.

Sometimes, the type of explosive can be determined by examinations of residues from the scene of a bombing. It should be noted that most residues remaining after the detonation of an explosive charge are water soluble. For this reason, these residues must be protected against exposure to excessive moisture. Also, other residues evaporate quickly, necessitating the immediate sealing of collected debris in new, airtight paint cans.

Post-blast Investigation Guidelines

The processing of bombing crime scenes, in spite of often massive destruction, must be conducted on the theory that everything at the scene, prior to the explosion, is still present unless vaporized by the explosion. While complex, it is possible to determine the cause of an explosion from the components found at the scene.

Purpose of Post-blast Investigation

The purpose of the Post-blast investigation process is to determine what happened, how it happened, and to gather evidence.

Special Considerations

The following steps are to assist in the preparation, supervision, and evaluation of activity connected with a bombing crime scene. The topics covered are not meant to be all inclusive, and no attempt has been made to comment on the many aspects of a bombing investigation. A comprehensive course of instruction in Post-blast crime scene processing is available through the Explosives Unit in the Post-Blast Investigator's School. For further information, contact the Explosives Unit.

Formulate a Plan of Action

Formulate a plan adapted to the particulars of the bombing crime scene. This plan should include consideration of the creation of an on?scene control center; establishment of a chain of command; assignment of various tasks such as evidence collection, photography, fingerprint processing, and crowd control; protection of the crime scene; acquisition of necessary equipment; periodically evaluating progress; providing pertinent information to the public; and public safety.

Control Center

Consider establishing an on?scene control center, particularly after a large bombing which may require days or even weeks to complete the investigation of the crime scene. The control center should coordinate efforts among investigative personnel, representatives of other agencies, and utilities, as well as handle inquiries from sightseers, persons associated with the scene, relatives of victims, and the press. One person should be in overall command of the bombing investigation, another person over the management of the crime scene search efforts, and yet another controlling the collection and handling of evidence. These three individuals must maintain close coordination and continually exchange information on an expeditious basis. The crime scene manager should report directly to the person in charge of the entire investigation.

Safety

Evaluate safety conditions at the outset of the crime scene search and on a continuing basis throughout the search. Consider

the possibility of additional devices, a device that has failed to function, the presence of live explosives in the debris, the presence of utilities (gas, electrical, etc.) in the vicinity of the blast, structural damage to buildings and, most importantly, the safety of crime scene personnel, residents, and the public. Only public safety or military explosive ordnance disposal personnel should handle suspected IEDs.

Protection of the Crime Scene

Take adequate safeguards to protect the crime scene from fire, law enforcement, utility, and rescue personnel as well as others, such as sightseers, victims, and individuals with a personal interest in the property. Also, since most residues remaining after the detonation of an explosive are water soluble, the crime scene should be protected as much as possible from exposure to excessive moisture such as rain, snow, broken water/sewer pipes, etc.

Crime Scene Photography

Take appropriate photographs to give an accurate photographic representation of the crime scene. These photographs should be made immediately before, periodically during, and at the completion of the crime scene processing. Properly identify each photograph as to location and orientation; coordinate the photographs with diagrams, maps and/or blueprints; and consider the necessity of aerial photographs.

Crime Scene Specialists

If there are no available trained specialists to handle and process bombing crime scenes, make arrangements to obtain such specialists. Although the basic principles of conducting a crime scene search apply in a bomb scene search, individuals with specialized knowledge of explosives, improvised explosive devices, damage produced by explosive charges, and other facets associated with bomb scene searches, such as the search and collection of physical bombing evidence are extremely valuable to the effective and efficient processing of a bombing crime scene. These specialists need not be qualified bomb disposal specialists. They should be the first persons to be selected for the evidence and crime scene search coordinator positions.

Equipment

Promptly make arrangements to obtain the necessary equipment to move debris and material at the scene. Although the equipment needed at a crime scene varies from incident to incident, the following is a typical representation of the necessary basic equipment:

Hand Tools: Shovels, rakes, brooms, bolt cutters, wire cutters, sledge hammers, hammers, screwdrivers, wrenches, chisels, hacksaws, magnets, flashlights, knives, 50' measuring tapes, and traffic wheel?measuring devices.

Personal Equipment: Hard hats, safety goggles, face masks or respirators, work and rubber gloves, foul weather clothing, coveralls, and work shoes.

Heavy Equipment: Dump truck, front?end loader, bulldozer, crane, and shoring materials.

Other Equipment: Screens for sifting debris, wheelbarrows, metal trash cans, power saws, cutting torch equipment, ladders, portable lighting equipment, metal detectors, plastic sheeting, photographic equipment, and rappeling equipment.

Crime Scene Kit: Usual equipment used for the collection, preservation, and identification of physical evidence.

Vehicle: If the suspected target or container was a vehicle, if possible, bring to the scene an identical vehicle to assist in identifying fragmented or distorted items.

Search for Evidence

Bear in mind that the search for evidence at a bombing crime scene is critical; it may contain important evidence for identifying the bomber(s) and/or assisting in the successful prosecution of the matter. The following guidelines are general in nature, as the exact method of searching depends on various uncontrollable factors.

It is extremely important that the area be photographed before a search begins, and when evidence is located.

Place one person in overall charge of the collection of the evidence from the various collectors, as valuable evidence may not be admissible in court if a proper "chain of custody" cannot be established. Include the location where evidence was

recovered. A diagram of the crime scene is always useful.

Do not stop the search after a few items have been found. Valuable evidence may be overlooked.

Avoid the tendency to concentrate only on obvious explosive?related physical evidence such as: safety fuse, blasting caps and leg wires, explosive residues, or unconsumed explosives, as this may result in overlooking other valuable evidence.

Look for evidence such as: fingerprints, hair and fibers, soil, blood, paint, plastic, tape, tools and/or toolmarks, metals, writing paper, printing, cardboard, wood, leather and tire tread?shoe print impressions which may produce a lead in the investigation.

Conduct a well?organized, thorough, careful search to prevent the necessity of a second search. However, have a secure disposal site for debris, should a second search be necessary.

Normally, initiation of the search should start at the site of the explosion and work outward. If the bomb crater is in earth, obtain soil samples from the perimeter, sides, and bottom of the crater, making sure to dig into the substrata. Soil samples should also be taken away from the scene for comparison purposes. If the crater is in another type of material, take samples from similar areas.

Sift small debris through a 1/4" wire screen onto an insect?type screen. Usually, screens are placed on 2?foot square wooden frames constructed from 2"x4" lumber.

X-ray the bodies of victims who were in close proximity of the explosion site, for possible physical evidence and, if possible, have the evidence removed. Victims' clothing should be retained as residues may be present on the clothing.

Search a sufficient distance from the seat of the explosion. Evidence has been found up to several blocks away from large explosions. A basic rule of thumb is to extend your perimeter half the distance past the site where the most remote piece of evidence was located.

Determine the probable flight path of bomb components to prevent needless searches.

Search trees, shrubbery, telephone poles, and the roofs, ledges and gutters of buildings. Instances have occurred where physical evidence was carried away on the tires of vehicles responding to the crime scene.

Establish a search pattern for large areas. A line of searchers moving forward has been found to be a satisfactory method. A bomb scene specialist should follow the line of searchers to evaluate the items found, control the searchers, and furnish guidance. If a second search is desired, the positions of the searchers on the line should be rotated. Charting the areas to be searched will ensure a thorough search pattern.

Retain all items foreign to the scene and items which the searchers cannot identify after seeking the assistance of those familiar with the bombed target.

Toolmark Identification

Toolmark identification is a microscopic side?by?side comparison that attempts to link a particular tool with a particular mark to the exclusion of any other tool produced. Such a singular identification can be accomplished by comparing both class characteristics (those marks left by a particular group of tools, such as a screwdriver blade that is one fourth of an inch wide) and the unique microscopic marks that could only have been left by one individual tool and no other.

The term "tool" is used in a very broad sense. It could mean a screwdriver blade, vice grips, a knife or a pry tool. It could also be the comparison of a piece of paint on a tool with the surface upon which that tool was used. Further, it could be the comparison of two pieces of rubber that have been pulled apart from each other, as can happen in a car stripping operation. The tools that can be compared in these types of examinations are only limited by the imagination of the police officer or laboratory examiner.

Conclusions

· Examinations may positively conclude that a tool did or did not produce a toolmark. Exams may also conclude that there are not sufficient individual characteristics remaining within the toolmark to determine if the tool did or did not produce the questioned toolmark.

· Class characteristics could not eliminate a particular tool and subsequently, the tool could have been used to produce a certain mark.

Toolmark Examinations

Examination of the toolmark can determine:
· Type of tool used (class characteristics);
· Size of tool used (class characteristics);
· Unusual features of tool (class or individual characteristics);
· Action employed by the tool in its normal operation, and/or in its present condition;
· Most importantly, if the toolmark is of value for identification.

Types of Toolmark Examinations

Fracture Matches

Fracture examinations are conducted to ascertain if a piece of material from an item such as a metal bolt, plastic automobile trim, knife, screwdriver, wood gunstock, rubber hose, etc., was or was not broken from a like damaged item available for comparison. This type of examination may be requested along with a metallurgy examination if questioned items are metallic in composition

Marks in Wood

This examination is conducted to ascertain whether or not the marks left in a wood specimen can be associated with the tool used to cut it, such as pruning shears, auger bits, etc. This examination may be requested along with a wood examination.

Pressure/Contact

Pressure or contact examinations are conducted to ascertain whether or not any two objects were or were not in contact with each other either momentarily or for a more extended time.

Plastic Replica Casts of Stamped Impressions

Plastic replica casts of stamped numbers in metal, such as altered vehicle identification numbers, can be examined and compared with each other as well as with suspected dies.

Locks and Keys

Lock and key examinations can be conducted to associate locks and keys with each other. Such associations are useful in establishing a conspiracy or link of commonality between or among individuals. It is often possible to illustrate this through their possession of keys which will operate a single, lockable instrumentality (e.g., vehicle, safe house, padlock, etc.). Laboratory examination of a lock can determine whether an attempt has been made to open a lock without the operating key.

Key without Lock

1. A key can be decoded to determine the manufacturer from a lock and code;

2. A determination can be made as to whether or not any number of keys were cut to operate a common lock;

3. A determination can be made as to whether a key is an original or a duplicate.

Lock without Key

1. Locks can be decoded to determine manufacturer and code.

2. Operating keys can be cut which will operate the lock.

3. A determination can be made as to whether an attempt has been made to compromise the lock (open it without the use of the operating key).

Lock with Key

1. A determination as to whether a key will operate a particular lock;

2. In obtaining and submitting lock and key evidence, identify type of lock and key and their function. Consideration should be given to the following:

If possible, submit operating key with lock;

In cylinder locks, remove the entire lock assembly, inducing the strike plate into which the locking bolt is thrown. While strike

plates are usually in door frames, locks are usually in doors.

In automobile locks, remove lock cylinders from doors, trunk and ignition.

Do not insert keys to operate lodes unless necessary to prevent destruction in lock removal.

In cases where the lock has been partially destroyed, look for and collect internal lock parts, e.g., lock pins, wafers, etc., that could be found at the scene.

Restoration of Obliterated Markings

Obliterated identification markings are often restorable, including markings obliterated by melting of the metal (welding, "puddling"). Obliterated markings can also be restored on materials other than metal, such as wood, plastics, and fiberglass. Because different metals and alloys often require specific methods for restoration of obliterated markings, the Laboratory should be contacted for number restoration procedures for field processing of items too large or heavy for submission to the laboratory.

Obtaining Evidence in Toolmark Cases

If possible, submit the actual toolmarked area for direct comparison. (Note: In footmark cases, the Laboratory will routinely make a plastic replica cast of the footmark for a possible future comparison with marking stamps.) If it is not possible to submit the original item of evidence, prepare and submit a cast of the toolmark, preferably in plastic. The instructions on how to prepare a plastic replica cast or impression are furnished below.

Photographs, although helpful in presenting the overall location of the mark, are of no value for identification purposes.

Do not forget to obtain samples of paint, safe insulation, and any other material likely to appear as foreign deposits on tools.

Do not place the tool against the footmark for size evaluation to avoid contamination.

Instructions for making a plastic cast or impression of stamped numbers in metal:

Recovering stamped numbers from keys and locks. Courtesy of Hans Mejlshede.

Take all casts and impressions before attempting any number restoration;

Use a suitable plastic replica kit to take a cast and impression. For best results, different formulas may be used in different temperature conditions. If possible, move the item to a heated area or garage;

Since the plastic replica will duplicate any foreign material left in the stamped characters, the first priority is cleaning the number area of foreign matter. Remove paint and dirt with a suitable solvent (acetone, gasoline or a commercial paint remover).

You may use a soft brush, such as a toothbrush, to help clean down to the bottom of the stamped impression area, but never use a wire brush as this will produce extraneous marks which scratch the numbers and make identification of the stamps impossible.

It is permissible to use '`Naval Jelly" to remove rust from the stamped numbers;

Build a dam around the stamped characters to retain the plastic while it hardens;

The dam material should be soft and pliable, such as caulking cord, "Play Dough," or modeling clay;

Ensure there are no voids around the dam to prevent leaking;

Following instructions in the kit, mix the liquid and powder from the kit for one minute in the plastic jar which contains the powder and pour into the prepared dam;

The plastic liquid should take no longer than 1/2 hour to harden. Wait until the cast is cool to the touch before removing it. If the cast has a lot of paint and rust, take additional casts and submit the best one to the Laboratory.

Submitting Toolmark Evidence

Pack to preserve the evidence and prevent contamination. Pay particular attention to the part of the tool which could have made the mark;

Identify each item to facilitate court presentation. Consider the possibility that the object from which the specimen was cut may be needed in court;

Submit the tool rather than making test cuts or impressions in field;

Mark ends of evidence which are or are not to be examined.

Reference Files

National Automobile Altered Numbers File (NAANF): The FBI Laboratory maintains in the NAANF selected specimens, including surface replica plastic impressions of altered vehicle identification numbers found on stolen cars, trucks and heavy equipment. The purpose of this file is to have a central repository for such specimens of altered numbers so that comparisons can readily be made at any time in an attempt to identify recovered stolen cars and possibly link such vehicles with commercialized theft rings nationwide, or other cases investigated by the FBI.

National Vehicle Identification Number Standard File (NVSF): The FBI Laboratory maintains in the NVSF standards of VIN plates from each factory of the major manufacturers of American automobiles. The purpose of this file is to enable the Laboratory to determine whether or not a submitted VIN plate is authentic.

Additionally, it gives the Laboratory the capability, in the event that bogus VIN plates are being prepared in an automobile factory, to identify not only which factory is involved, but also which machine is being used to produce the bogus VIN plates. Any suspect VIN plate encountered in investigations should be forwarded to the Laboratory for examination.

Hair and Fiber Examinations

Hairs and fibers examinations aid the investigation by placing the suspect at the scene of the crime, identifying the scene of the crime, identifying the weapon or the instrument of the crime, identifying hit?and?run vehicles, and corroborating witness

testimony. Questions concerning the collection, packaging and submission of this type of evidence should be directed to the Hairs and Fibers Unit, telephone (202) 324 4344. Evidence or samples should be sent to:

Director Federal Bureau of Investigation Attn.: FBI Laboratory, Hairs and Fibers Unit 10th Street and Pennsylvania Avenue, N.W. Washington, D.C. 20535

Examinations are valuable in that they assist in placing the suspect at the scene of the crime:

· Hairs or fibers found on victim's and suspect's clothing in crimes of violence such as rape, assault, and murder.

· Hairs or fibers from suspect found at the scene of crimes such as burglaries armed robberies and car thefts.

Identifying the scene of the crime:

· Hairs or fibers left at the scene of crimes such as murder, rape, and kidnapping.

Identifying the weapon or the instrument of a crime:

· Hairs or fibers on knives or clubs.

Identifying hit?and?run vehicles:

· Hairs or fibers adhering to suspect automobile.

Examinations are also valuable in that they corroborate the witness testimony.

Fiber Examinations

Examinations identify the type of fiber:
· Animal (wool)
· Mineral (glass)
· Synthetic (man?made)
· Vegetable (cotton)
· Determination as to whether or not questioned fibers are the same type and/or color and match in microscopic characteristics with those fibers of a suspects or victim's garments.

· **Not positive evidence, but good circumstantial evidence.**

Fabric Examinations

A positive identification can be made if a questioned piece of fabric can be fitted to the known material Composition, construction, and color fabrics are compared.

Cordage/Rope Examinations

A piece of rope left at the scene of the crime may be compared with similar suspect rope.
· Composition, construction, color and diameter can be determined.
· Manufacturer can sometimes be determined, if a tracer is present.

Botanical

Botanical examinations are conducted where plant material from a known source is compared with plant material from a questioned locale.

Wood-Types Examinations

The presence of a suspect at the crime scene can often be established from a comparison of wood from clothing, vehicle, or possessions with wood from the crime scene. Specific source:

· **Side or end matching**
· **Fracture matching.**
· **Species identification.**

Miscellaneous Examinations

These examinations include the following:
· **Fabric impressions;**
· **Glove prints;**
· **Feathers;**
· **Clothing manufacture's source information through label searches.**

Materials Analysis Examinations

These examinations entail the use of instrumentation such as infrared spectroscopy, X-ray diffractometry, capillary phoresis, high performance liquid chromatography, gas chromatograph/mass spectrograph, or other techniques to identify or compare the chemical compositions of paints, plastics, explosives, cosmetics, tapes, soil, glass and related materials. Other services include metal analyses, metallurgy, and bullet lead comparisons by elemental analysis. Also available are methods to mark materials, but they are not presented in this handbook.

Cosmetics, Paints, Plastics, Polymers, and Tapes

Cosmetics

Unknown or suspected cosmetics and/or makeup can be compared with a potential source in assault cases such as rape. The investigator should be alert to the possible transfer of such materials between victim and suspect.

Automobile Paints

It is possible to establish the color, year, and make of an automobile from a paint chip by use of the National Automotive Paint File which contains original paint systems representing paints used on all makes of American cars, light, medium, and heavy trucks, vans, and many popular imported cars such as Mercedes-Benz, Volkswagen, Porsche, Audi, BMW, Honda, Subaru, Nissan and Toyota.

A very careful search of the accident or crime scene and the victim's personal effects should be made to locate small chips because:

Paint fragments are often found in the clothing of a hit?and?run victim. Therefore, the victim's clothing should be obtained and submitted to the Laboratory whenever possible.

Paints may be transferred from one car to another, from car to object, or from object to car during an accident or the commission of a crime. Occasionally it is better to submit an entire component such as fender or bumper if the paint transfer is very minimal.

Non-automobile Paints

Paint on safes, vaults, windowsills, door frames, etc., may be

transferred to the tools used to open them. Therefore, a comparison can be made between the paint on an object and the paint on a tool.

Plastics, Polymers, and Tapes

It is usually not possible to specifically identify the source, use, or manufacturer of plastic items from composition alone, but the Laboratory can make comparisons such as:

Trim from automobiles, depending upon the uniqueness of the composition, are compared with plastic remaining on the property struck in a hit?and?run type case. In some instances where the manufacturers part number is present on the trim, the specific year and make can be determined.

Plastics comprising insulation on wire used in bombings or other crimes are compared with known or suspected sources of insulated wire.

Plastic/rubber tapes from crime are cotton. compared with suspected possible sources.

Polymers used in surgical cloth?backed tape are compared with known sources.

Miscellaneous plastic material from crime scenes is compared with possible sources.

A positive identification may be made with the end of a piece of tape left at the scene of the crime and a roll of suspect tape. If no end match is possible, composition, construction, and color can be compared as in other types of examinations to associate the question tape with the known.

General Notes to Investigators

If paint samples are to be obtained from any painted-surface, if possible, chip the paint from the surface down to the foundation! substrate rather than scrape it off. When paint is chipped off a surface, its layer structure is intact. Each layer is a point of identification. It is better to have multiple layers of paint on a questioned and known specimen rather than only the top top layer in the known specimen for Comparison and identification purposes.

Be extremely careful in obtaining, packing and marking small paint chips and other small particles of evidence. Be sure they are placed in a leakproof container such as a pillbox or screw?top vial.

1. Do not stick small paint particles on adhesive tape. Small particles have to be removed from the adhesive, laboriously cleaned, and prepared for sophisticated instrumental analyses. Contamination at the time of procurement could prevent a meaningful analysis.

2. Do not put small particles in cotton. It is difficult to remove the particles from the cotton;

3. Do not send small particles in an envelope, unless protected in a "druggist" fold to prevent small particles from leaking and contaminating other evidence.

Mineralogy Examinations

Mineralogy includes many materials, mostly inorganic, crystalline or mineral in nature. Comparisons will, by inference, connect a suspect or object with a crime scene, prove or disprove an alibi provide investigative leads or substantiate a theorized chain of events.

Materials include glass, building materials, soil, industrial dusts, safe insulation, minerals, abrasives, other debris and precious stones/gems.

Soil, Glass and Building Materials

A mineral can generally be thought of as a naturally occurring inorganic compound having a definite chemical composition and a well?defined crystal structure. Materials such as soil, glass, and a variety of building products either consist of or directly derive from rocks and minerals. Quartz and feldspars are common components in most soils, but quartz sand is the principal ingredient in common window glass and Portlandite is the man-made mineral found in hardened concrete. Additionally, wallboard, safe insulation, industrial abrasives, gemstones and other related products are fundamentally minerals

Forensic Utility of Soil

Soil is generally considered to be the natural accumulation of weathering rocks, minerals and decomposing plants. The formation of soil is a dynamic process influenced by geologic parent material, relief, climate, biological activity, and time.

Soil may be developed in place or after being deposited by wind, water or/and man. Additionally, and of forensic significance, soil may contain man?made materials such as fragments of brick, roof shingle stones, paint chips, glass, and other compounds. These man?made materials improve characterization and, consequently, may strengthen the association between specimens.

Glass

The American Society for Testing and Materials (ASTM) defines glass as "the inorganic product of fusion which has cooled to a rigid condition without crystallizing." However, conceptually, and for practical purposes, glass can be regarded as a hard, rigid, brittle solid that is usually translucent to transparent. The examination of glass can be divided into several categories based on its optical, physical and chemical properties.

Fracture Analysis

Given that glass behaves like a brittle solid when broken, the resulting fracture or perforation may yield valuable information regarding the type and general speed of the responsible object, and sometimes, the general direction of impact, also referred to as the angle of incidence.

With regard to the type and general speed of the object, there are two general categories: fractures and perforation that are characteristic of objects traveling at what can be described as a "high velocity," and those believed to have been traveling at a relatively "low velocity."

High velocity impact fractures and perforations are usually characteristic of the projectile being propelled by a means other than "arm thrown," namely, a bullet from a firearm, a rock from a slingshot, a BB from an airgun and the like. These fractures and/or perforations typically produce an individual hole with small and limited radial fractures. They morphologically resemble a "cone," with a greater amount of glass absent on the opposite side of the impact.

Low velocity impacts, conversely, are characterized by an

increased number of well developed radial fractures, usually accompanied by concentric fractures surrounding the point of impact.

There are a number of variables that contribute to the resulting characteristics of the fracture: the size and hardness of the projectile, its shape and density and the distance between the "shooter" and the window, which relates to the projectile's initial and terminal velocities. Also, the thickness and type of glass affect the type of fracture or perforation to be sustained by the window. Accordingly, the interpretation of the fracture can depend upon reasonable assumptions that are likely developed through other aspects of the investigation.

When large pieces of glass are recovered from two different locations, there exists the possibility that pieces from each source may be physically fitted together. This type of association is considered "individual" or single source, to the exclusion of another source. It is possibly the strongest association between glass specimens.

Submitting Glass Specimens

Glass specimens, depending on their size, should be properly preserved. Large sheets or containers should be packaged in hard, sturdy, shock absorbing containers.

Smaller particles travel well in 35 mm film canisters. All specimens should be sealed, and known and questioned specimens should be isolated from each other to prevent cross?contamination in the case of damage and leakage during shipment. When the size of recovered glass is too small for fracture fitting, optical and compositiona1 analytical techniques will be employed to compare the specimens.

The omnidirectional nature of breaking glass serves law enforcement by typically transferring glass particles from the window to the suspect's hair and/or clothing and, subsequently, to the soles of his/her shoes. Particles may also become embedded in the object used to break the glass. Accordingly, the proper preservation and examination of these specimens may associate a suspect with the crime scene long after they have departed.

Typical window glass can be compositionally considered a soda?lime? silicate; soda, referring to the sodium component, derived (in part from salt lime contributes calcium and comes

from limestone, silicate refers to the element silicon which quartz sand provides: this is a simplified/idealized formula.

The complete elemental composition is responsible for a variety of glass properties. Some are desirable ones to facilitate the manufacturing process, others tailored to end use properties like transparency. There are numerous elements that, although minor in proportion, significantly contribute to the product.

Historically, refractive index (RI) determinations have been used to compare small particles of glass (particles as small as specks of finely ground black table pepper).

The RI of glass is dependent upon its composition and temperature. The temperature of the specimen is controlled by the laboratory, its composition established by the manufacturer as per the recipe given desired properties. By determining the RI of glass particles, the examiner can indirectly infer something about the composition. If two particles share the same RI, they likely have similar compositions and, hence, could have been produced by the same manufacturer at the same time.

If particles are of sufficient size, similar to that of very coarse sand (1?2 mm) they can be analyzed compositionally. Specific elements can be identified in concentrations measured in parts per million(PPM). When specimens are compositionally indistinguishable there is increased scientific certainty that they share the same origin.

Building Materials

Building materials encompass a variety of construction?related products, and selected building materials are generally natural or man made mineral and/or rock products.

Hardened concrete can be differentiated from other seemingly similar samples by comparing its color, texture and composition to include its aggregate. A wide variety of mineral aggregates are used that may help restrict the number of possible sources from which a piece of concrete block or similar building material could have originated.

Wallboard is principally gypsum. When discovered on tools or clothing it can support the modus operandi as observed from the crime scene. Additionally, the composition of wallboard can vary from type to type and manufacturer to manufacturer, hence, it too

can sometimes be somewhat specific regarding its origin.

Explosives

Instrumental analyses of explosives and explosive residues are conducted to determine:

From unknown substances, if they are high explosive, low explosive, mixtures of explosives, or incendiary mixtures.

From confiscated or unknown explosives, if they are (by compositional analysis) consistent with known explosive products or homemade mixtures like those used in previous bombings.

From explosive residues, the type of explosive(s) used to cause the explosion.

While some explosive residues are water-soluble and they must be protected against rain or excess of moisture, other residues evaporate quickly. They should be collected as soon as possible in airtight containers and submitted to the Laboratory in a timely fashion. Explosive residues can be deposited on metal, plastic, wood, paper, glass, etc.

The presence of a trained explosives chemist at crime scenes is very important, but if not possible, evidence collected for residue analysis must never be touched by "unprotected" hands and must be packaged in clean containers.

Metallurgy Examinations

Metals or metallic objects may be metallurgically examined for comparison purposes and/or informational purposes.

Examinations for Comparison Purposes

To determine if two metals or two metallic objects came from the same source or from each other, the Laboratory must evaluate surface characteristics, microstructural characteristics, mechanical properties, and composition.

Surface Characteristic: Are evaluated from macroscopic and microscopic features exhibited by the metal surface on fractured areas, accidental marks or accidentally damaged areas, manufacturing defects, material defects, fabrication marks, and

fabrication finish. The fabrication finish reveals part of the mechanical and thermal histories of how the metal was formed, e.g., if it was cast, forged, hot rolled, cold?rolled, extruded, drawn, swaged, milled, spun, pressed, etc.

Microstructure Characteristics: Are revealed by optical and electron microscopy of the internal structural features of a metal. Structural features include the size and shape of grains; the size, shape and distribution of secondary phases; nonmetallic inclusions, and other heterogeneous conditions. The microstructure is related to the composition of the metal and to the thermal and mechanical treatments which the metal had undergone; it therefore contains information concerning the history of the metal

Mechanical Properties: Describe the response of a metal to an applied force or load, e.g., strength, ductility, and hardness.

Composition: Determines the chemical elemental make?up of the metal, including major alloying elements and trace element constituents. Because most commercial metals and alloys are nonhomogeneous materials with substantial elemental variations, small metal samples or particles may not be representative of the composition of the bulk metal.

Examinations for Informational Purposes

Some of the types of information which can result from metallurgic examinations of metals or metallic objects in various physical conditions:

Broken and/or mechanically damaged (deformed) metal pieces or parts.

1. Cause of the failure or damage, i.e., stress exceeding the strength or yield limit of the metal, material defect, manufacturing defect, corrosion cracking, excessive service usage (fatigue), etc;

2. The magnitude of the force or load which caused the failure;

3. The possible means by which the force or load was transmitted to the metal and the direction in which it was transmitted;

Burned, heated, or melted metal.

1. Temperature to which the metal was exposed;

2. Nature of the heat source which damaged the metal;

3. Whether the metal was involved in an electrical short?circuit situation.

Rusted or corroded metal

To determine the length of time a metal has been exposed to the environment, it is necessary to submit information concerning the environmental conditions surrounding the item when it was recovered.

Cut or severed metal

1. Methods by which a metal could be severed are by sawing, shearing, milling, turning, arc cutting, flame cutting (oxyacetylene torch or "burning bar"), etc.

2. Relative skill of the individual who made the cut.

Metal Fragments

1. Method by which the fragments were formed;

2. If fragments had been formed by high velocity forces, this may possibly determine if an explosive has been detonated and the magnitude of the detonation velocity;

3. Possible identification of the item which was the source of the fragments;

Nonfunctioning watches, clocks, times and other mechanisms.

1. Condition responsible for causing the mechanism to stop or malfunction.

2. Whether the time displayed by a timing mechanism represents a.m. or p.m. (usually calendar?type timing mechanisms only).

Items unidentified as to use or source

1. Possible identification of use for which the item was designed, formed, or manufactured, based on the construction of and the type of metal in the item.

2. Possible identification of the manufacturer and of specific fabricating equipment utilized to form the item.

3. Identification of possible sources of the item if an unusual metal or alloy is involved.

Objects with questioned internal components

X-ray radiography can nondestructively reveal the interior construction, and the presence or absence of defects, cavities, or foreign material.

Packing and Shipping Evidence

Today's mandatory regulations help ensure that there will be no problems encountered in the shipment of hazardous materials. Regulations are enforced by agencies empowered by specific legislation such as the U.S. Code of Federal Regulations (CFR).

The following pages contain excerpts of Title 29, Occupational Health and Safety Administration (OSHA); Title 42, Department of Health and Human Services; Title 49, Department of Transportation (DOT); International Air Transport Association (IATA); and shipping, handling, and labeling rules for hazardous and nonhazardous materials.

For information on shipping regulations for blood, urine and other liquid diagnostic specimens containing etiologic agents, contact IATA 1001 Pennsylvania Ave., N.W., Washington, D.C., 20004, telephone (202) 624-2977. When using the U.S. Postal Service, it is advisable to contact the Postal Inspector in your jurisdiction since the U.S. Postal Service has specific restrictions for mailing. For information on shipments that are sent to the FBI Laboratory, call the FBI Laboratory before shipping.

Inquiries concerning the Code of Federal Regulations may be addressed to the Director, Office of the Federal Register, National Archives and Records Administration Washington, D.C., 20408 (telephone 202-512-1557). The sale of the Code of Federal Regulations is handled by the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402, telephone (202) 783-3238.

Proper Sealing of Evidence

A package containing evidence must have an invoice letter, and it is imperative to have access to this invoice without breaking the inner seal of the package. This must be done to comply with regulations that establish that examiners must receive any kind of evidence as it was sealed and packed by the sender. The first person to receive a package may not be the examiner. The method permits access to the invoice without breaking the inner seal.

1. Pack bulk evidence securely in box.
2. Seal box and mark it "evidence."
3. Place copy of transmittal letter in envelope and mark it "INVOICE."
4. Stick envelope to outside of sealed box.
5. Wrap sealed box in outside wrapper and seal with gummed paper.
6. Address to: Director. Federal Bureau of Investigation
Attention: FBI Laboratory 10th Street and Pennsylvania Ave., N.W.
Washington, D.C. 20535
Place the label under a clear Yellow plastic cover or yellow tape (ONLY on packages containing evidence).
7. If packaging box is wooden, tack invoice envelope to top under a clear yellow plastic cover or yellow tape.

8. REMARKS:
If evidence to be sent falls into the category of Hazardous Materials, call for instructions). Please use clear yellow plastic cover or yellow tape ONLY for packages containing evidence

Packaging and Labeling of Etiologic Agents

The Interstate Shipment of Etiologic Agents (42 CFR, Part 72) was revised July 21,1980, to provide for packaging and labeling requirements for etiologic agents and certain other materials shipped in interstate traffic. For further information on any provision of this regulation contact Centers for Disease Control, Office of Health and Safety, 1600 Clifton Road, Atlanta, Georgia 30333. Telephone: (404) 639-3883.

General Information

Prior to sealing a packaging container, all unused space in the container must be filled with brown wrapping paper, bubble wrap, or any other acceptable packaging filler to prevent the material from shifting and breaking open in transit.

For sealing, use extra gummed paper tape or nylon?reinforced filament tape. However, be aware that some shippers insist on the use of one of these two kind of tapes.

Packaging containers (i.e., envelopes, boxes, tubes, etc.) must be reinforced with continuous nylon?reinforced filament tape placed around the container.

Standard opaque packaging containers must be sealed with plastic or gummed paper tape so that it appears "mummy wrapped." Thereafter, at least three continuous strips of nylon reinforced filament tape must be placed around the container .

Allow application and retention of adhesive stamps, postage meter impressions and postal endorsements made by hand stamp, ball?point pen, or number two pencil. The use of masking, cellophane, nylon?reinforced, and/ or plastic tape on the outer finish of registered mail is prohibited.

Packaging containers must not be reused for shipment purposes. Standard opaque packaging containers may be reused only when the container is structurally sound, with no holes, tears, or missing flaps.

Obsolete address mailing labels and markings must be removed or covered prior to shipment.

Shipments must have the sender's and recipient's complete telephone number.

All packages must pass the National Safe Transit Association Project 1A Testing in addition to any regulations set forth by the Title 49 (Code of Federal Regulations).

The U.S. Department of Transportation (DOT) and the International Air Transport Association (IATA) define "Dangerous Goods" as "Hazardous Materials."

Boxes containing Hazardous Materials require specific DOT Diamond Labels on at least two sides of the package. For more information write or call Federal Express or UPS.

The IATA mandates: training and periodic recertifications for persons handling Hazardous Materials Dangerous Goods, and the IATA Dangerous Goods Regulations and U.S. Department of

Transportation Emergency Response Guidebook, two manuals that must be readily available at workplaces where employees handle Hazardous Materials/Dangerous Goods.

Title 29 ? U.S. Department of Labor Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., N.W. Washington, D.C. 20210, telephone: (202) 219-8151

Title 29, Part 1910 sets forth specific safety and health standards as they relate to the workplace.

Title 42 ? U.S. Department of Health and Human Services, Office of Health and Safety, 1600 Clifton Road, Atlanta, Georgia 30333 telephone: (404) 639-3883

Title 42 has specific regulations for Interstate Shipment of Etiologic Agents, see page 94.

Title 49 ? U.S. Department of Transportation 400 7th Street, Southwest, Washington, D.C. 20590 telephone: (202) 366 4000

CAR Title 49, Section(s) and/or Subpart(s) for D?Marking specify that the person who offers hazardous material(s) for transportation must mark each package in the manner required by this title, a telephone number is provided to obtain specific directions.

25_3.3 Tool Marks

Tool marks play a critical role in the development of evidence in both covert and forced entry cases involving locks, safes, security containers, keys, and keying systems. The topic is more thoroughly covered in Section **32_4.0**.

25_3.4 Forensic Photography

The author recommends the following photographic equipment for documenting forced entry of locks, safes, and containers, for for recording tool marks on lock components. Both film and digital imaging is suggested. Although Canon is recommended for its optics and functionality, the author has also utilized the Minolta 9XI camera, lens and ring strobe. This system was first introduced in 1992, but is still one of the best macro photography options available.

Digital imaging has progressed to the point that it is an

acceptable alternative for film, unless enlargements are required. **Canon** (D30) and **Nikon** (Coolpix 990 and 995) produce the best hardware for the forensic locksmith. A camera with a minimum of 3,000,000 pixels is required, with the capability of shooting in low resolution (72 dpi) mode, as well as high resolution (300 dpi). The Nikon is ideal for macrophotography because of its extremely sharp lens complement. The Canon D30 with ring strobe and macro lens produces superior photographs. All of the digital images contained within this Infobase were produced with either the Nikon or Canon.

- **Canon 35mm EOS-1 series camera body**
- **Canon 100mm macro lens**
- **Canon ring light MR-14EX**
- **Canon D30 Digital camera body**
- **Nikon CoolPix model 990 or 995**
- **Minolta 9XI camera body**
- **Minolta 100mm macro lens**

Additional items for photo documentation that should be available to the forensic locksmith or criminalist include:

- **Comparison microscope with camera port 10x-40x minimum**

Discussion regarding microscopes for use in forensic analysis. Courtesy of Hans Mejlshede.

- **Ruler**
- **Wide-angle lens**
- **Tripod (small and large)**
- **Copy stand**
- **Filter kit**
- **Adjustable multielement fiber optic light source**

25_3.5 Admission of Evidence

The end result of all investigations is the development of legally admissible evidence. In order for evidence to be accepted by a court, it must be relevant, competent, and material. Each of these legal concepts is briefly explained in the I.A.I.L. manual, and in numerous legal and criminal investigation textbooks.

Suffice it to say, if these three primary criteria are not met, the evidence will not be accepted by any court.

In order for a forensic locksmith or criminalist to testify in a case involving locks and related matters, he or she must demonstrate expertise so that the trier of fact can rely upon the evidence presented by such an expert. Defense counsel will attempt to show that an expert does not have sufficient training or knowledge to state an opinion about a particular set of facts. Only an expert witness can state an opinion regarding a hypothetical or actual set of facts.

The investigative locksmith as a witness. Courtesy of Don Shiles.

The following issues and facts can provide the ability to destroy the value of testimony, and may lead to its rejection by a court.

- **Reliance or use of misleading data or information in testimony;**
- **Failure to adhere to established procedures in the course of an investigation or analysis;**
- **Showing bias;**
- **Lack of knowledge regarding a relevant issue;**
- **Failure to maintain a proper chain of custody;**
- **Evasive or misleading statements during testimony;**
- **Intentional disregard of relevant information during the course of an inquiry;**
- **Testimony based upon contingent fee or similar payment arrangement; Recantation of prior reports or testimony;**
- **Conducting an investigation, or testifying on matters beyond raining or expertise;**
- **Failure to complete an investigation in a timely manner, unless good cause is shown; or failing to take into account facts that subsequently became available;**
- **Conflicts of interest;**
- **Prior relationships with defense or prosecution counsel that could influence the results of an inquiry.**
- **Failure to consult professional literature, if required;**
- **Failure to consider all factors in an investigation;**
- **Adopting a condescending attitude while testifying;**
- **Losing composure while testifying.**

- **Previous inconsistent statements;**
- **Proving that a statement of fact is not true;**
- **Character of witness is questioned;**
- **Sensory defect in witness which prevents accurate testimony;**
- **Violation of professional code of ethics(241).**

25_3.5.1 Court Rulings and Federal rules on Admissibility

There are a number of significant court rulings on the admissibility of evidence and expert witnesses. In **Kumho Tire v. Carmichael**, 526 US 137 (1999) the United States Supreme Court enlarged the authority of judges to act as "gatekeepers" with regard to expert testimony.

Kuhmo involved a suit against a tire maker for design defects that resulted in a fatal accident. The expert witness for the Plaintiff determined concluded that there was a defect in the manufacture of the tire. The defendant countered that the Plaintiff's expert failed to follow reliable methodology in his analysis, based upon the standard set forth in **Daubert v. Merrill Dow**, 509 US 579 (1993). The case was appealed; the appellate court reversed the lower court but the Supreme Court affirmed the lower courts ruling. Kumho was cited and affirmed in **Weisgram v. Marley Company**, 169 F3d. 514, (2000) by the Supreme Court.

As a result of these rulings, expert scientific testimony, at least in Federal courts, will be scrutinized with regard to whether the expert's theory or technique has been tested, reviewed by other experts, is accepted by the technical community, and whether error rates have been considered. Such rulings will not be reversed unless there is an "abuse of discretion" on the part of the trial judge.

Federal Rules of Evidence control the admissibility of evidence in federal trials. Federal Rule 702, cited in Kumho and Daubert, specifically applies to expert witnesses.

Rule 702.(242) Testimony by Experts [Proposed Amendment]

If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise.

Rule 703(243). Bases of Opinion Testimony by Experts [Proposed Amendment]

The facts or data in the particular case upon which an expert bases an opinion or inference may be those perceived by or made known to the expert at or before the hearing. If of a type reasonably relied upon by experts in the particular field in forming opinions or inferences upon the subject, the facts or data need not be admissible in evidence.

Rule 704.(244) Opinion on Ultimate Issue

(a) Except as provided in subdivision (b), testimony in the form of an opinion or inference otherwise admissible is not objectionable because it embraces an ultimate issue to be decided by the trier of fact.

(b) No expert witness testifying with respect to the mental state or condition of a defendant in a criminal case may state an opinion or inference as to whether the defendant did or did not have the mental state or condition constituting an element of the crime charged or of a defense thereto. Such ultimate issues are matters for the trier of fact alone.

Rule 705.(245) Disclosure of Facts or Data Underlying Expert Opinion

The expert may testify in terms of opinion or inference and give reasons therefore without first testifying to the underlying facts or data, unless the court requires otherwise. The expert may in any event be required to disclose the underlying facts or data on cross-examination.

Rule 706. Court Appointed Experts

(a) Appointment.

The court may on its own motion or on the motion of any party enter an order to show cause why expert witnesses should not be appointed, and may request the parties to submit nominations. The court may appoint any expert witnesses agreed upon by the parties, and may appoint expert witnesses of its own selection. An expert witness shall not be appointed by the court unless the witness consents to act. A witness so appointed shall be informed of the witness' duties by the court in writing, a copy of which

shall be filed with the clerk, or at a conference in which the parties shall have opportunity to participate. A witness so appointed shall advise the parties of the witness' findings, if any; the witness' deposition may be taken by any party; and the witness may be called to testify by the court or any party. The witness shall be subject to cross-examination by each party, including a party calling the witness.

(b) Compensation.

Expert witnesses so appointed are entitled to reasonable compensation in whatever sum the court may allow. The compensation thus fixed is payable from funds which may be provided by law in criminal cases and civil actions and proceedings involving just compensation under the fifth amendment. In other civil actions and proceedings the compensation shall be paid by the parties in such proportion and at such time as the court directs, and thereafter charged in like manner as other costs.

(c) Disclosure of appointment.

In the exercise of its discretion, the court may authorize disclosure to the jury of the fact that the court appointed the expert witness.

25_3.6 Specialized Forensic Investigations

Forensic investigators are called upon to assist law enforcement, insurance agents, and corporate security in many types of investigations where they may have expertise in specific types of locks, locking systems, containers and motor vehicles. Such investigations may involve forced and covert entry or sabotage.

Experts are often required in motor vehicle cases relating to theft and arson.

Evidence in car theft investigations. Courtesy of Don Shiles.

Analysis of vehicle locks. Courtesy of Hans Mejlshede.

Analysis of vehicle theft cases. Courtesy of Hans Mejlshede.

Simulation of vehicle theft. Comments on investigation. Courtesy of Hans Mejlshede.

Investigations involving vehicle fires. Courtesy of Hans Mejlshede.

Analysis of marks produced by a slimjim bypass tool. Courtesy of Hans Mejlshede.

25_3.7 Forms and Reports

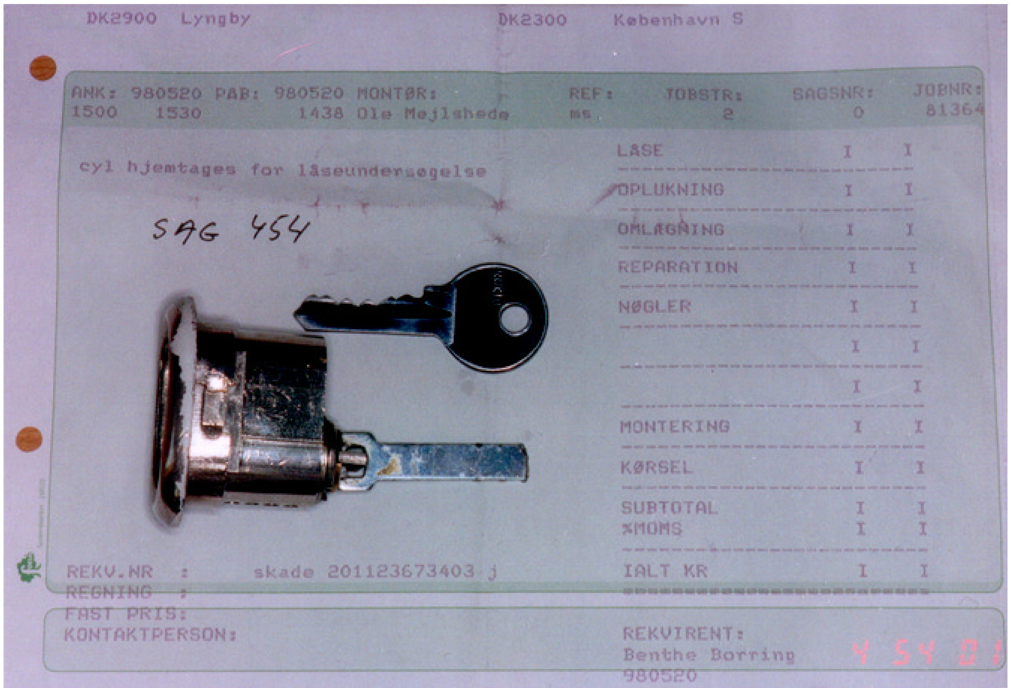
The following forms have been provided by I.A.I.L as a guide. As noted elsewhere in this text, complete documentation is required anytime that evidence is handled, analyzed, or stored. it is essential that the forensic locksmith or criminalist record all data regarding the identification, condition, test procedures, and alternations made to any key, lock, locking device, or other

item that has been submitted for evaluation.

Physical Security Device Worksheet
Forensic Inspection Request
Crime Scene summary form

The results of any forensic examination relating to locks and keys must usually be provided in written form to the court, investigative agency, defense counsel, or insurance company. It is essential that such reports be complete, well documented, concise, and accurate. Reports from several case investigations conducted by Hans Mejlshede have been reproduced. Note the form,

style, and content.


DK2900 Lyngby
DK2300 København S
ANK: 980520 PÅB: 980520 MONTØR:
1500 1530 1438 Ole Mejlshede
REF:
ms
JOBSTR:
2
SAGSNR:
0
JOBNR:
81364
cyl hjemtages for låseundersøgelse
SAG 454
LÅSE
OPLUKNING
OMLÆGNING
REPARATION
NØGLER
MONTERING
KØRSEL
SUBTOTAL
%MOMS
IALT KR
REKV.NR : skade 201123673403 j
REGNING :
FAST PRIS:
KONTAKTPERSON:
REKVIRENT:
Benthe Borring
980520


Ruko



Figure LSS+2502 Hans Mejlshede log-in of evidence contains a photograph of the lock and key submitted,
as well as the evidence that proves or disproves bypass. A report(246)

summarizes his findings and appears below.

Mejlshede Låse A/S

Nørrebrogade 84
2200 København N
Tlf: 31 393939
Fax: 31 391004

e-mail: info@mejlshede.dk
Giro 3 13 39 15
Bank: Arbejdernes Landsbank
Nørrebro afdeling

OBS!
Nyt telefonnummer fra 22. juni 1998
Tlf: 35 39 39 39
Fax: 35 39 10 04

Danica Forsikring
Parallelvej 17
2800 LYNGBY

Attn.: Benthe Borring
Ref.: Claim no.: 201123673403 J
Insured: Thomas S. Davidsen, Bremensgade 1, 3 tv, 2300S

Copenhagen N. May 23. 1998 Our ref.: 454 hm

On May 20. 1998 our locksmith Ole Mejlshede collected a cylinder for a do
mentioned address. The cylinder and the key are shown on photo 454 01. In
key is shown on photo 454 two and the face of the cylinder on photo 454 thr
The cylinder is a Ruko type 5201 as is used for Ruko's program of rim locks
type, the age is estimated to 15-20 years. The key profile is Ruko's universal
there is no key control. The key is not one of the originals. It is a copy made
blank.

Most locksmiths consider this type cylinder as easy to pick, but all picking to
leave marks on the inner parts of the cylinder, marks that are easy to trace in
this cylinder there is an enormous amount of marks. In photo 454 04, the two
shown from the tip, and on 454 05 from the side. These marks have NOT be
picking tool, but most likely with a smaller screwdriver. If the marks have be
attempt to open the lock, then the individual who made them hasn't got the s
lock picking.

However, this doesn't conclude the findings. Photo 454 06 shows the two la
cylinder. On these pins, there are clear marks from a pick gun, but the marks
They are more likely 1-2 years old. This is seen on the oxidation of the mark
that the key has produced over the marks

Hans Mejlshede report regarding analysis of crime scene involving theft

This case involved a theft of video equipment from a school in Denmark. An analysis was conducted of the condition of the locks and doors by Hans Mejlshede. The report illustrates the differences in court presentation in Denmark and the United

States.

The report of Hans Mejlshede regarding the analysis of a Ruko cylinder for indication of picking, together with photographs,

shows the required detail and documentation.

Mejlshede A/S

Nørrebrogade 84
2200 København N
Tlf.: 31 39 39 39
Fax: 31 39 10 04
Telex: 15534 mkey dk

Giro 3 13 39 15
Bank:
Arbejdernes Landsbank
Nørrebro afdeling

OK Taksation & Vurdering Vest
Samsøvej 30
8382 Hinnerup

Attn.: Claus Nørgaard
Reg: A-289/93 CDN – Berit Kjær Petersen/TopDanmark

Dato: 5. July 1993 Vor ref.: 263/HM Deres ref.:

In this case we have on the 2. July received in our office by certified mail one Ruko cyl
with three keys. The received cylinder and keys are seen on photo 263 01. The front o
cylinder is shown in larger magnification on photo 263 02, and the keys on photo 263 03
263 04.

The cylinder is a seven-pin Ruko profile cylinder type 7102/K. The keyway of the cyl
is the standard keyway for Ruko's seven pin program, which means that keys can be co
everywhere without proof of ownership. Of the received keys two are original Ruko keys
one is a copy made on a Silca RU6 steel key blank. A cylinder of this kind always c
with three original keys. There is some wear on the cylinder and it is estimated to be bet
five and ten years old.

A cylinder like this one is considered by professionals to be difficult to pick. Picking
will with great certainty leave marks on the inner parts of the cylinder, marks that are
to trace with a microscope.
This cylinder has many marks. On the face of the plug, where the key is inserted ther
visible marks after a flat instrument, most likely a screwdriver, which has been pressed
seven millimeters into the keyway. The marks are shown on photo 263 07. This vi
treatment has produced some unevenness in the keyway that makes it impossible to
either of the original keys into the cylinder, while the slimmer non original Silca key sti
be inserted. With the Silca key the cylinder functions without problems.
On photo 263 05 the two first bottom pins of the cylinder are shown. There are marks
a flat instrument on the side of both pins and signs of some wear by using the keys, b
signs after any picking tools. The other pins have no marks from any tool.

It is my conclusion that it is extremely unlikely that this cylinder should have been pi
The marks that appear on the face of the plug and on the first two pins could have bee
there in order for someone to believe that the cylinder had been picked.

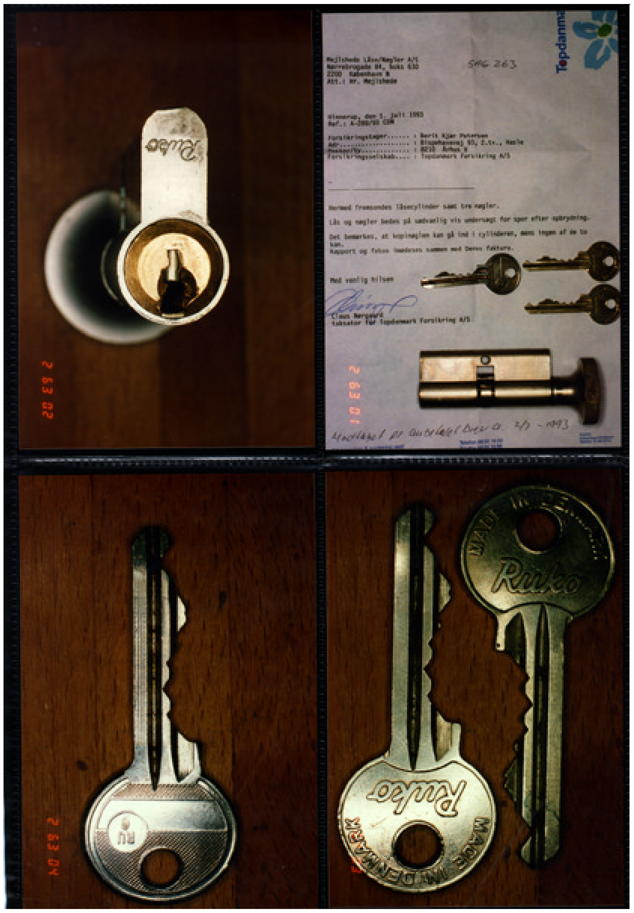


**Figure LSS+2503 Sample forensic analysis report from Hans Mejlshede documenting receipt of evidence,
photographs of pins within the lock, and the keyway.**

Logging receipt of evidence. Courtesy of Hans Mejlshede.

25_3.8 Bibliography for Forensic Locksmiths

Many articles, law enforcement textbooks, and articles have been written regarding specific aspects of forensic locksmithing. The following bibliography provides a reference for additional research. The articles from Keynotes may be available through ALOA(247) or from I.A.I.L.

MAGAZINE ARTICLES

"Microscopic Examination Distinguishes Between Lock Pick Marks

and Marks Made by Keys". By Arthur R. Paholke, Keynotes April 1973, (3 pages)

"The Forensic Locksmith in Criminal Investigations", By Arthur R. Paholke, Keynotes July/August 1990, (**3 pages(248)**)

"Investigating Lock Entries", Has My Lock Been Picked? By Hans Mejlshede, Keynotes July/August 1990 (4 pages)

"Are You Sure It Happened This Way?" By Arthur R. Paholke & William Sherlock, Keynotes June 1991 (**4 pages(249)**)

"The Investigative Locksmith & The Court" By James H. Glazier, CML, CFL, Locksmith Ledger, September 2000, **Page 120(250)**

"The Forensic Locksmith's Tool Kit", By James H. Glazier, CML, CFL, Locksmith Ledger, July 2000, **Page 194(251)**

"Thieves Always Leave A Trail", By James H. Glazier, CML, CFL, Locksmith Ledger, June 2000, **Page 98(252)**

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"Forensics, The Newest Field in Locksmithing", By Donald H. Shiles, RL, CFL, National Locksmith, September 1996, Pages 108-110

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FICTIONAL NOVELS ON FORENSIC LOCKSMITHING

"Murder At The Locksmith Convention", By Mary Ellen Cooper, 1997

"The Wright Special" By Mary Ellen Cooper, 1995

RESOURCE BOOKS ON FORENSIC/INVESTIGATIVE LOCKSMITHING

"Crime Scene & Evidence Collection Handbook", U.S. Department of

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"Crime Scene & Evidence Photographers Guide", By Steven Staggs, Staggs Publishing, 1997.

"Crime Scene Search & Physical Evidence Handbook", National Institute of Justice Publication, Paladin Press, 1992

"Criminalistics for the Law Enforcement Officer", Anthony L. Califana, McGraw?Hill, Inc. 1978 (364.12)

"Coroner At Large, Forensic Pathology", By Thomas T. Noguchi, M.D., Simon & Schuster, 1985 (614.1)

"Grave Secrets", By Cyril Wecht, M.D., J.D., Penguin Books USA, Inc. (614.1)

"Hard Evidence", By David Fisher, Simon & Schuster, 1995 (363.256)

"Modern Criminal Investigation", Fifth Edition, By Harry Soderman, D.Sc. & John J. O'Connell, Revised by Charles E. O'Hara, 1962, Funk & Wagnalls Co.

"Scientific Evidence In Criminal Cases", By Meonssens, Moses & Inbau, The Foundation Press, 1973

"Scene of the Crime", U.S. Government Forensic Handbook, Paladin Press, 1992.

"The Casebook of Forensic Detection" By Colin Evans, 1996 (614.1)

INVESTIGATIVE CATALOGS

Criminal Research Products, Inc., P.O. Box 408, Conshohocken, Pa. 19428-0408, (215) 828-5326, FAX (215) 825-1228. Law Enforcement Investigative Products.

Sirchie Fingerprint Laboratories, 5825 Triangle Drive, Unstead Industrial Park, P.O. Box 30576, Raleigh, NC 27622?0576, (919) 781?3120, FAX (919) 787?2952.

Edmund Scientific Company, Consumer Science Division, 101 East Gloucester Pike, Barrington, NJ 08007-1380, (800) 728-6999, FAX (609) 547-3292. Edmund handles a complete line of microscopes and other examination equipment.

CHAPTER TWENTY-SIX: EVIDENCE OF ENTRY

Forensic Examination: Tool Marks and Trace Evidence

Master Exhibit Summary

Figure LSS+2613 Forensic marks on pin caused by conventional picking
Figure LSS+2614 Forensic marks on pin from a pick gun
Figure LSS+2615 Forensic marking on pin from a 999 key or bump key
Figure LSS+2616 Scanning electron microscope configuration, Jeol 5900
Figure LSS+2617 SEM photograph of pick tracks within lock, 220x magnification
Figure LSS+2618 SEM photograph of pick tracks within lock, 1000x magnification
Figure LSS+2619 SEM photograph of pick tracks within plug, 400x magnification
Figure LSS+2620 SEM photograph, surface of pick at 220x magnification
Figure LSS+2621 SEM photograph of pick marks on pin at 1000x magnification
Figure LSS+2622 SEM photograph of pick marks on plug
Figure LSS+2623 SEM photograph of surface of pick at 50x magnification
Figure LSS+2624 SEM photograph of surface of pick at 50x and 500x magnification
Figure LSS+2625 SEM photograph of surface of pick at 100x magnification

LSS101: Scanning electron microscope Part I: Michael Platek

LSS101: Scanning electron microscope Part II: Michael Platek

LSS101: Scanning electron microscope Part III: Michael Platek

LSS203: The forensic investigation of locks and keys, by Hans Mejlshede.

Forensic indication of the use of a ""999"" or "bump key," Courtesy Hans Mejlshede

The age of picking marks can sometimes be determined through the analysis of corrosion within the lock. Courtesy of Hans Mejlshede.

Destructive analysis of locks is often required in an investigation. Courtesy of Hans Mejlshede.

Analysis of marks within the plug after it has been cut apart. Courtesy of Hans Mejlshede.

Marks left from a turning wrench. Courtesy of Don Shiles.

Use of a scanning electron microscope (SEM). Courtesy of Hans Mejlshede.

The use of pick guns with profile locks. Courtesy of Hans Mejlshede.

Forensic analysis of pick gun marks. Courtesy of Hans Mejlshede.

Pick gun marks and order of picking. Courtesy of Hans Mejlshede.

Dust motes, visible in forensic analysis. Courtesy of Don Shiles.

Marks on wafers from picking. Courtesy of Hans Mejlshede.

Pick marks may appear on surface of wafers. Courtesy of Hans Mejlshede.

Analysis of presence of grease on wafers in forensic investigation. Courtesy of Hans Mejlshede.

Marks produced from turning wrenches are identifiable. Courtesy of Don Shiles.

Forensic indications of the use of an electric pick gun. Courtesy of Hans Mejlshede.

Cylinders may be opened by rapping them. Courtesy of Hans Mejlshede.

A forensic examination takes five minutes or less. Courtesy of Hans Mejlshede.

Forensic investigations involving locks that have been impressioned. Courtesy of Hans Mejlshede.

Forensic analysis of gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

Marks on Ford wafer locks produced by gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

Wear information and tests on pins. Courtesy of Hans Mejlshede.

Wear marks on pins. Courtesy of Hans Mejlshede.

Markings on components by manufacturers. Courtesy of Don Shiles.

Milling marks on pins during manufacture. Courtesy of Don Shiles.

Forensic marks and their observation with proper lighting. Courtesy of Don Shiles.

Bypass techniques must be known to the forensic investigator. Courtesy of Hans Mejlshede.

An analysis of latches and bolts may be required. Courtesy of Hans Mejlshede.

Loids may be utilized to bypass latches and bolts. Courtesy of Hans Mejlshede.

Virgin areas of the plug will provide an indication that the locks was picked. Courtesy of Hans Mejlshede.

Normal appearance of pins and what type of marks appear. Courtesy of Hans Mejlshede.

Forensic marks from the use of a lock pick. Courtesy of Hans Mejlshede.

Pickability or ease with which a lock can be picked. Courtesy of Hans Mejlshede.

Turning wrench or torque wrench will leave identifiable tool marks. Courtesy of Hans Mejlshede.

Tool mark comparison. Courtesy of Hans Mejlshede.

Picking marks on wafers from vehicle locks. Courtesy of Hans Mejlshede.

Marks produced by raking. Courtesy of Don Shiles.

Marks produced from keys making contact with pins. Courtesy of Don Shiles.

Different marks are created from various lock picks. Courtesy of Don Shiles.

Marks produced by methods of entry, courtesy of Harry Sher.

26_1.1 Introduction

LSS203: The forensic investigation of locks and keys, by Hans Mejlshede.

This chapter will concentrate on the most difficult aspect of the forensic analysis of locks: the search for evidence of surreptitious entry left by the manipulation of components. How marks are made by the different bypass techniques and detailed information regarding their appearance will be presented here. The material has been organized from general to specific types of evaluations. The goal is to develop leads and additional inquiries for investigators to pursue, anciliary questions that may be considered, and suggestions of supplemental forensic examinations that can be performed.

External indicia of non-destructive entry include tool marks, metal marking, and distortion of components. **Internal** evidence of surreptitious entry may leave tool marks, material transfer and debris, foreign materials appearing in the plug, and slight deformation of internal components. In analyzing external and internal components, the criminalist will search for the

following information:

- **Method of entry and whether it was destructive or non-destructive;**
- **Types of tools used to effect bypass;**
- **Whether there are any tool marks present, and how they got there;**
- **The skill of the perpetrator.**

The forensic investigator may also be looking for indicia of bypass of secondary locking mechanisms, such as latches and bolts. Loids or other techniques may have been utilized to circumvent the operation of these components.

An analysis of latches and bolts may be required. Courtesy of Hans Mejlshede.

Loids may be utilized to bypass latches and bolts. Courtesy of Hans Mejlshede.

26_1.2 Preparation and Dissection of the Plug for Examination



It is usually necessary to disassemble the lock and to dissect the plug in order to search for tool marks. The proper procedures for disassembly have already been covered in **Chapter 16.** Dissection of the plug will be detailed here.

Destructive analysis of locks is often required in an investigation. Courtesy of Hans Mejlshede.

Analysis of marks within the plug after it has been cut apart. Courtesy

of Hans Mejlshede.

Prior to dissection, all internal components will be removed and placed in a setup tray or other storage container. Be certain to use plastic or nylon tongs to handle pins, so they will not be scratched. If a padlock is to be analyzed, it may have to be destroyed if no keys are available.

The tools that are required for dissection are a saw, plastic tweezers or tongs, a setup tray, modeling clay to hold the components for microscopic examination, and a zoom microscope with a range of at least 10X-40X. The author uses an Olympus binocular zoom microscope with a camera port. Generally, the keyway is analyzed before cutting the plug in order that evidence is not destroyed. The criminalist should be particularly alert to brass particles and tracks. If the lock has security components such as hardened pins to prevent drilling, then these must be removed first.

A plug must be examined internally, because there are areas where the key never encounters metal surfaces. This is due to the profile of the keyway and the reaming tool used in the broaching process. These "virgin" areas will yield information regarding bypass.

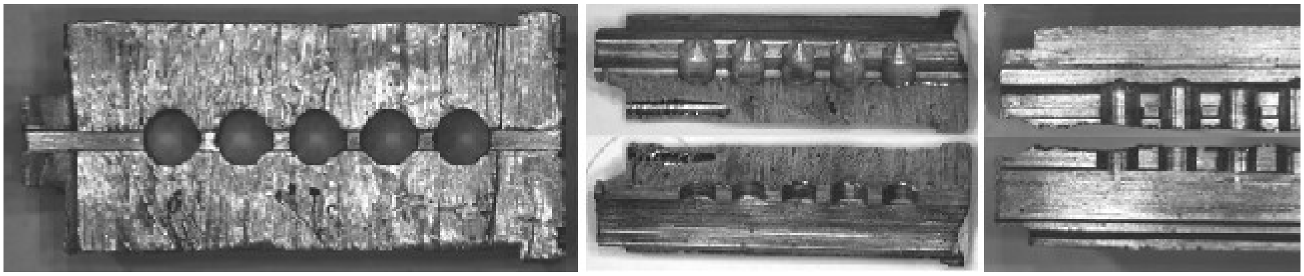
Virgin areas of the plug will provide an indication that the locks was picked. Courtesy of Hans Mejlshede.

The examiner is looking for places where no marks would be expected from normal operation, insertion, and removal of keys. The only way such marks could have been made is through the picking process. Once dissected, all surfaces can be examined.

The areas above the key and on the sides of the keyway will never be touched throughout the life of the lock, because the bitting is always lower than the top of the keyway. Consequently, corrosion in this area will be used as a control for comparison purposes. The only way to examine such evidence is to dissect the plug. Dust motes may also be present. These are surface particles of dust that will be visible under the microscope as round projections.

Dust motes, visible in forensic analysis. Courtesy of Don Shiles.

In practice, the plug is sliced horizontally, just below the top of the keyway, causing it to separate into three parts (left half, right half, and top section).



Exploded view of internal area of plug 1, 2, 3, 4.

The plug may be cut with a hacksaw or other fine cutting tool. The author uses a jeweler's hacksaw that has a thin wire blade. Care must be exercised to cut laterally and exactly perpendicular to the keyway. Compressed air may be used to clean the components once they are cut. Do not use cloth or any material containing fibers, as they are attracted by the rough surface of the brass and are extremely difficult to remove.

26_1.3 Forensic Analysis Protocol

Statistically, only one or two percent of burglary investigations actually involve lock-picking and other forms of surreptitious entry. That data is obviously based upon known cases of burglary, where a threshold determination has been made that in fact there was an entry or attempt. The problem, of course, is that there may be many cases of surreptitious entry or bypass that remain undiscovered and thus will not be included in any crime statistics. Such is the work of professionals in the business of espionage, sabotage, theft of information, and covert entry.

It is estimated that in approximately five to ten percent of the reported cases, apparent pick marks are present where perpetrators attempted to create the belief that picking was the method of entry. Attempts to cover fraudulent claims and destruction of evidence are much more common than actual lock-picking and other bypass techniques. For the uneducated public there is a perception that making the lock appear to have been picked will satisfy the police, and more importantly, the insurance company.

Both the criminal investigator and criminalist should evaluate the likelihood that the lock was picked or otherwise bypassed, based upon the intended target and local practice. Sophisticated methods will not be used where a small claim is involved. If a

method of bypass is common or popular in an area, that may of course be factored into the analysis.

Particularly in fraud cases, the insured will often use a hammer and screwdriver to make entry appear as if the lock was picked. There will be imprints, and generally many marks on the first and second pins. There will be no marks on the rear pins unless the lock actually was picked or the perpetrator was familiar with picking techniques. It is imperative that all marks be recorded on each pin for this correlation.

The thrust of this chapter, and indeed this text, is surreptitious entry and bypass. That is because high-value items such as cash, information, documents, and data are generally the targets of more sophisticated criminals. This is of heightened concern to criminal investigators, internal security, and intelligence officers. It is important that the criminalist is able to make a very educated guess as to what tools may have been used to effect bypass and entry. That information will provide clues as to the skill of the perpetrator and will form the basis for a more positive match in the case of tool marks. The criminalist must be aware of different bypass techniques for the specific lock or locking system that is being analyzed.

Bypass techniques must be known to the forensic investigator. Courtesy of Hans Mejlshede.

The forensic analysis of the plug, once dissected, may take less than five minutes. As detailed below, the examiner is searching for any unusual marks anywhere within the lock.

A forensic examination takes five minutes or less. Courtesy of Hans Mejlshede.

Generally, the lock is examined, according to the six primary evaluation phases, in the order listed below:

- **Lock specifications and data;**
- **Operation of the lock;**
- **Security of the lock;**
- **Indication of manipulation and bypass: tool marks;**
- **Material transfer;**
- **Keys.**

In the first two phases of the examination, as described earlier, a determination is made that the lock meets factory specifications, that it is operating properly, and the level of its security. Then, an examination of internal components is made through dissection of the plug. A search is conducted for the following:

- **Tool marks;**
- **Tracks;**
- **Deformations;**
- **Corrosion and oxidation in clear areas;**
- **Corrosion and oxidation over existing marks.**

It may be necessary to run tests in an attempt to extrapolate the time required to corrode or obliterate picking marks within a given lock for a given environment. Marks will be affected to differing degrees depending upon where the lock operates, i.e. inside, outside, salt air, or corrosive environment. After a search for tool marks, an analysis may be undertaken for additional evidence to determine:

- **Any material transfer within the plug;**
- **Security rating of the lock;**
- **Evaluation of the keying system;**
- **Any keys that may be involved in the investigation.**

26_1.4 Method of Entry

26_1.4.1 Analysis of Methods of Entry

Surreptitious methods of entry will vary widely, depending upon the lock, its location, and skill of the perpetrator. Information regarding methods of attack may be obtained from visual inspection of external and internal components and surfaces. Indicia may be present from tumbler, wafer, or lever distortion, caused by excessive application of force. Residue from tools may also provide an indication of the methods employed. For example, magnetic tracks on the face of a safe, made visible using magnetic spray, can provide clues as to the type of drill rig that was utilized. In other cases, depending upon the mode of entry, there will be no evidence. In the following instances bypass may be achieved without physical trace:

- **Use of keys;**
- **Power failure which cause electronic mechanism to open, as in the case of certain hotel locks;**
- **Decoding of pin-stack combination and production of a key.**

Investigators should also be alert to lock failures that may have been externally caused through criminal agency in order to cover up bypass. For example, an apparent simple sabotage of a locking mechanism that appears as a burglary attempt may actually have been orchestrated. This may have been perpetrated so that the lock and any evidence of tampering would be destroyed without giving a clue as to whether entry actually occurred. Power failure, dead memory batteries, lockout requiring picking or drilling, loss of internal memory, and logic failure may all be seen as potential abnormal events requiring further examination.

26_1.4.1.1 Queries Regarding Methods of Entry

- **Is there visual evidence of bypass, including tool marks, metal fragments or filings, distortion of the plug, broken keys in the plug or other marks;**
- **Are there any tool marks on the door, jamb, strike, or surface area of the lock;**
- **Is there any foreign material in the plug, including Freon residue;**
- **Are there any metal scrapings within the lock, in the keyway, or chambers;**
- **Does it appear that excessive pressure was applied to the plug, causing marks to be made between the plug and shell.**

26_1.4.2 Types of Tools Used for Entry

Many types of bypass tools are described in this book, most of which have been designed to open pin tumbler cylinders. Because of its prevalence, the conventional pin tumbler lock is the prime focus of forensic analysis. Some data will also be presented regarding the lever lock due to its popularity in countries outside the United States. Although this chapter examines most common forms of bypass and the forensic trail that such techniques leave, certain sophisticated tools will leave little or no trace or will imprint a unique signature when employed.

These devices are used to open lever and pin tumbler locks.

Certain procedures and devices have been developed for special variations of the pin tumbler and wafer lock. For example, there are decoding and picking tools for dimple locks, disc wafer locks (such as Abloy), for rotating tumbler mechanisms (Medeco), and for telescoping pin high-security locks (such as Mul-T-Lock). Some of these will leave very minute traces. The decoder/pick for dimple locks, for example, may only leave fine fragments of foil if the operator is not careful. Lubricant such as grease may also be present as the result of the use of this technique.

It is perceived that a security risk and potential compromise of intelligence operations would likely flow from the disclosure of certain bypass techniques and specialized tools developed for such procedures. Therefore, the author has presented only a summary of the principles of high-security bypass and their forensic implications in this chapter. A detailed description is included within the **LSS+/^{X} CD/ROM**, with restricted release to government agencies specifically dealing with high-security bypass.

26_1.5 Tool Marks Produced by Specific Entry Techniques

Marks produced by methods of entry, courtesy of Harry Sher.

In this section, we will be primarily concerned with marks produced by picking, impressioning, decoding, and 999 rapping techniques. Tool marks in many forms can be left by lock picks and impression tools and special manipulation keys (999 rapping). Minute traces of brass or other metal debris may also appear on the pins or at the bottom of the plug, as an indicator of manipulation.

For the purpose of this chapter, the author defines tool marks as any physical indication of bypass caused by the introduction of any mechanical implement or device into the keyway or locking mechanism. Physical indication is dealt with in detail later in this chapter. It includes scratches, striations, marks, tracks, alteration, scoring, cuts, compression, and debris. Tool marks may be found anywhere, on any surface of any internal or external component of the lock. Any unusual, irregular, or enhanced marking may be considered.

On any conventional five pin tumbler lock there is always a random chance that the cylinder was opened with a cross-key combination: a key made for another lock that also just happened to fit the suspect lock. The perpetrator employed no special techniques. A detailed listing of causative factors that will contribute to the presence or absence of tool marks is presented. The forensic examiner should consider each of these factors when initially looking at the lock. This will provide a better image of whether marks may be present, and if so how they may have been created.

Tool marks and evidence of bypass may be produced in many ways and are related to techniques and implements. They can be caused from, provide evidence of, or result from any of the following processes or conditions upon any internal or external lock component:

- **Application of torque or forward pressure to lock components;**
- **Use of bypass tools such as picks, tension wrench, nose puller or plug puller;**
- **Screw-marks from plug pullers;**
- **Drilling marks;**
- **Tolerance error from the application of force;**
- **Foreign material and lubricant, cleaner, grease or other matter in the keyway;**
- **Broken key or object in keyway;**
- **Non-working segments or parts;**
- **Application of heat or cold;**
- **Evidence of cutting the plug at a weak point to split in half;**
- **Evidence of drilling the plug for the introduction of a shim or to create a shear line;**
- **Deformity.**

26_1.5.1 Tool Marks: General Considerations

Normal appearance of pins and what type of marks appear. Courtesy of Hans Mejlshede.

What appear to be tool marks and thus indicia of bypass may in fact have been caused by the normal operation of the lock. The

examiner must be cognizant of and always consider the possibility that marks were in fact produced through normal use. How long marks have been present and if actual marks could have been masked or obliterated are of prime concern.

When keys are inserted into the keyway, there often will be shiny spots or marks on one side of the wards or plug surface. This may be caused by the way in which the plug is turned for opening. Therefore, the entire length of the plug should be examined. Usually, there will be no marks above the keyway on the chamber walls.

Tool marks may also be generated from the bypass of bolt mechanisms. Marks from a sharp pointed wire, ice pick, or other object may be present on secondary bolts or cams. So also, shim marks may be in evidence in certain sophisticated bypass applications involving pin tumbler locks and cylinders. See the discussion below relating to high-security applications.

Locks with well-designed keyways will be more difficult to pick and impression and thus will leave better marks during these processes. Angled rather than square wards will produce finer tolerances in the keyway and require more movement of the pick thus producing more marks.

The reader is also directed to Section **32_4.4** for a general discussion of tool marks.

26_1.5.1.A Methods of Examination of Tool Marks

Tool mark comparison. Courtesy of Hans Mejlshede.

The methods to compare and identify striated tool marks are different than will be employed with respect to impression marks. The tool mark examiner must demonstrate that the suspect object could produce striae that are identical to those obtained from a crime scene as evidence.

In order to compare a suspect tool or object with an evidentiary mark, the examiner must at the outset analyze and take into account several issues. These will include: could the tool have possibly made the mark, based upon its size, shape, structure, and material; location of edges or surfaces which are consistent with the hypothesis that a mark could have been made by a specific suspect object; how tests are to be conducted in order

to establish a comparison; and finally, the determination or conjecture as to which angles of attack are most consistent with the mark(s) in question.

The procedure and criteria for the selection of test materials is fairly straightforward. They must be sufficiently similar to the evidentiary material and surface to allow a valid comparison without potentially damaging the suspect tool or object. Lead is commonly used for such purpose.

In practice, the examiner creates a number of test marks, varying the attack angle, pressure, and speed. Not all tests are expected to produce useable marks, or perfect identification. Usually, fewer than a dozen tests are required, and often, between six and twelve.

The procedure for the examination of Ford locks and keys was detailed in a study by E. Lee Griggs, a technical advisor to AFTE, and published in 1999, are summarized here, to provide a protocol for forensic examination. An earlier study by **W.G. Plumtree(255)**, conducted in 1975 was cited, with regard to the analysis of pick marks on pun tumbler locks.

In the tests performed on Ford locks, Griggs employed certain definitions were are relevant to note, not only with regard to the tests that he performed, but to serve as a guide in all forensic examinations of locks and keys.

Proper Key: Prepared on correct blank and cut to the correct bitting depths to open the lock.

Improper Key: A key that has been cut to an incorrect code depth for any given tumbler, or cut on an incorrect blank.

Discs: All references to wafers, discs, tumblers are equivalent.

Active or working surface: Any surface that is contacted by the blade, bitting surface, or wards of the key.

Ford Lock: Six wafer configuration that are utilized in ignition locks. These mechanisms employ two sided keys, although, as noted elsewhere in this text, there is only one active surface. These are referred to as convenience keys.

Tests to be performed:

As discussed elsewhere within the chapters on forensic examination, extensive testing can be accomplished on all active locking components. It is critical to eliminate issues that can be raised by defense counsel to testing procedures. Thus, careful preparation of samples, and the development of a comprehensive protocol is essential to avoid challenges to identification evidence that may be derived.

In analyzing and testing disc tumbler or wafer locks, the following surfaces and components must be examined:

Keys:

- Lands forming ward pattern
- Bitting surface

Discs:
- All active surfaces that come into contact with the key

Plug:
- Active surfaces of discs that may be driven by irregular key, or improper usage

Springs:

- Normal
- Broken
- Fragmented
- Stretched or compressed

Complicating factors:

- Dirt or debris in keyway
- Broken spring in keyway
- Spring fragment in keyway
- Bent disc or wafer
- Deformed keyway

Specific testing procedure to be followed:

- **Obtain new original locks, plugs, and keys;**
- **Prepare photomicrographs of the discs and keys prior to any testing to document the condition of each component, and provide a standard for comparison;**

· Prepare some of the plugs with a broken or missing spring(256) in one or more chambers;
· Prepare some of the plugs with stretched springs in other chambers;
· Insert two-sided Ford keys into the keyways in a random fashion to simulate normal use of the lock
· Select an insertion sample rate that would be considered normal for the lock.
In the instant case, keys were inserted an average of 720 or more times to approximate one year's use of the vehicle, with two start-stop cycles per day.
· Utilize a factory-cut key to obtain wear data from both the key and lock;
· After all insertion-removal tests have been conducted, remove the discs from the lock plugs and reexamine them with a microscope to evaluate the presence of striae on the surface of each disc.
· Prepare photomicrographs of each disc and key for marks.

26_1.5.1.B Results of Testing

Test results will vary, depending upon many factors involving the condition of the lock, plug, key, and individual use characteristics. The findings in the Griggs tests can be summarized and provide a guideline to examiners as to expected indicia in similar examinations. The results are categorized by control sample and normal lock sample.

Control sample:

· **Keys:** No wear patterns on the operating surfaces (sides) or bitting surfaces;
· **Discs:** no wear patterns or striations;

Normal lock sample:

· **Discs:** wear patterns from the insertion of keys. An amount of material has been "rolled over" the edge of the lands of the key as it is inserted into the keyway and moves across the active surface of the disc.

· **Cylinders with normal springs:** wear on the lands is most pronounced on the first disc. It is least in evidence toward the far end of the cylinder, as would be expected. It should be noted that theoretically, the position of the discs could be determined by their wear pattern, if wear were constant for each disc, depending upon the number of root surfaces of the key come into contact with each wafer in an insertion and removal cycle.

It is not possible to determine an error factor, as the examiner has no way of determining if discs and springs were "always" in a normal operational condition.

· **Springs:**

· Extended or stretched springs can cause uneven wear on a particular disc associated with that spring.

· Broken, collapsed, or fragmented Springs: Wear patterns can be noticeably less than on other discs. If the spring is in the first or second position of the plug, the wear was less, but the error rate was higher in assessing the position of the disc.

· Complicating factors: Several factors may complicate the analysis of active components, and may skew wear factor, causing uneven or excessive wear. These include:

o debris in the keyway;
o broken springs;
o bent or damaged springs;

Microscopic Examination of Disc: Wear patterns were noted on the lands of the discs;

· No identifiable striations were in evidence to match the operating key for that specific lock;

· No identifiable marks were present on the lands of the discs and the side wards of the key;

· It was not possible to determine or match the side of the key that came into contact with a particular surface on the disc.

· Test marks made on new discs showed the same lack of identifiable characteristics as the tested discs: wear patterns without identifiable striations.

· As has been noted elsewhere in this text, the bitting surface of the key acts as an abrasive on the discs. This creates a wear pattern and striations without an identifiable pattern. Each time the key is inserted and removed, a tiny bit of material is removed from the disc. Movement of the key causes the discs to move in both vertical and horizontal planes (forward, backward, left and right, up and down).

· There can also be slight evidence of impressions upon the first disc, where the tip of the key contacts its surface.

· Examination of the lands of the discs upon removal of key: No identifiable striae could be linked to a particular side of a key, as it contacted the disc surface.

· Uneven bitting and non-linear surface: A key with a raised burr on one side of the wards, and an uneven (bent) longitudinal surface was inserted and removed from test cylinders. Upon examination, the burr left an identifiable mark on the first three discs. This was based upon the position of the burr on the surface of the key.

· The wear pattern on the first four discs was of a wider nature, due to the bent key and the attendant misalignment.

· The undamaged side of the key did not obliterate markings on the discs. The undamaged key key did not leave any observable or identifying marks.

· A different key without any burrs or other damage would, in time, obliterate any prior markings; thus, the one time insertion of a normal key will not provide any "last key used" marks.

· Discs exposed to high temperature: discs that have been damaged by fire will likely contain carbon deposits and oxidation of the material. These will show that the wear surface of the land cannot be examined for evidence marking.

· Key with Improper code: A key with an improper code and which will not open the lock will not produce observable striations to provide an indication that such a key had been inserted.

Summary of findings:

It is not possible to determine that a specific key has been

utilized with a specific lock, absent a deformation that will cause unique marking;

Wear patterns appeared as a single wear area on the land of the affected disc. "There are no obvious striated or impression marks on the tumblers of cylinders that have only been operated by the proper key."

Locks that are tested for "last key used" will not provide any comparable striations or impression marks that could be related to the last key that was used in the cylinder.

Although the literature is scant, the reader can find articles regarding forensic examination in the **AAFS(257)** and IAI journals, and in general literature(258).

26_1.5.1.1 Queries Regarding Keys

There are several inquiries involving the use of keys and their interface with lower tumblers that must be considered in assessing tool marks. The operation of keys described below must be compared against the use of properly cut keys having smooth bitting surface and ramps with no sharp edges.

Thus if the lock is operated with a key:

- **Made of steel, rather than brass or nickel silver:**
    - **Produced on a machine with teeth missing from the cutting wheel, thereby creating very jagged or rough bitting surface;**
- **With ragged ramps that act as an abrasive surface (file) against the tumblers:**
    - **How long will the lock continue to function;**
    - **What effect will there be on the lower tumblers;**
    - **What type of wear will be evident on lower tumblers;**
    - **How many passes of the key will be required to distort or obliterate pick marks (relevant to the determination of when the lock was picked);**
    - **When the key is inserted, are spots normally produced along the length of the keyway, based upon imperfections in the milling of the blank.**

26_1.5.2 Marks from Lock-Picking

The age of picking marks can sometimes be determined through the analysis of corrosion within the lock. Courtesy of Hans Mejlshede.

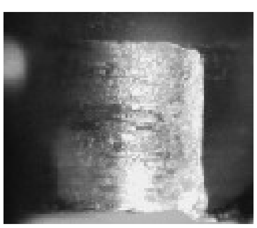
Different marks are created from various lock picks. Courtesy of Don Shiles.

See **Chapter 29** regarding picking techniques. The underlying theory of lock-picking is simple and is based upon cumulative tolerance errors within the lock. Picking relies upon and requires that the plug and shell be not in perfect alignment; that a gap of a few thousandths of an inch exists between the two. As each pin tumbler is picked to shear line, this gap increases. Picking (whether successful or not) will generally require two distinct concurrent physical operations: raising each tumbler, and the application of torque and subsequent rotation of the plug. Each of these procedures can and generally does produce tool marks.

Forensic marks from the use of a lock pick. Courtesy of Hans Mejlshede.

Marks from lock picking: what do they mean? Courtesy of Hans Mejlshede.

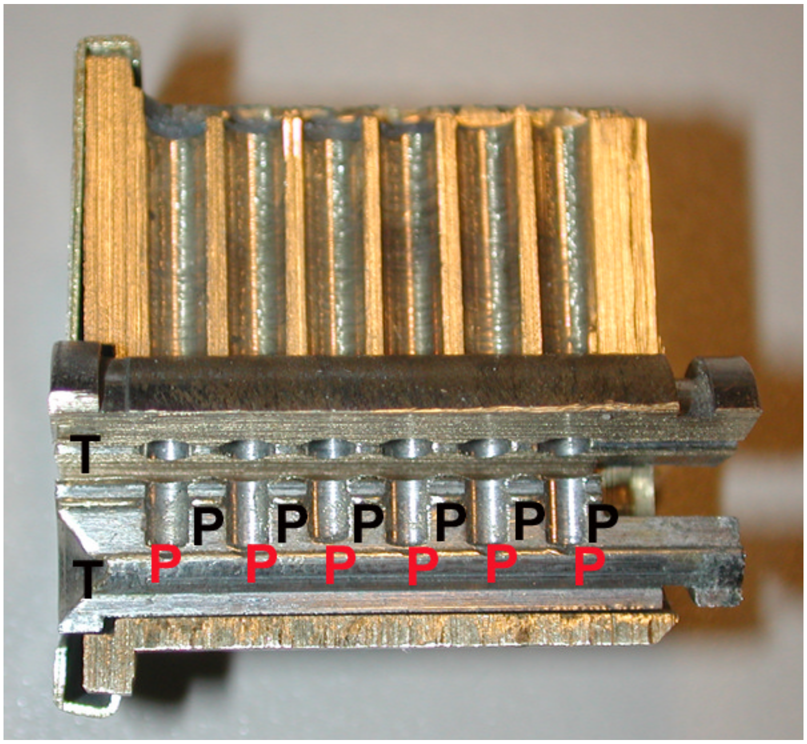
During the picking process, each lower tumbler is raised until the top of the pin reaches shear line and is stopped by the alignment error between the plug and shell. It is generally unavoidable that marks will be created during the picking process, regardless of the tools used. This may not be true in the case of decoding procedures.

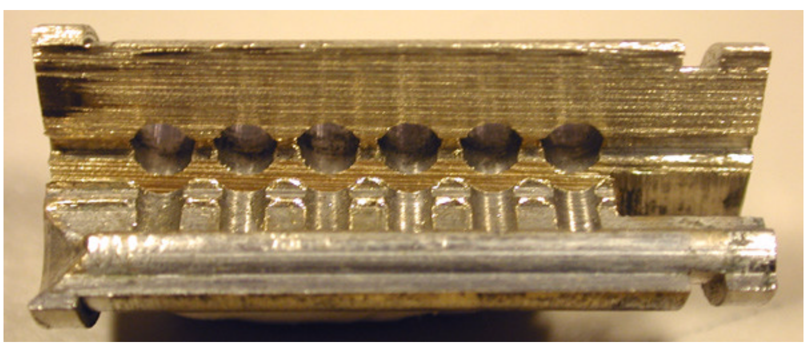


Tool marks appear from picks because there is friction and contact between sharp pick tools and soft brass or nickel silver component surfaces. The marks are created due to the resistance between pin and wall of the pin chamber and the pick. Force must be applied to move the pins, even if the lock is bypassed with only one rake action. The photographs below show the areas where

marks from picks (P) and a tension wrench (T) can be expected to appear.

Marks produced from turning wrenches are identifiable. Courtesy of Don Shiles.





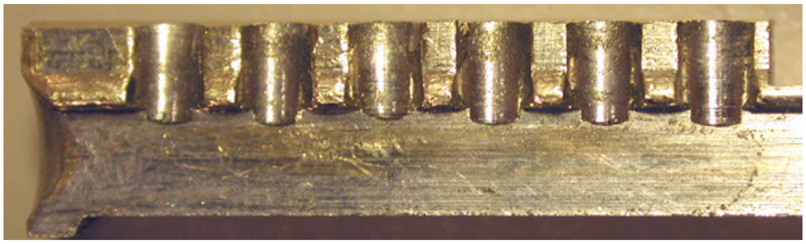


Figure LSS+2601 shows a cutaway view of a plug within a shell, denoting the areas where pick (P) and tension wrench (T) marks are likely to appear. Particularly examine areas between pin chambers, and at the base of each chamber. See the linked image view which denotes tension wrench in red, and pick marks in blue. The bottom photograph shows the mating half of the plug. Note that P (red) denotes marks within the chambers; P (black) shows where marks would appear between pin chambers.

The lower the skill level of the lock picker, the more pronounced will be the marking. The higher the security of the lock, the more difficult it will be to pick, often with corresponding additional indications of entry. Examiners should always check the back of the locking cam because often pick marks are left there also by an amateur.

The application of torque using a tension wrench will also produce marking of the plug, regardless of the design of the tool. There are many types of tools for applying rotating pressure. These include conventional turning wrenches, spring-loaded tweezers- type wrenches, plug spinners, and the Falle-Safe type adjustable wrench.

Turning wrench or torque wrench will leave identifiable tool marks. Courtesy of Hans Mejlshede.

Marks left from a turning wrench. Courtesy of Don Shiles.

The conventional tension wrench is inserted into the keyway at the bottom or the top. The tang or flat perpendicular portion of the wrench that is actually inserted into the keyway will often mark the sides of the plug. This will depend upon its size, material, stiffness, and thickness, as well as applied torque.

Marking will also depend upon the tension required to hold the pins against the shell, the skill of the lock picker, and the number of attempts required to pick the lock. In large measure, the varying application of torque is a personal preference, in

combination with the physical characteristics of the particular lock. Some locks require a large amount of pressure to retain the pins at shear line; others will open with a featherweight touch. Tweezers-type wrenches are made of spring steel, formed with two points that engage the very top and bottom of the keyway. Marking is problematical; it may or may not occur and can be very difficult to detect.

"Plug-spinner" type wrenches are round spring-loaded devices with wire pins protruding from the twelve and six O'clock positions. The center is hollow, much like a donut, allowing the insertion of picks into the keyway. The device, measuring about one or two inches in diameter, is pressed against the surface of the cylinder during picking; the two pins engage the plug and allow precise control of rotation. Their advantage is that they do not obstruct the keyway or block movement of picks. As with the tweezers wrench, marking may or may not occur depending upon the factors noted above.

A special tension wrench has been developed by John Falle, (Falle-Safe Security) that is a modification of the plug-spinner. It is adjustable and inserts anchoring pins at the top and bottom of the keyway. It is operated perpendicular to the face of the lock for better control of plug rotation. Similar marks will be made by the plug-spinner or tweezers.

Tool marks from bypass will most often be caused for the following reasons:

- **High-security locks, making picking difficult and requiring many passes of the lower pins;**
- **Proper pinning of the lock, with differences in adjacent pin depths (high next to low cut);**
- **Use of security tumblers;**
- **Paracentric keyway, or keyway that makes manipulation of a pick very difficult;**
- **Lock parts made of soft metal such as brass, while the pick tool is made of stainless steel or hardened tool steel.**

The examiner is searching for unusual marks, spots, scratches, tracks, distortions, deformations, and tolerance errors caused by the application of force, non-working segments or parts, or other evidence of irregular operation. During the manufacturing process, certain patterns are created upon metal surfaces. When

altered by bypass techniques, these differences can also be visible. During picking, patterns created in metal surfaces during the manufacturing process will be disturbed in a different way than would be caused by normal wear. Other areas within the lock may be similarly affected.

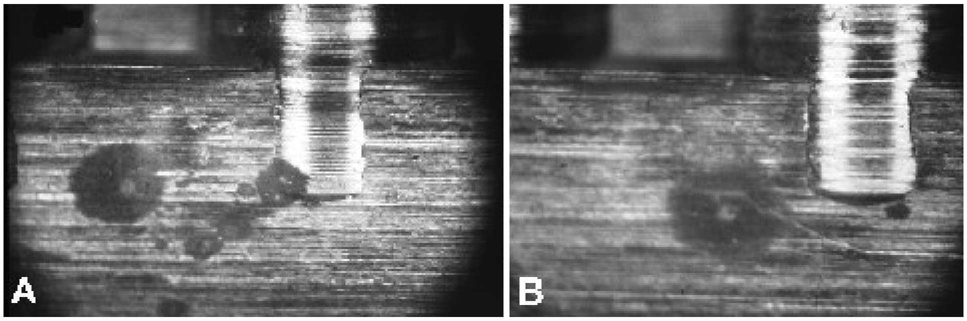
Markings on components by manufacturers. Courtesy of Don Shiles.

Milling marks on pins during manufacture. Courtesy of Don Shiles.

Thus, indents from placing the turning wrench in the keyway may appear on the top and sides of the entry to the plug. There may be angled indents caused by heavy pressure from the torque wrench. There also may be markings on the sides of pins from excessive turning pressure, indicating impressioning. The most critical question for an examiner is whether marks or other indicia were caused by routine operation of the mechanism. In the alternative, were they created in circumstances not present in normal use of the lock or key. Any marks that would not usually occur are suspect.

One must be extremely cautious in defining the cause of marks. Thus, a poorly milled blank that does not precisely fit the keyway can leave markings that might be mistaken for the tang of a tension wrench. Repetition must be checked. If an improper blank is the culprit, marks may be created along the length of the keyway. A tension wrench would only create tracks over a very short area, and the marks would be at an angle. For example, scratches will never appear within pin chambers from normal operation. They can however, appear on the bottoms of tumblers, caused by improperly cut keys. Scratching will rarely be produced on the sides of the pins. So if there are such scratches present, then suspicion regarding picking must occur.

Because the key blade is always lower than the top of the keyway, such areas will never be touched except by picks and other bypass tools. Normally there will be corrosion or oxidation in this area and it can be used as a reference to compare with other areas in order to show changes. Generally, the corrosion or oxidation will cause very small bubbles to form on surfaces. They will be broken when touched by a pick or anything else. These areas are very sensitive. Once broken, they will remain in that state.



Normal insertion and removal of a key, over time, may create a track on the bottom of the tumblers, causing them to appear in horizontal alignment. That is, the bottom of each tumbler will be pointing in the same direction or orientation as the bitting of the key. This alignment may be disturbed during picking.

Forensic marks and their observation with proper lighting. Courtesy of Don Shiles.

Wear information and tests on pins. Courtesy of Hans Mejlshede.

Wear marks on pins. Courtesy of Hans Mejlshede.

Marks produced from keys making contact with pins. Courtesy of Don Shiles.

So also, the tops of the lower pins may wear at an angle, especially if the plug is rotated predominantly in one direction. If, for example, a lock were used on a door that was continually accessed by turning the key to the right, then the tumblers may wear more in one direction. If marks were made some time ago, then the oxidation will cover such marks, thereby offering an indication of age. Some marks may also be impacted with lint, dust, and grease.

Just as important to remember, marks may not be present but yet the lock was in fact picked or otherwise manipulated. For many reasons, marks may not be created, although it is most common that they will appear. Thus, picking cannot be ruled out as a means of entry in the absence of tool marks. Why would tool marks **not** be created during the bypass process? There are several reasons and they all relate to making the lock easier to pick:

- **The lock is made of significantly harder material than the lock pick. Nickel silver pins or plug may not mark;**

- **The lock was decoded rather than picked; then a key was produced from the decoding process;**
- **The pin-stack configuration or combination may be extremely conducive to picking. That is, all tumbler positions may be close to the same depth or in a stair-step pattern;**
- **Maison keying may be in effect. There may only be two or three tumblers in the lock;**
- **Complex master keying may be employed with many cross-combinations available;**
- **The lock may only have three, four, or five tumblers;**
- **No wards or obstructions in the keyway;**
- **The tolerance between plug and shell may be quite sloppy. This may be due to poor manufacturing controls, the top of the plug was filed by an amateur locksmith, or due to wear;**
- **A key may have been run through the lock several times to obstruct evidence of picking, at least with respect to scratches on the bottoms of tumblers. The lock may also have been operated many times inadvertently prior to discovery of the surreptitious entry;**
- **The horizontal center-point alignment between chambers may be erratic, making picking easier. This means that not all of the pin chamber holes in the plug/shell are precisely in a straight line. When the lock is picked it will be easier to cause pins to hang at shear line;**
- **No security tumblers are used;**
- **The perpetrator may be very skilled in lock-picking;**
- **The perpetrator may have carefully picked in conventional fashion each tumbler, rather than raking;**
- **The suspect lock may be inherently easy to pick due to its design (especially if a wafer mechanism);**
- **The perpetrator may have been lucky and was able to pick the lock on the first attempt;**
- **The perpetrator may have raked the lock rather than conventional picking of each individual pin and may have succeeded on the first try;**

- **The springs do not present much tension, and thus low-pressure levels were required to lift them. Very light torque may have been applied;**
- **The perpetrator used non-metallic picks or pick tips;**
- **The perpetrator was able to open the lock by withdrawing a blank key while applying the correct amount of tension;**
- **The perpetrator was able to lift all tumblers using a pocket knife, because each depth was close to the same level;**
- **Rocker picks were utilized in a lock having a pin combination that matched the signature of the picks.**

26_1.5.2.1 Location of Marks

Tool marks may remain as the result of bypass attempts in many locations within the lock and on surface areas. Examiners should thus consider the potential for finding such marks on the plug face, anywhere within the shell/chamber area, and on pins and springs, both bottom and sides.

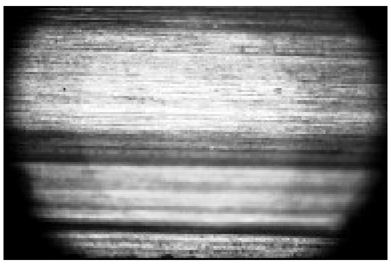
With respect to the shell/chamber areas, marks may be produced within pin chambers within the plug or shell, between chambers in the plug, or around the opening between plug and shell. Marks may also be created on the front of the plug or shell during the impressioning process, discussed below. The marks are caused by the application of pressure against the front of the lock. If the color is scratched off the bottom pins or there are scratches on the bottoms of the pins, it may indicate that a new or jagged-cut key was used.

Other types of bypass tools may cause different tool marks. For example, chisel marks on the sides of pins may indicate the use of a 999 rapping technique. The examiner must also take into account the metal surfaces with which picks or other tools may come into contact. If ball bearings or nickel silver pins or plugs are employed, diminished marking may occur.

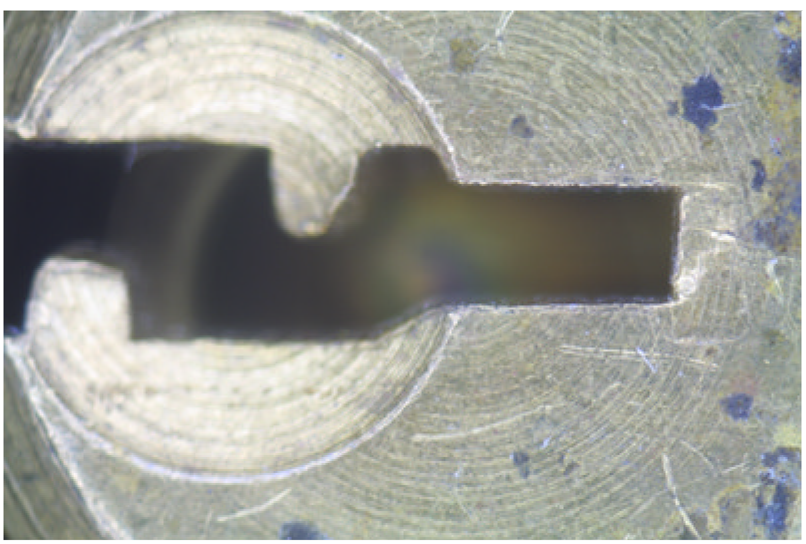
Note that all of the microphotographs of pins and cylinders in the following sections were taken by the author with an Olympus 10x-40x binocular microscope with a Canon D30 digital camera, lens adapter, and florescent ring light. The photographs were captured at 300 dpi, enhanced, and then reduced to 96 dpi.

26_1.5.2.1.1 Tool Marks in and on the Surface of the Plug

Tool marks may be found on the front surface of the plug, within the chamber walls, between pin chambers, and throughout broached areas. In addition, pick tracks may be evident within grease, oil, or plug lubricant anywhere along the keyway. Depending upon the type of bypass technique, there may be spreading, warping, denting, bending or distortion of wards within the keyway. There may also be tool or blank shoulder imprint marks on the face of the plug caused by the pressure exerted by an impression vice.



Examiners should also be alert to very fine holes drilled through the front of the plug at shear line. Some holes (which can be filled) are often imperceptible; yet, they will allow the insertion of a shim wire allowing the plug to be rotated. If tubular locks such as Abloy, Chicago, Ace, or Tubar are utilized, consider the possibility that the face was ground away and the entire lock replaced.



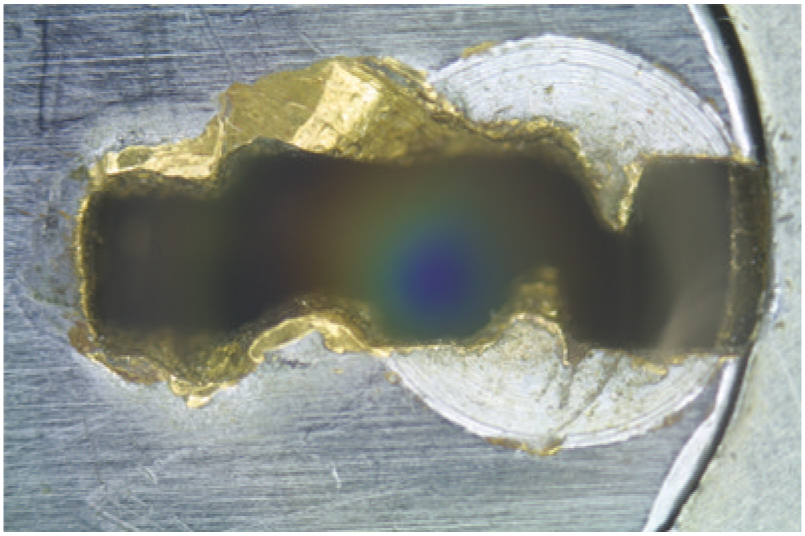
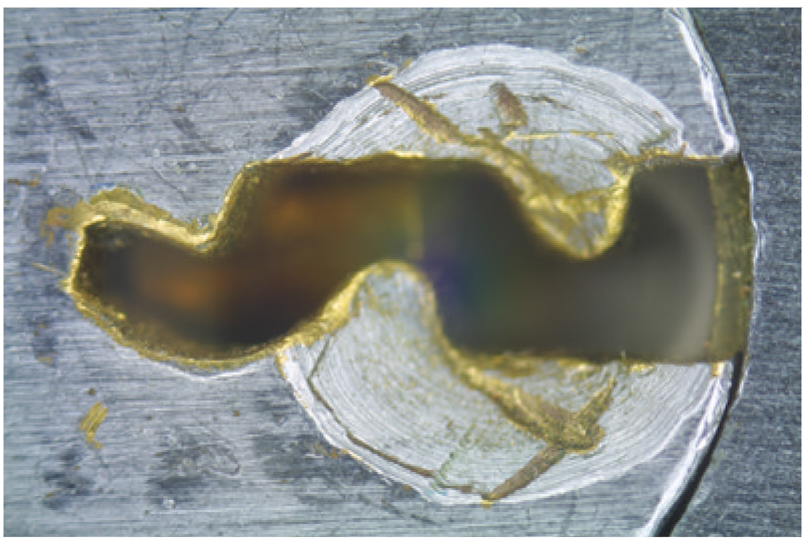


Figure LSS+2602 A cylinder that has been picked and raked (left) and picked, then a forced entry tool was utilized.



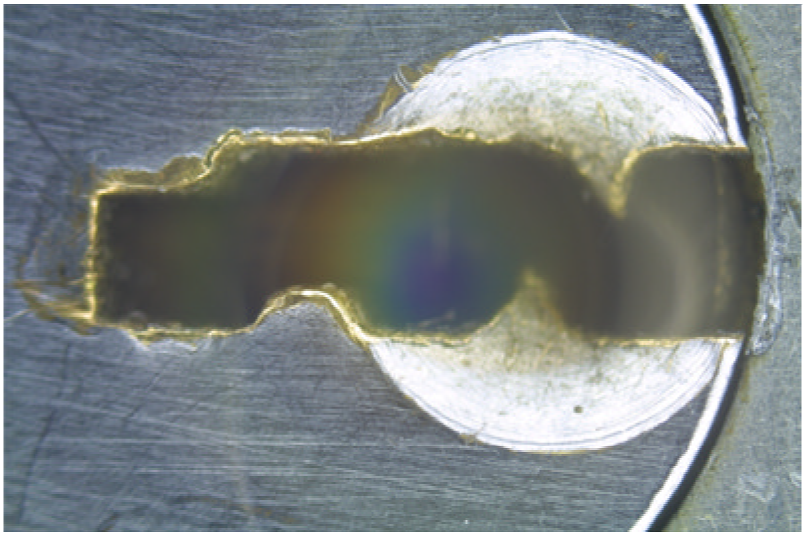
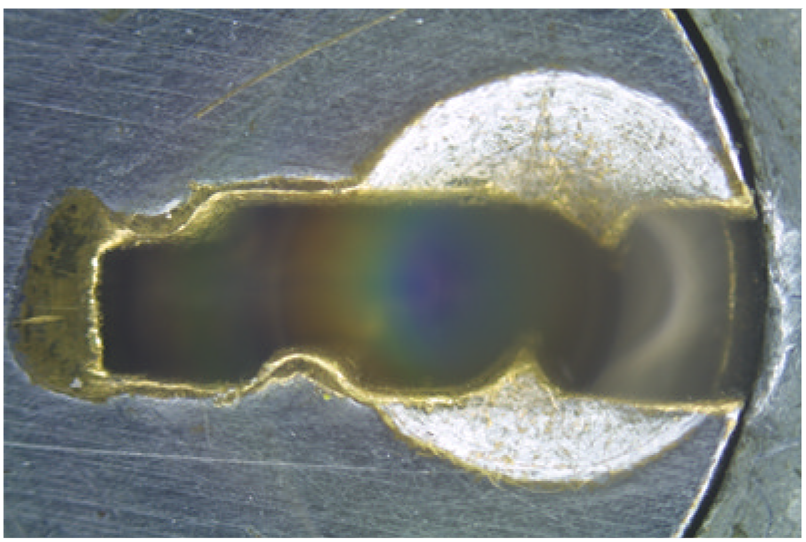


Figure LSS+2603 An electric pick gun was utilized to open the lock on the left; impressioning and picking was utilized to open the lock on the left.



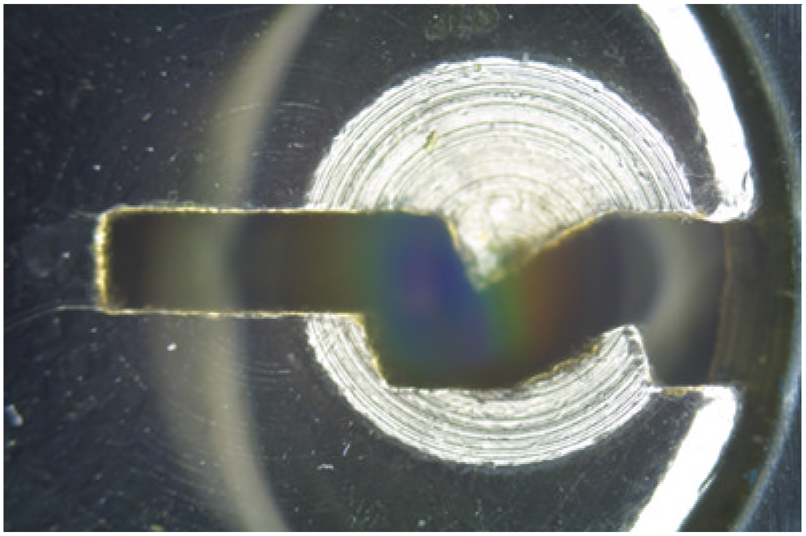
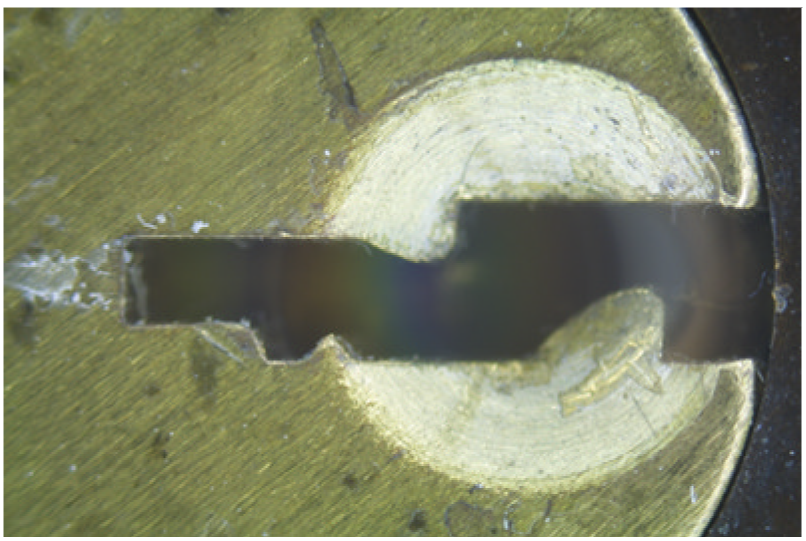


Figure LSS+2604 The cylinder on the left was opened by impressioning, raking, and picking. The cylinder on the right was picked by a left-handed person.



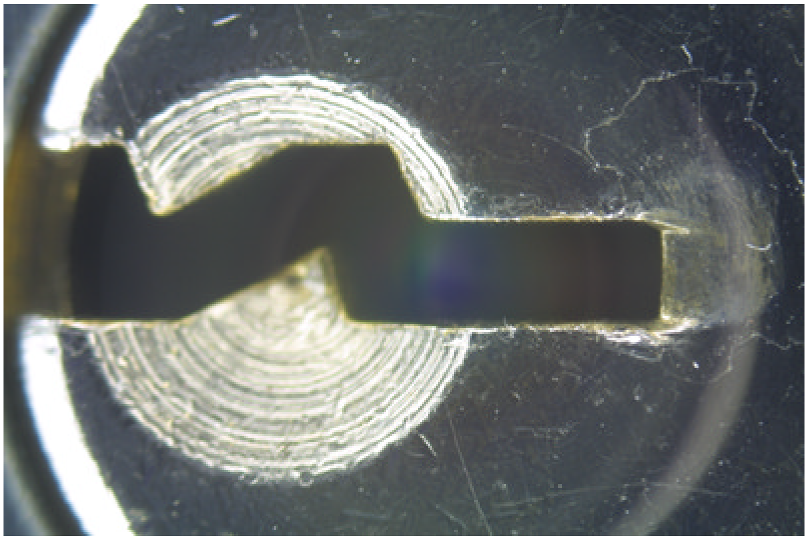
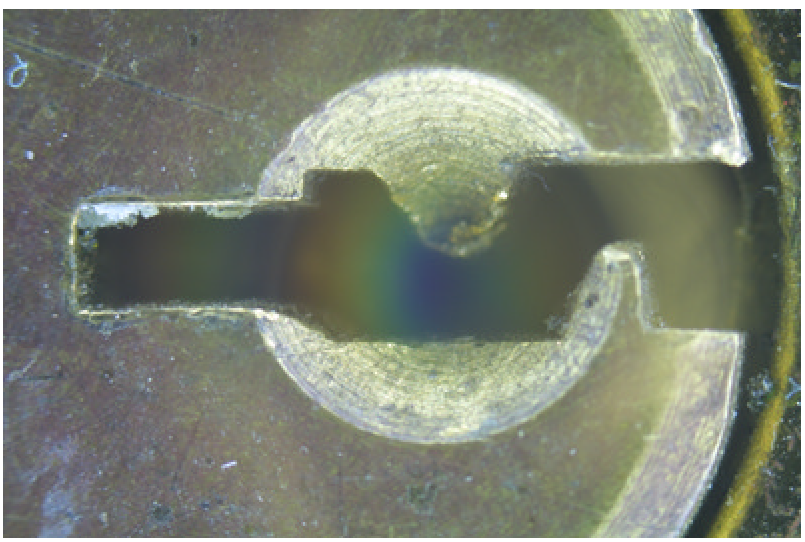


Figure LSS+2605 The cylinder on the left has not been bypassed. It shows normal wear marks from the use of a key only. The cylinder on the right was impressioned and opened by left turning.



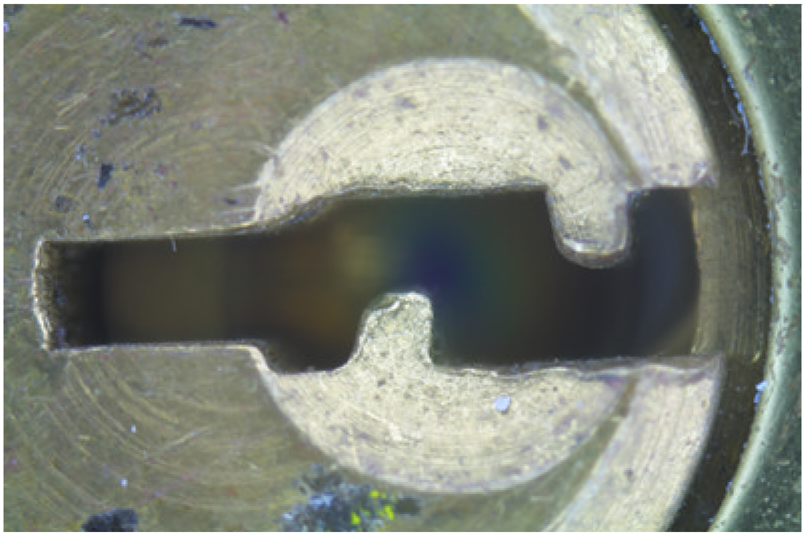


Figure LSS+2606 Both of these cylinders were opened by picking.

26_1.5.2.1.2 Tool Marks on Pins

Normal appearance of pins and what type of marks appear. Courtesy of Hans Mejlshede.

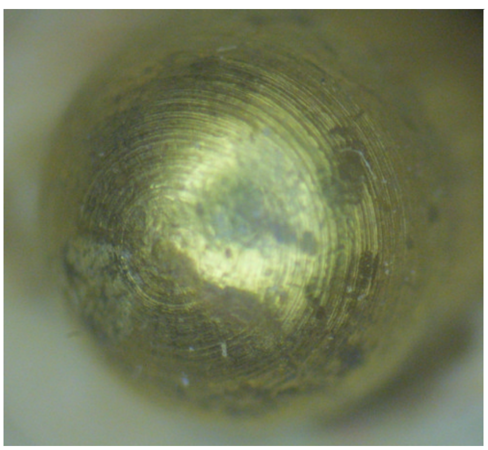
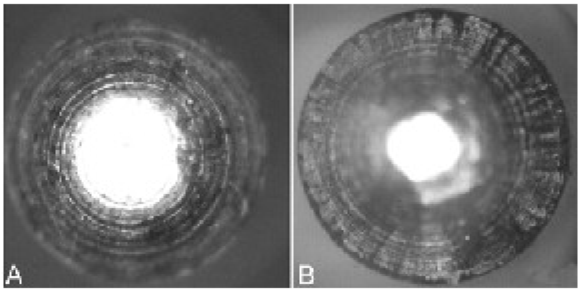


Figure LSS+2607 This normal pin shows factory machining marks, and has not been picked.

All pins and pin surfaces (bottom and sides) should be examined for evidence of tool marks and distortion. This is especially true for the pin that is the most out-of-alignment with respect to centering of pin chambers. This pin will be picked or impressioned first.



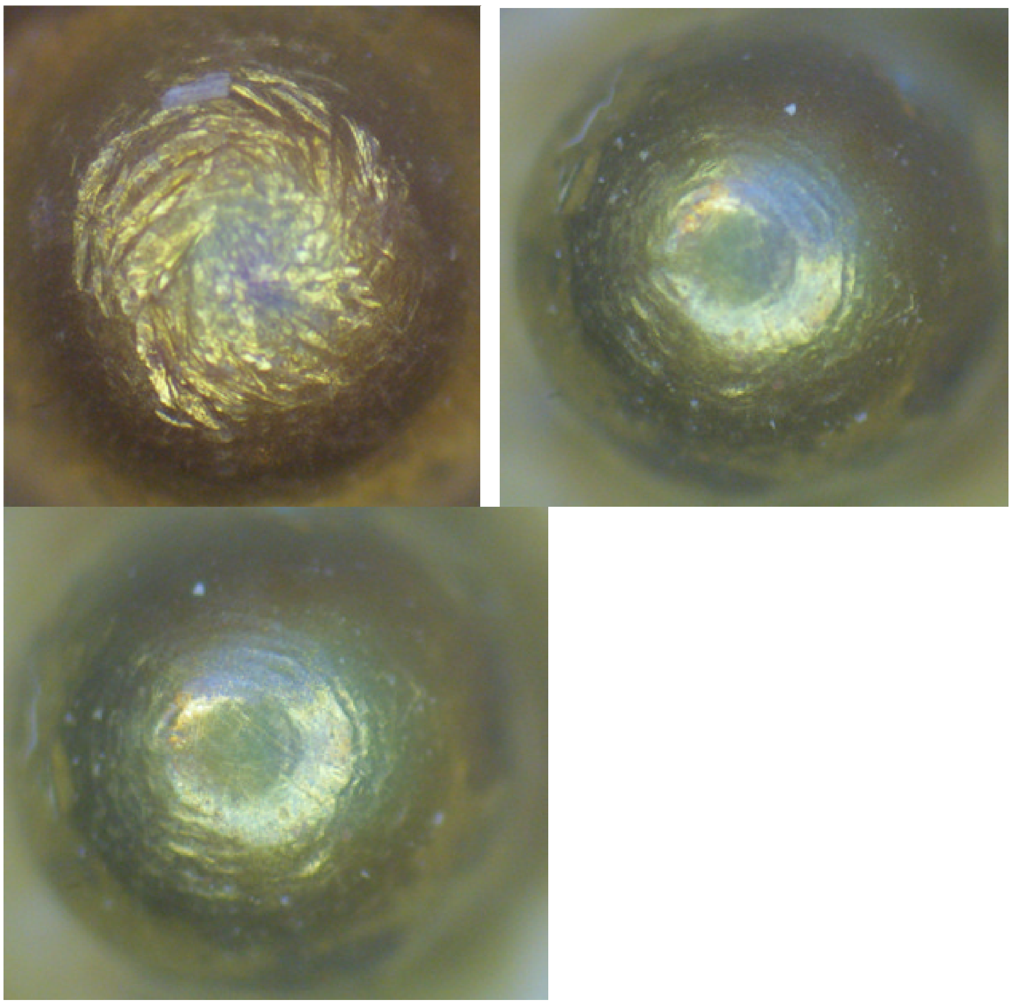


Figure LSS+2608 An electric pick gun was utilized on the pin shown in the left photograph.
A snap pick was utilized on the other two pins shown.

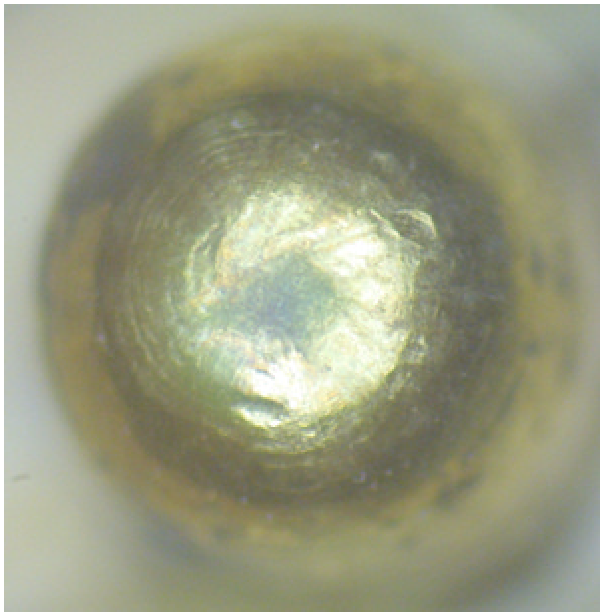
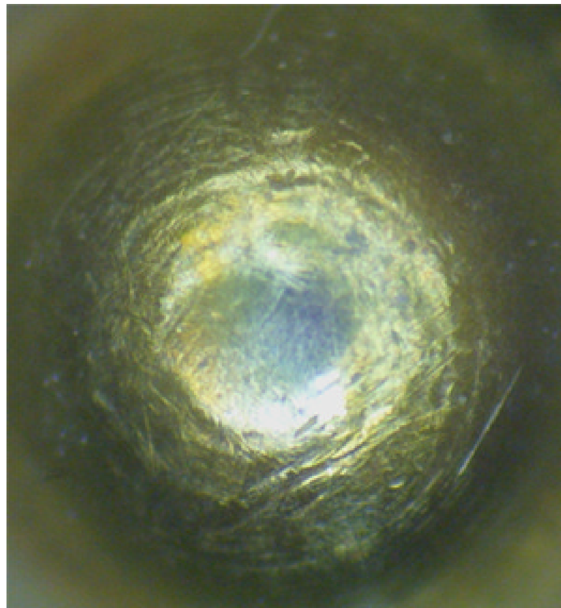


Figure LSS+2609 An impact tool was utilized on this pin. Note the deep impressions around the circumference.

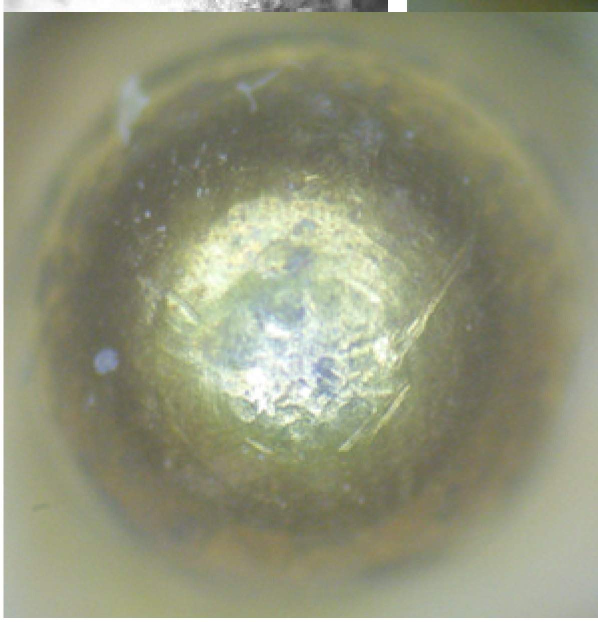
Tool marks may appear as scratches on the bottoms and sides of lower pin tumblers. The size of marks may indicate the type of pick. Marks on longer pins next to shorter ones will clearly point to picking with conventional tools; equal marks on the bottoms of all pins will indicate that a snap gun was used.

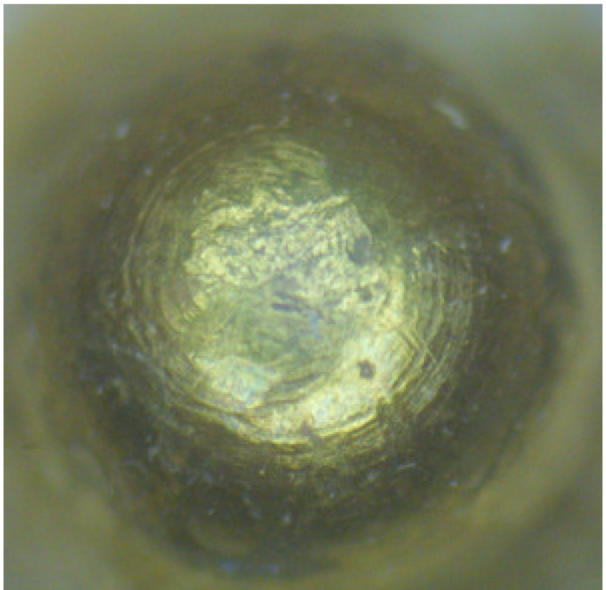
The location of the marking on pins will depend upon the keyway orientation. Methods of picking, especially with snap guns, must be determined so that an accurate estimate can be made as to where marks should occur. A test cylinder should be picked using various techniques to verify markings.

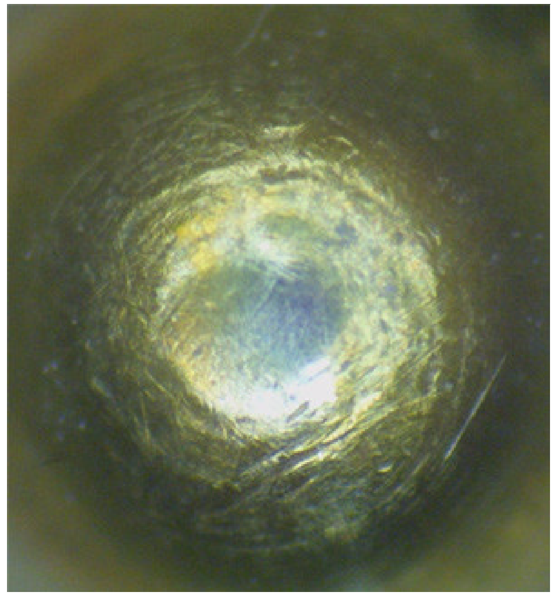




v







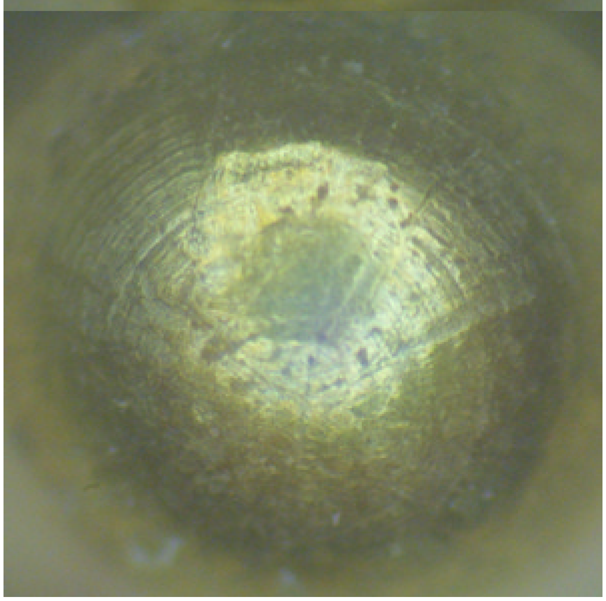


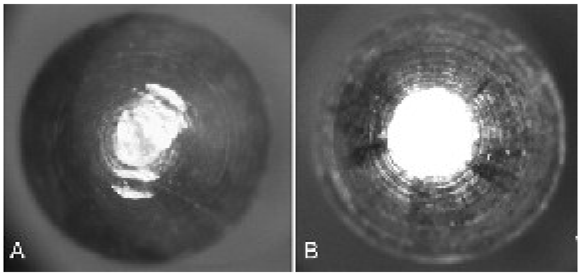




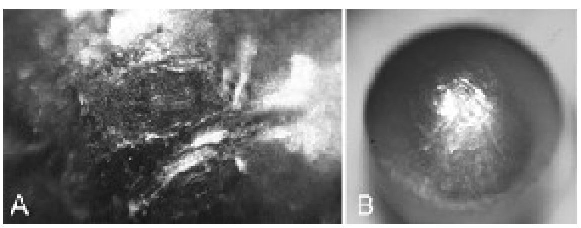
Figure LSS+2610 Examples of marks produced by different types of manual picks (above). In the photographs below, a Medeco Biaxial five pin cylinder has been picked using a probe to apply pressure against the edge of the pin. Although not a completely reliable means of opening, the technician reports that he could open this lock in between thirty seconds to one hour.

Indentation marks may be present on the sides of both lower and upper tumblers. This would indicate impressioning with the use of extreme torque.

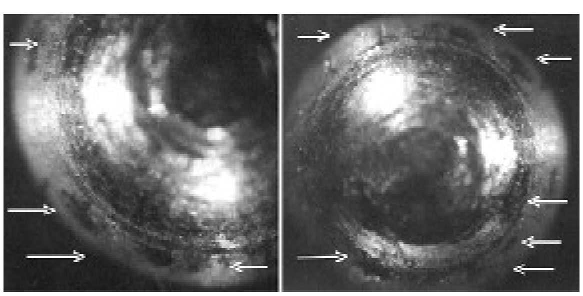
There may be compression marks on the tops of pins, caused by the spring wire being exposed to the tumbler surface. This would offer evidence of the use of a comb pick, or substitution of lower pins for drivers. A comb pick requires that all pins be compressed into the shell. The force required to accomplish this can leave marks.

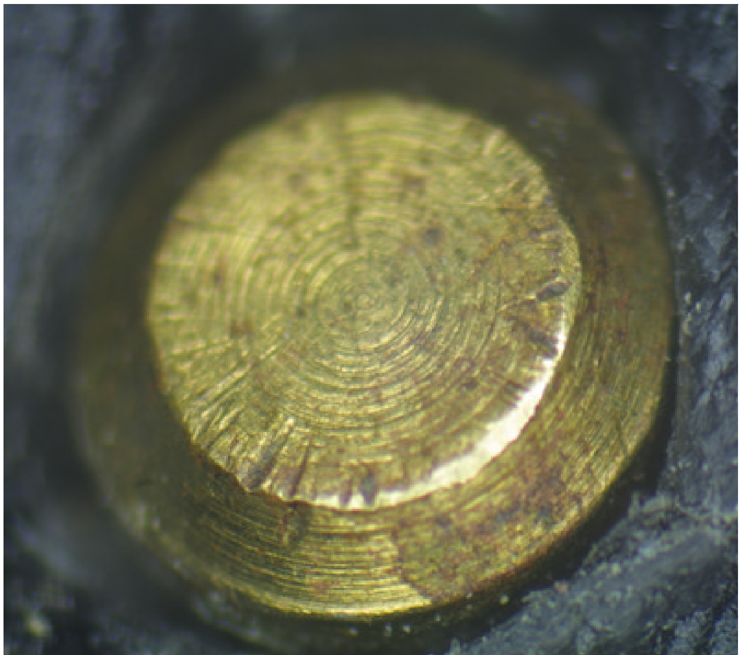


However, if markings are encountered, examiners must eliminate the possibility that such scratches were in fact produced from the bottom tumblers originally being used as driver pins, with the rounded surface oriented toward the springs. Sometimes, a locksmith will substitute bottom pins for drivers, especially when working on a lock in the field. If pins were substituted, generally the corresponding spring will be broken, with a jagged piece of wire contacting the pin. In such cases, the marks will appear to go around the dome of the pin. Examiners should also be alert to color coded pins with portions of the color missing.



Lower pins may slightly rotate during normal use, distributing wear until they are so worn that tracks are created on their base. Essentially, every time a key is inserted, the tumbler is contacted and marked. After many years, this will be quite pronounced. If a pin is hit at the same point many times, a flat spot will occur. In contrast, if the lock is picked, especially with a pick gun, the pin is rotated and marks will occur around the center-point of the lower pin. They will often appear like the spokes of a wheel.





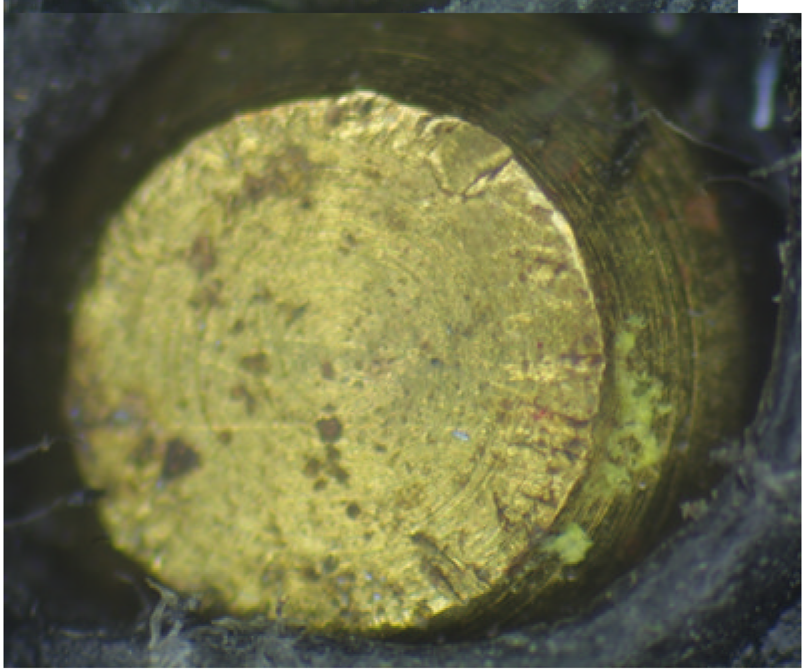


Figure LSS+2611 Marks produced by a pick gun (left) and rake pick (right). Note the multiple markings that are made by the pick gun around the circumference of the pin.

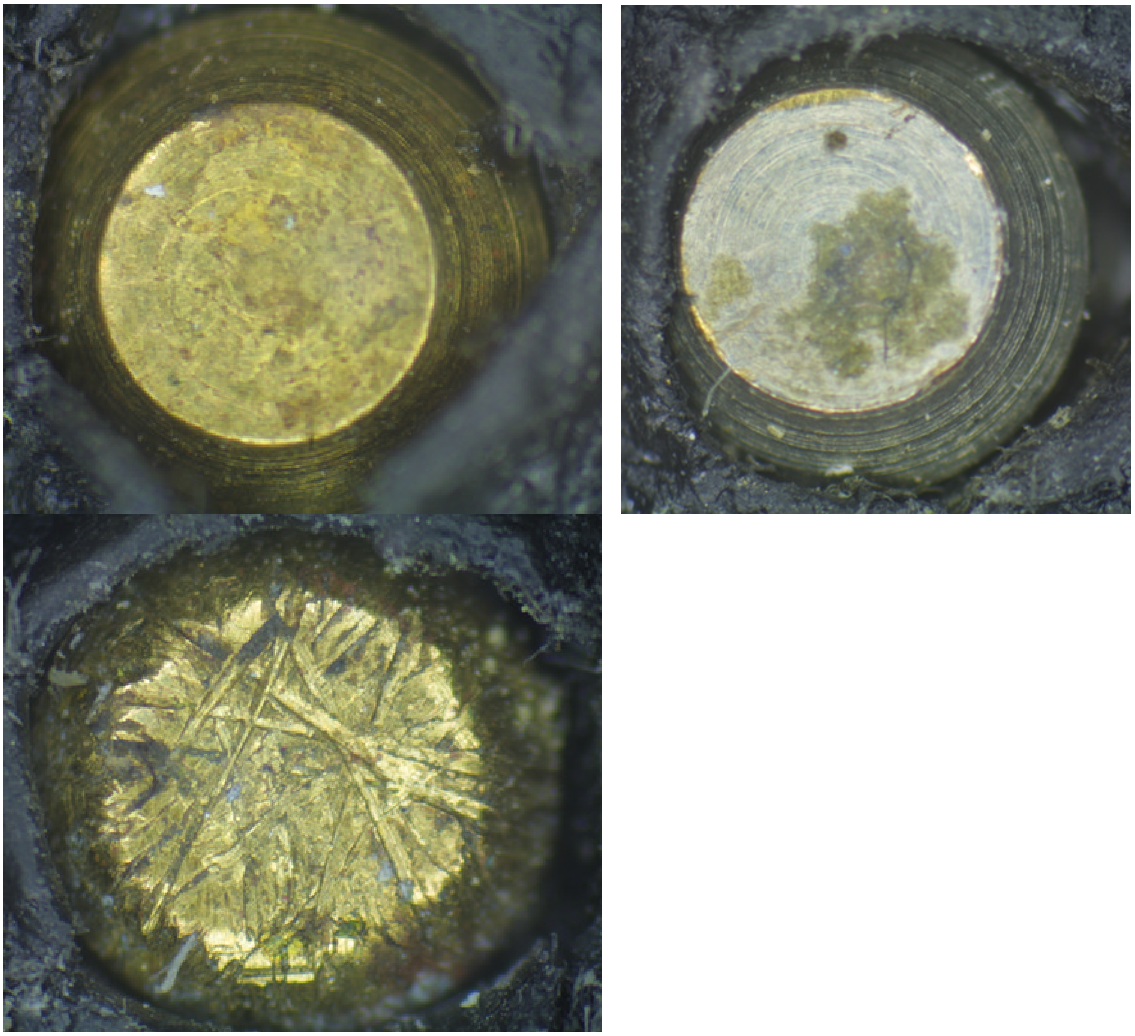


Figure LSS+2612 Marks produce by a pick (left, by a key only (center) and by an electric pick gun (right).

26_1.5.2.1.3 Marks on Springs

Sometimes, marks will appear on springs. This may indicate that a fine drill was used to create a shear line. Compression of springs may indicate that extreme pressure was applied with a comb pick.

26_1.5.2.2 General Queries Regarding Tool Marks from Picking

If it is determined that the lock was likely picked, then the following inquiries may be pursued:

- **Are there any tool marks on the surface components or within the plug;**
- **Are there pick or scratch marks on the top, bottom, or sides of any pin. Long marks may indicate that tumblers were raised improperly, caused by picking rather than normal key use. Marks will be created by applying torque to the plug while raising a tumbler. The friction of the pin rubbing against the chamber wall will cause discernible scoring;**
- **Are there tang marks (from the tension wrench) on the top, bottom, or sides of the plug;**

- **Are there scratch marks on the surface of the shell or plug, notably on the front escutcheon, keyway, chambers, or pins. This would be especially important in the case of dimple locks, because a different technique is generally used to apply torque;**
- **Are there apparent pick marks. If such marks were caused by picking the lock, how old are they. When were they made. Could normal operation of the lock cause the questioned marks. Are there alternative explanations;**

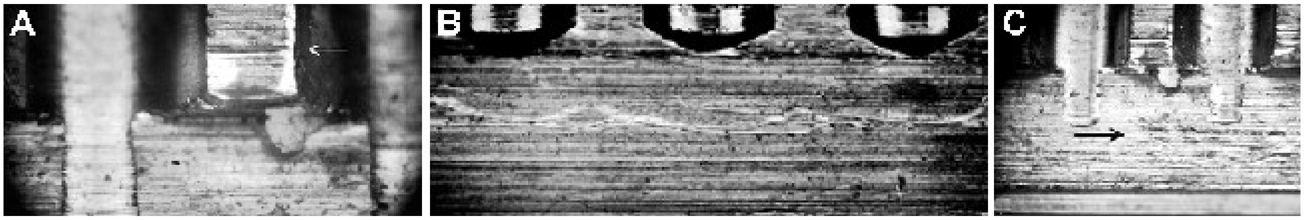
- **Was the lock picked by raking, conventional techniques, or pick gun;**
- **What type of pick tools were used;**
- **Have the tumblers been rotated by picking. This is why it may be important to maintain the exact vertical position of the tumblers when opening the lock, as noted earlier in the chapter. If the lock was picked, the tumblers may have revolved which would be indicated by misalignment with respect to normal key track wear.**

26_1.5.2.3 Marks from Conventional Picks

Marks produced by raking. Courtesy of Don Shiles.

Marks made by conventional picks may take many forms with respect to depth, length of track, and width. Picking with conventional tools has the same basic result: a scratching will occur as the

tip of the pick moves across pin and plug surfaces.



Optimally, the examiner will find locations within the plug where the key cannot encounter any surface. If marks appear there, it is almost certain that bypass occurred. Remember, picks may be sharp, rounded, sloping, angled, or of other design. Therefore, the marks created may be quite varied.



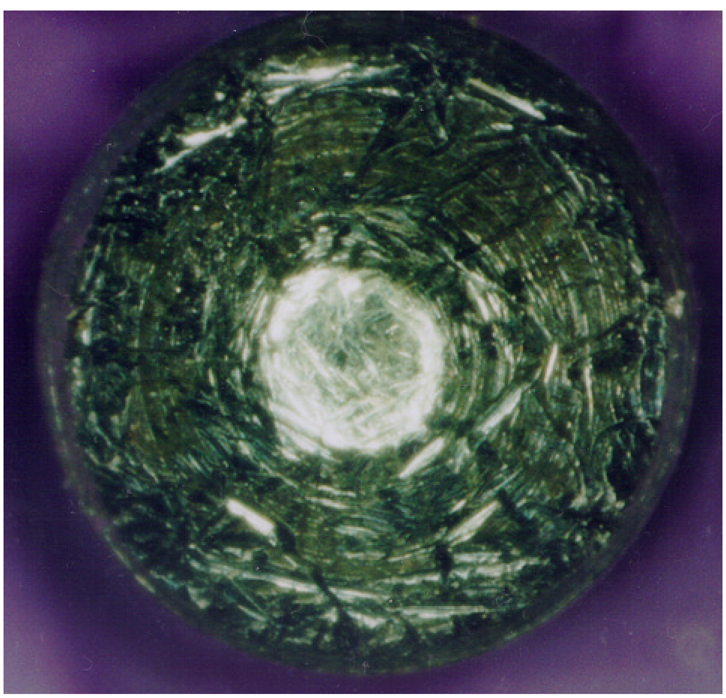


Figure LSS+2613 Marks produced from conventional picking tools are distinct, and will appear around the head of the pin as it is rotated during the picking process.

26_1.5.2.4 Marks from Pick Guns

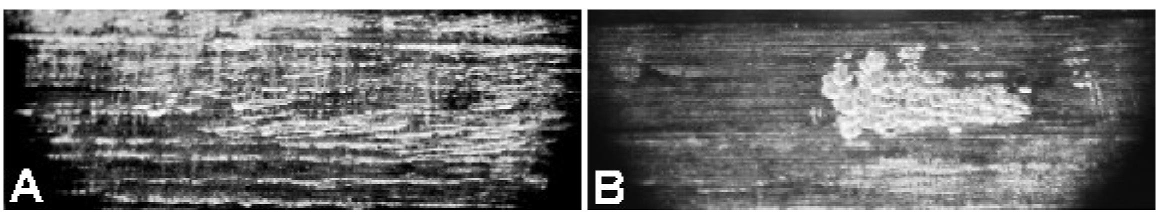
The use of pick guns with profile locks. Courtesy of Hans Mejlshede.

Forensic analysis of pick gun marks. Courtesy of Hans Mejlshede.

Pick gun marks and order of picking. Courtesy of Hans Mejlshede.

Forensic indications of the use of an electric pick gun. Courtesy of Hans Mejlshede.

All pick guns, whether mechanical or electrical, perform the same function: to generate a rapid, focused shock wave applied to the base of the lower pins. Markings from the use of these tools can be quite pronounced because there is usually several attempts before the lock will open. Each time the tool is triggered, marks are created. The active end of the tool (the metal pick that meets the tumblers) presents a relatively hard surface against soft metal pins.



There are three types of pick guns: mechanical snap, electric solenoid snap, and electric vibrating. Each will produce markings on tumblers. The snap guns all work on the same principle and relates to Newton's theory of motion that for each action, there is an equal and opposite reaction.



Figure LSS+2614 Marks produced from pick gun.

Based upon the same premise as striking a pool ball with a cue, in turn striking another ball which is then moved to the pocket, the working end of the snap pick is the pool cue. It meets the base of one or more tumblers to create a shock or burst of energy. This energy is transmitted to the driver (upper) tumbler. The upper pin is moved as the "opposite" reaction to the force being applied to the lower pin. In principle and with the proper skill, **all** drivers will be simultaneously bounced above shear line for a few milliseconds. If during this very brief interval a turning force is applied to the plug, there will be nothing to stop its rotation.

The HPC mechanical snap gun described in **Chapter 29** is simply a device for rapidly cocking and releasing a long, straight piece of spring steel, formed to make contact with the base of each lower pin tumbler. For proper operation, the pick will be aligned with the bottoms of all tumblers at a perfect 90° angle. It is important that all pins be contacted at the same time and with the same force. To open the lock, the operator will repeatedly release the pick. Each time this occurs, a very brief force will be applied to the pins. With skill, the proper timing of shock and turning is achieved and the plug rotates.

The electric solenoid pick accomplishes the same function, except that the shock wave is generated by the action of a magnetic field rather than manual spring. The results are identical. The HPC vibrating pick is based on a similar theory as the pick gun. The tool generates rapid oscillations of the pick blade that may be adjusted to personal preference.

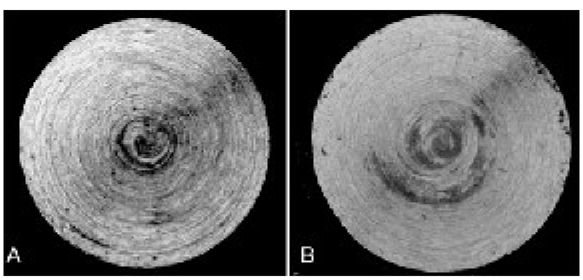
Each of these picking tools will cause similar marks to be

produced on the bottoms of the tumblers and perhaps on the sides of the keyway. The marks will be varied and often will be many in number, because the pins tend to rotate as the process occurs with multiple abrasive contacts. There will also be marks around the center of the pin. This is dependent upon the design of the wards and the freedom of the pick to move vertically. If the pick gun can be located directly under each tumbler, then all marks will appear in the center.

If a pick gun is triggered five times there will theoretically be five sets of marks, although this is not absolute. The angle of attack and the keyway will dictate where the marks occur. If there is a mark on one tumbler but not on others and there is corrosion present between chambers in recesses of the keyway or above it, then it is fairly certain that a pick gun was **not** used. Corrosion over the marks must also be checked and estimation made as to how fast picking marks would corrode in the specific environment where the lock is utilized.

26_1.5.2.5 Tool Marks from Comb Picks

A comb pick may be utilized in locks that are improperly pinned or which do not contain balanced drivers. Apparently many manufacturers are still not aware of this tool and thus do not compute the length of the pin stacks in their locks. The pick resembles the teeth of a comb; one for each pin. It will not work in any lock where the pin-stack (drivers and lower pins together) are balanced or longer than the upper pin chamber. The tool will function only when all lower pins can be pushed into the upper chambers above shear line. Then, the teeth of the pick form a new shear line allowing the plug to rotate.



This tool will leave marks on the bottoms of all tumblers because a fair amount of pressure must be exerted to raise them simultaneously, although such pressure is distributed. Springs may also be compressed as the result of such bypass. Examination should include the interior of plug chambers, both upper and

lower, for marks. Because of the design of the comb pick, marks may be quite symmetrical with respect to their relative location in each chamber. As remarked previously, the initial examination of the lock should also include verification of the length of the pin-stack for each chamber to ascertain whether a comb pick could actually work.

26_1.5.2.6 Marks from 999 Rapping

Cylinders may be opened by rapping them. Courtesy of Hans Mejlshede.

Rapping of a lock using a “999” style key is common in some countries, notably Denmark. The procedure involves the insertion of a specially cut key described in more detail in **Chapter 29**, followed by the application of rapping or repeated shocks to the end of the key using a mallet, plastic screwdriver, or similar instrument. The rapping motion is transmitted to all tumblers, (at a 45-90^{o} angle to the bottom pins) simultaneously. In theory, much like the pick gun, the forward motion of the key will momentarily cause the driver tumblers to be bumped upward above shear line. With the proper timing, a lock can be successfully rapped open in a couple of attempts.

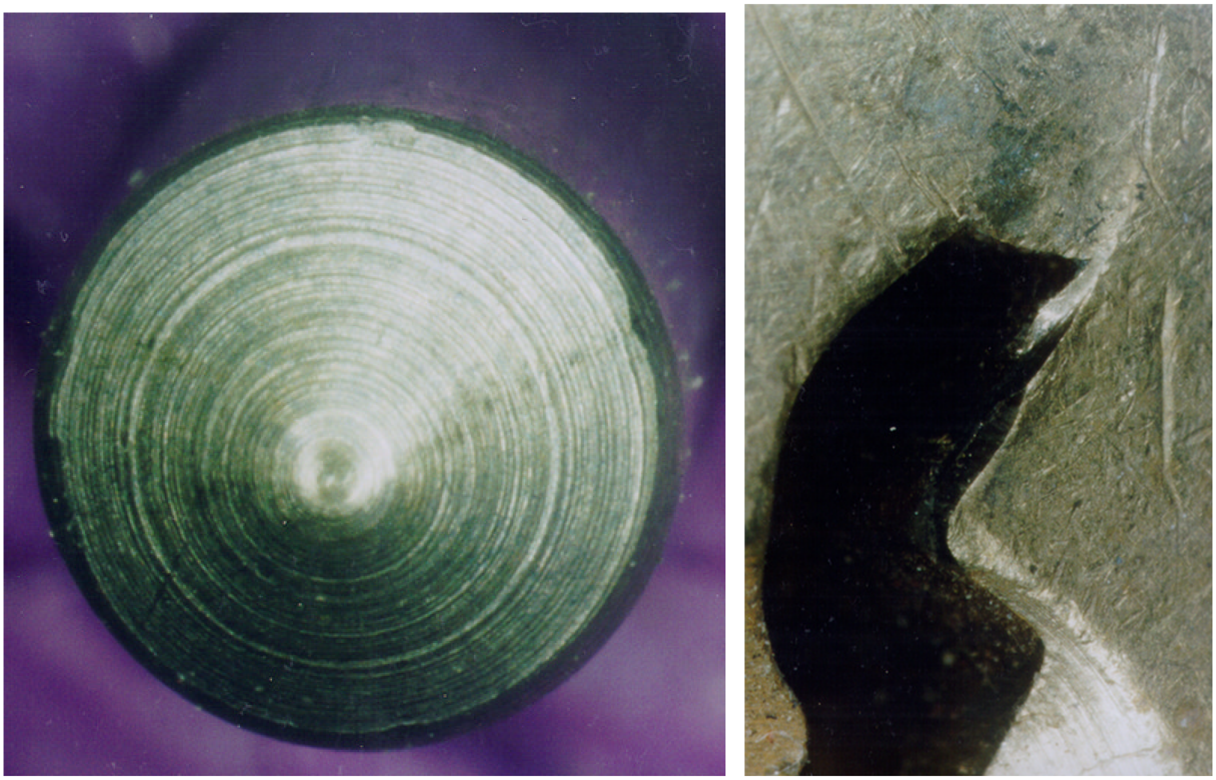


Figure LSS+2615 indicia of the use of a "999" or "bump" key. Note the tearing at the top of the keyway and the deformation of the pin circumference.

Forensic indication of the use of a ""999"" or "bump key," Courtesy Hans Mejlshede

The design of a 999 key would preclude its normal use. It would rarely if ever be encountered except in suspicious circumstances. Possession of such a key would warrant further inquiry. A 999 key will have all cuts at maximum depth and will often contain long ramps between cuts. These ramps will serve to catch each lower pin as rapping is applied.

The procedure will leave evidence in two areas: on the sides of all tumblers and on the plug. There will be marking where the shoulder strikes the face of the plug because the key is often hit too hard. If there is a visible indentation, the technique should be suspected. However, such could also represent a lock with heavy use. The pins should be closely examined; they will appear as if struck with a brass chisel. A radial mark will be present because the angle of the key is not the same as on the pin. Scratches on the sides and bottoms of the pins can show that a 999 rapping technique was applied, or that there was too steep

a ramp angle on a key that was forced into the lock.

26_1.5.3 Marks from Impressioning

See **Chapter 30** regarding impressioning techniques.

Impressioning requires that a blank key be inserted into the lock. Torque, in concert with a specific lifting motion, is applied in an effort to bind the lower pins until they are precisely at shear line. The underlying theory of impressioning (within the pin tumbler mechanism) can be simply stated. As torque is applied, pins that are below or above shear line will mark the bitting surface of a key when it is moved vertically. A pin will not bind when **at** shear line, if vertical pressure is applied to it. When the key is cut to the proper depth during the impressioning process, no marking will occur on the blank.

Various marks will be produced through impressioning techniques, depending upon the type of lock and the procedures employed. These generally will take the form of keyway distortion and marking on the walls of the keyway and chambers, on the sides of pins, and in other areas of the plug. Marking may also be seen at the bottom end and sides of the top pins. Side indentation may occur because of the rotational pressure of the plug that occurs just before the lock opens. Significant indentation may also be in evidence at the top and bottom of the plug, resulting from the heavy sliding action between the blank and the keyway. Angled indents on pins will be caused by the extreme application of torque and resulting pressure on the sides of tumblers.

Depending upon the age and use of cylinders, marks caused by impressioning will be different. Tests may be required on specific locks after all photographs and measurements have been taken. Impression marks may be left on lower and upper walls of chambers, caused by torque and vertical movement of the plug binding against the pins. The pins actually will scrape the chamber walls. Indicia may also be left on the face of the plug, both top and/or bottom, because of the application of pressure against the shoulder of the key.

Keyway wards may also be warped, deformed, or marked as a result of the interaction between the blank and sides of the plug. Spreading of the keyway can also occur. Marks on keyway wards may likewise be caused by an improperly fitting blank, generally a non-factory original. Elongated or distorted chambers may be found in the plug or shell because of the process. If a dimple

lock is impressioned, pins may be bent, distorted, or crushed, especially in the high-security mechanisms such as Kaba and Mul-T-Lock. In the case of plastic or nylon plugs, cracking can happen if too much torque is applied. In a forensic examination to determine impressioning, the following areas must be checked for marks:

- **On the front of the plug, from pressure caused by impression tool, vice grips, pliers, nose puller, screw marks, or other devices;**
- **On the face of the plug-top and/or bottom;**
- **Chambers, plug sides, and chamber spaces;**
- **Measurement of plug/keyway warping and spreading of keyway and of wards;**
- **Scraping of chamber walls, of driver and lower pins, and pin sides;**
- **Pins, on the bottom forward side, for impression marks that will indicate a hard pressure exerted against the blank. It may also indicate a poorly cut key with too deep of a slope angle, typical of hand cutting;**
- **Marks on the cam;**
- **Widening of pin chambers;**
- **Cracks or fractures of metal or plastic keyway.**

Forensic investigations involving locks that have been impressioned. Courtesy of Hans Mejlshede.

26_1.5.3.1 Queries Regarding Impressioning

- **Are there marks on all top surfaces of lower pins. This may indicate impressioning or a loose plug. Try to pull the key out. If it sticks, the cam-retaining screws are loose;**

- **Are there marks on the bottom of lower tumblers. This may indicate that the lock was impressioned or that a poorly fitting, worn, or improperly spaced key was utilized. Does the key have to be slightly withdrawn or jiggled to work;**

- **Examine the cylinder for scoring. This can occur if**

the key is improperly cut, causing tumblers to be raised slightly higher than shear line;

- **Are there multiple vertical tracks in the chambers or on pins. Markings on chamber walls, especially if they correspond in upper and lower chambers, can indicate impressioning or the use of comb picks. Vertical tracks in several chambers may also show impressioning;**

- **Are there spots on the bottom of tumblers. This may provide evidence of impressioning or that a poorly fitting key had to be lifted to raise the tumblers to shear line was utilized;**

- **Are there any tracks between the upper surface of chambers. This would indicate that the lock was picked, not impressioned;**

- **Is there any tracks or scoring on the interior radius of the shell, drawn in a circle or ring, that correspond with plug rotation. This would generally indicate that the plug was rotated using a key that was cut slightly high, so that the bottom pins scored the surface of the shell. It could, however, also provide evidence that a comb pick was utilized, although this is more remote;**

- **Are there narrow or wide tracks on the bottoms of tumblers. Narrow markings would indicate picking. Wide tracks would tend to indicate impressioning or extreme wear caused by heavy use of the lock;**

- **Are there spots on the sides of the keyway. This may indicate a number of conditions, depending upon the precision of broaching and the milling of the blank(s) used to open the lock;**

The spots can be caused by the interaction of a poorly milled blank that makes contact with certain points within the keyway, but not all points. Spots may also touch the keyway, especially if some pressure is required to insert the blank. A combination of the two errors may also contribute to spots. The exertion of

extreme pressure and torque upon a blank during impressioning can also cause them.

- **Are there shiny spots or indents on both the longitudinal surfaces throughout the length of the keyway, as well as vertical spots or distortions. Are there single or multiple spots or markings on the sides of the tumblers and chambers. Such would definitely be evidence of impressioning because both horizontal and vertical movement of the blank is required;**

- **Multiple vertical spots on one or more chamber walls would be highly suggestive of impressioning because of the procedure involved in making the key. Can a correlation be made between the number of spots within a single chamber and the depth of the tumbler cut.**

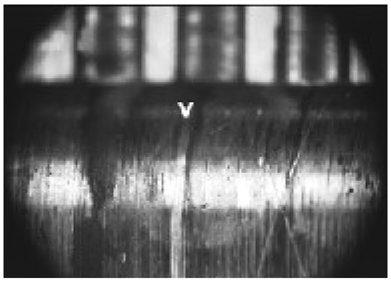
Thus, if the tumbler requires a deep bitting surface on the key, a corresponding number of samples would be required before a determination could be made of the correct depth. Each time the key is filed and the new depth is tested, a potential new marking will occur at a different position;

- **Are there distortions at the top of the plug chamber holes or the very bottom of the upper chamber holes. If so, this would indicate impressioning. The distortions are caused by torque being applied to the plug and the tops of the lower tumblers binding just above shear line;**

- **Are there marks on the bottom pins. These may have been caused by a poorly cut duplicate key. Excessive pressure and resultant marking can be caused by the insertion of the key, especially if ramp angles are too steep or there are jagged or sharp edges on the surface;**

- **Are there lateral marks that begin at the surface of the plug and extend inward a short distance (1-2 mm) along the keyway. These marks may appear anywhere, although usually they will be at the top, bottom, or against a protruding ward. Such markings would**

indicate the use of a tension tool. Remember that tang marks will generally not protrude past the first or second tumbler. If longer tracks are present, it may indicate the use of a flat-blade screwdriver, possibly to simulate picking. It may also be that such a tool was used as a turning wrench.



26_1.5.4 Markings on Lever Locks

Lever locks are popular throughout the world for all security applications. They are favored in Europe for safes and vaults as well as traditional uses. Almost all lever locks can be picked or decoded, even those promising the highest security levels and previously thought to be impenetrable. In the experience of the author, up to ninety-nine percent of all high-security lever locks employed on the finest safes and vaults in the world can be quickly compromised without detection or trace.

There are at least five methods for opening these locks, covered in detail in later chapters. Some decoding methods will leave little if any trace, while others may leave very tangible evidence. Marks will be present on the sides of levers. Although marks may also appear on the bellies (depending upon bypass methods), care must be exercised in their evaluation. Improperly cut keys or the insertion of the wrong key may leave marks that appear inconsistent with normal operation. In some instances, deposits of plasticine, type-correct solution, putty, nail polish, or carbon may be present because of impressioning attempts. Certain sophisticated decoders will leave virtually no trace. Their use is discussed in the **LSS+/^{x} CD/ROM.**

26_1.5.5.A Markings on Wafers: General Issues

The reader should also see **Section 32_4.4** for an introductory discussion regarding the different types of tool marks and how

they are produced.

Picking marks on wafers from vehicle locks. Courtesy of Hans Mejlshede.

Marks on wafers from picking. Courtesy of Hans Mejlshede.

Pick marks may appear on surface of wafers. Courtesy of Hans Mejlshede.

Analysis of presence of grease on wafers in forensic investigation. Courtesy of Hans Mejlshede.

There have been few reported studies regarding the analysis of marks on wafer and disc tumblers, especially in vehicle locks, and the subsequent determination of factors regarding the use of specific keys within a given lock. In this regard, there are at least three significant issues to be considered by the forensic technician, and for which an examination may be conducted:

- **Can a determination be made with regard to the last key that was used to operate the lock;**
- **Can it be ascertained specifically which were the most recent key or keys that were used to operate a given lock;**
- **A determination if other than the authorized key has been used to operate the lock, through an analysis of internal components and suspect keys.**

An analysis of locks used in automobiles will further require the evaluation of keyways; marks left on wafers, discs, and pins from authorized and unauthorized production of keys; and exposure of internal components to extreme heat, as may be encountered in a car fire. In this regard, the deposit of carbon residue and potential oxidation upon component surfaces must be considered as a potential artifact to a valid analysis.

26_1.5.5 Markings on Disc Tumbler Locks

Disc or wafer tumbler locks are found everywhere and are used in low to medium security applications. They are an inexpensive substitute for pin tumbler locks. See **Chapter 15**. All critical components (springs and tumblers) are self-contained. Locks can be configured as single, double, or triple bitted.

Disc tumbler locks are used in desks, cash drawers, money bags, alarm panels, key cases, access control, display cases, and hundreds of other applications. Because of their popularity,

they may be the focus of surreptitious bypass in burglary investigations or where covert penetration is suspected.

Disc or wafer tumbler mechanisms can be easily identified by the appearance of the wafers viewed from the front of the lock and by the relative diameter of the plug and shell. Wafers will appear flat, rather than rounded, when examined from the outside of the keyway. The diameter of the plug is large in relation to the diameter of the shell. Very little space is required above the plug in contrast to the pin tumbler lock that must have sufficient room for driver tumblers and springs.

An experienced lock picker can bypass these mechanisms in seconds, leaving little if any trace. Generally, keys will make marks on the bottoms of the wafers. Any scratches or marks on the sides of the wafers should be cause to suspect picking. Many varieties of disc tumbler locks are also utilized in automobiles, and will be discussed in the following section.

26_1.5.6 Markings on Sidebar Locks in Cars

Briggs and Stratton developed the original sidebar lock in 1935, for use in automobiles. They are essentially the same design today and have been copied in many forms of high-security locks. General Motors continues to utilize sidebar locks as do other manufacturers. There have been several keyway changes since the original mechanism was introduced in 1935. Today, the locks contain six discs with five depths: a “1” depth is a no cut and a “5” is the deepest.

They are difficult to pick but can be decoded and opened with special tools. They are often drilled; a small hole is made directly above the sidebar so that pressure can be exerted as each tumbler is raised to shear line. On certain sidebar locks, a borescope or ophthalmoscope may be used to read the depth coding number stamped on the face of each tumbler.

In the laboratory, key codes may be determined by disassembling the lock and examining each tumbler in the order installed. Remember that the combination of a sidebar lock can be easily changed or the lock removed and replaced. It may be wise to verify the code number of the lock as shipped from the factory with the vehicle in order to determine if it has been altered or replaced.

26_1.5.7 Markings on Dimple Pin Tumbler Locks

When certain dimple-style pin tumbler locks are impressioned, visible damage may be caused regardless of the method employed. This is especially true in the case of some of the high-security mechanisms that utilize telescoping pins or tumblers with extremely thin walls. Kaba and other locks employ such pins. They are easily warped, distorted, or crushed if too much torque is applied during the impressioning process. The reader is directed to **Chapter 30** and the **LSS+/^{x} CD/ROM** for a more detailed discussion of the techniques for impressioning these locks.

26_1.5.8 Markings on Axial (tubular) Cylinder Locks

Axial locks, such as Chicago Ace and Fort, are used primarily in vending and access control. They may be picked, impressioned, and decoded. For this reason, it may be useful to perform an analysis to determine surreptitious entry, although conclusive results may be difficult.

They are generally configured as cam locks, offering low to medium security. They are pin tumbler mechanisms with all pins positioned in a 360^{o} radius. The numbers of tumblers vary, generally from six to nine, and they may be exposed or recessed. High-security pins, including telescoping and mushroom, may be employed. The standard key measures .375" OD; the most common cross-reference blank is Taylor 137 or Ilco 1137S. Regardless of design, all axial pin tumbler locks will have one or more shear lines resembling conventional devices.

There are a number of different methods to open these locks, including conventional picking, decoding, impressioning, and manipulation with special pick tools. These locks may be forcibly opened using the HPC "**lock killer**" or special hole saw. Although normal pick tools may be used, the process can be awkward due to the difficulty in locating and securing a torque wrench in the keyway guide slot. An Allen wrench may be used as a tension tool, or a small hole may be drilled in the center of the lock for a tension tool to be screwed into the plug.

Conventional picking of axial locks requires several rotations to achieve one revolution of the plug. Also, the lock may be left in a partially picked state. This will provide direct and generally indisputable evidence of attempted bypass. It will also render the lock inaccessible for normal use because the key will be blocked from entry into the plug. The criminalist should be alert for such condition.

The preferred method of opening is to utilize one of the specially designed pick tools sold by HPC and other vendors. These are designed for specific locks, taking into account the number of tumblers, their spacing, diameter of the plug, and other characteristics. These tools generally have sliding steel shims embedded axially; their position to correspond with the pins. To open the lock, the tool is pressed against the tumbler, and with torque applied, rapidly inserted and withdrawn. The action resembles traditional impressioning: the tumblers bind until reaching shear line, and will cause movement of the shims. The advantage to using decoding/impressioning scheme is that once the lock is opened, a key may be generated directly from the tool.

One must be very cautious in drawing a conclusion that a lock has been bypassed or that an attempt has been made simply from the fact that the plug is rotated to a partially picked position. If the top guide-pin on the key has been removed, the key may be withdrawn in any position. See **Chapter 29** for a detailed description of picking these locks.

26_1.5.9 Markings on Abloy and Abus Disc Wafer Locks

Abus (German) and Abloy (Finnish) each manufacture high-security disc wafer locks that appear quite similar in their design. Disc wafers, resembling the wheel pack in a traditional combination lock, are rotated so that their gates are aligned, thereby allowing a sidebar to retract and the plug to turn. Each company produces a series of extremely popular cylinders and padlocks employing this design.

These locks can be decoded and opened using highly specialized tools. Evidence of such decoding can be quite pronounced in the form of scratches and gouges on the surface of discs and potentially on the spacers between the discs. See **Chapter 31** for detailed information on bypass of these locks.

26_2.0 Material Transfer and Residue

Trace materials found within locks may link tools, keys, suspects, and remote locations to crime scenes. They can provide valuable evidence that a bypass (or attempt) occurred, as well as techniques, expertise, and identity of perpetrators.

Transfer may occur between keys, bypass tools, or anything that has been inserted into the plug. Materials that may be deposited or produced will include dirt, lint, tobacco, clothing fiber, lubricant, cleaner, graphite, oil, grease, wax, metal foil, wood, and metal fragments. Trace elements may be left from tools inserted into the questioned lock after being transferred from other locks prior to bypass, or picked up from materials with which such tools came into contact. These may include carrying cases, pockets, toolboxes, and work areas.

26_2.1 Trace Evidence: Foreign Material in Plug

Materials found within locks may be significant, or they may simply have been deposited, created, or transferred through normal use. Trace materials and their possible origin and significance are listed below. Metal fragments or particles may be found within a plug, often on wards or other areas that are exposed to keys. Materials may also be found in recessed areas. It is important that a preliminary determination be made as to the probable means by which the material was created or transferred and if normal use of the lock could have caused such transference or creation.

Materials may be transferred, deposited, or created for a variety of reasons. The criminalist or investigator may therefore wish to eliminate as many causative factors as possible, especially since each may be potentially raised by a defendant to create reasonable doubt. These include:

- **Remnants of original manufacturing process;**
- **Normal use of the lock;**
- **Routine maintenance by a locksmith;**
- **Transferred from a newly cut key;**
- **Abnormal or unusual actions, circumstances, or conditions of authorized access person in handling or storage of keys;**
- **Random act of vandalism or sabotage;**
- **Intentional act of vandalism, sabotage, or planting of evidence;**
- **Earlier bypass attempt, undetected;**
- **Current bypass attempt;**
- **Bypass attempt by more than one perpetrator;**

- **External environmental conditions that may cause chemical or metallurgical changes within the lock, such as humidity, temperature, particulate matter in air, or unintentional introduction of chemicals into the lock or its proximity.**

26_2.2 Specific Trace Evidence and Causation

Following is a list of common materials that may be detected or found within a lock and their probable source, origin, or cause.

26_2.2.1 Maintenance and Transfer of Materials from other Locks

Lubricants and cleaners including graphite, WD-40, oil, grease, Cosmoline and gasoline.

26_2.2.2 Impressioning

Carbon, metal foil, cellophane tape, electrical tape, wax, plasticine, grease, type-correct solution (White-Out), nail polish, paper fragments, putty, Vaseline, soap, broken key or fragment thereof, broken key extractor, or parts.

26_2.2.3 Impressioning of Dimple Lock

Grease, wood fragments, metal foil, cellophane tape, and electrical tape.

26_2.2.4 Impressioning and Molding of Keys

Clay, silicone, epoxies.

26_2.2.5 Impressioning and Decoding of Locks

Plasticine, paint transfer on wards.

26_2.2.6 Recently Duplicated Key by Machine or by hand operated in the Lock

Brass filings on bottom of pins, oil.

26_2.2.7 Picking

Brass fragments or particles, steel or stainless steel fragments or particles, gun-blue material transfer, metal particles at bottom of plug, dissimilar metal fragments present in plug.

26_2.2.8 Vandalism, Interruption of Entry Attempt, Sabotage

Toothpicks, paper, glue, other foreign materials, broken key.

26_2.3 Contact between Bypass Tools and Lock Components

Two primary sources of evidence may be available to prove that bypass tools were used. Metal transfer to or from pick tools may occur, resulting from the interaction between sharp hard points on the tool and the relatively soft surfaces within the lock. It may be possible to retrieve and identify such metals, especially if completely dissimilar elements are present. For example, a spring steel pick tool may leave a trace on brass. Normally, steel would never be present, especially if it can be identified within pick tracks. Both spectral analysis and a scanning electron microscope may be employed to develop such evidence.

Difficulties regarding the presence and analysis of different metals to prove the introduction of bypass tools may be varied. They can raise many questions that should be anticipated in any defense. These would include:

- **What metals and alloys are present in the plug, shell, and tumblers;**
- **Are dissimilar metals incorporated within the lock, such as in chamber sleeves and security anti-drill pins;**
- **From what materials are the suspect bypass tools constructed;**
- **Can a positive match be made between bypass tool materials and metals found within the lock;**
- **Can a lock manufacturer and specific lock be identified from the materials transferred to bypass tools;**
- **Can foreign materials found within a lock be identified as to content and source.**

It may also be possible to match striations or irregularities in the tip of the pick tool on surfaces of impressioning tools or blanks, with corresponding marks on interior areas of the lock. There can be a great deal of pressure exerted on internal components during the impressioning process that may be transferred to the keyway or other areas of the plug. If available, they should be examined closely. Marks may be left on pins and chamber walls that can be matched under a scanning electron microscope or other high- magnification technique. Metal may also be transferred to tips of picks.

26_2.4 Use of Scanning Electron Microscope

LSS101: Scanning electron microscope Part I: Michael Platek

LSS101: Scanning electron microscope Part II: Michael Platek

LSS101: Scanning electron microscope Part III: Michael Platek

A scanning electron microscope (SEM) utilizes electron beams, rather than light and lenses to magnify objects. The author has utilized a Jeol 5900 for testing of locks and picking tools. This is one of the more sophisticated systems that is available, and allows the magnification of images up to 1000x. These systems also allow for the targeting and analysis of materials with respect to elemental content. As can be seen in the accompanying video, specific metal composition can be easily displayed.



Figure LSS+2616 A Jeol 5900 SEM system and a specimen container for placing a small amount of material in the chamber to be analyzed. This system is in operation at the University of Rhode Island Forensic Laboratory.

An SEM is especially useful in cases where non-destructive testing of materials is required. A sample can be analyzed without destroying the material, as is the case with other forms of testing. In addition, as can be seen in the photographs below, there are no depth of field issues as encountered with traditional microscopy. All areas are in focus, because light is not utilized as the source of illumination. Although a conventional microscope with a 10x-40x zoom will suffice for most forensic analysis of locks, the SEM can offer options not otherwise available in cases where an analysis of metal content is required, or extremely high resolution tool marks is needed.

An SEM may be employed in certain instances to make the following determinations:

- ***Identification of pick marks on pins, keyway, or chamber walls;***
- ***Identification of impressions or distortions on pins, wards, and keyway;***
- ***Identification of tool marks on keyway wards or plug walls, produced from blanks used during impressioning;***
- ***Presence and identification of dissimilar metals***

within the plug in order to prove entry of a specific key or bypass device. Such metals may include brass, nickel silver, steel, iron, aluminum, or alloys such as Avional, lead, and zamak. It should be noted that manufacturers will cease to use lead in the future due to environmental concerns. Thus, the presence of lead in a cylinder may provide additional identification criteria for certain keys;

- **Presence of metals used within a plug, shell, pin, or chamber sleeve upon a bypass tool or key in order to prove entrance by such tool or key;**
- **Tool marks on surface of pins, plug, or keyway that are produced from a specific bypass tool such as a pick;**
- **Introduction of a specific key into a lock, evidenced by tool marks produced on bottom pins.**

Additional sources of evidence of surreptitious entry may be developed and will depend upon many variables. These include lock design, metal content of components, keyway, methods of bypass, construction of tools, what metals are present in the tools, the physical shape of a tool, and the competence of the perpetrator.

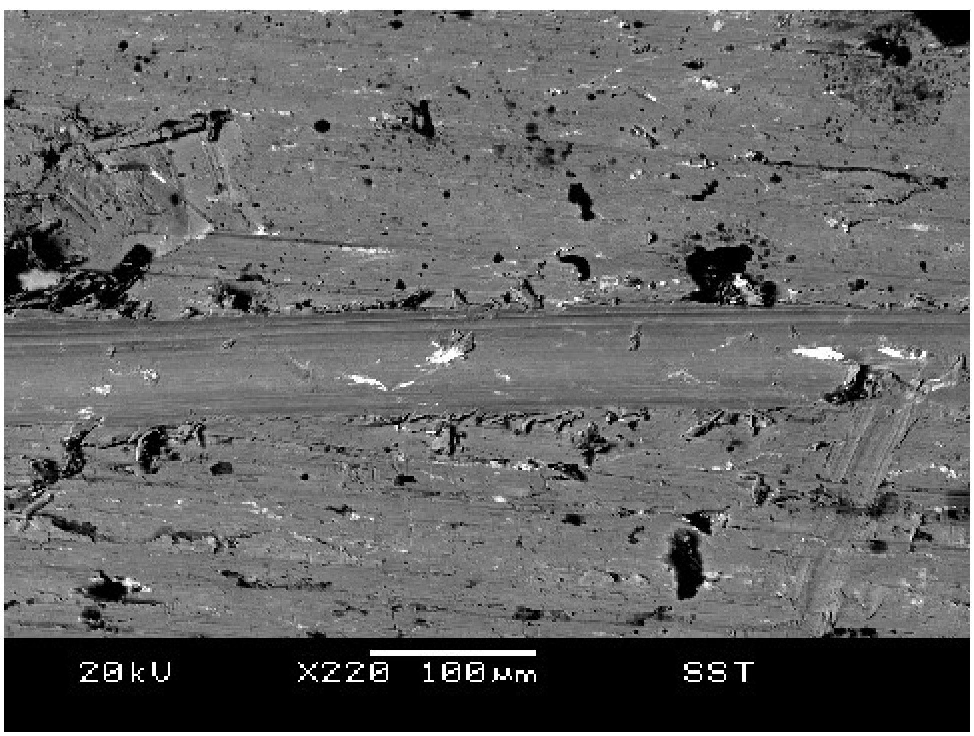


Figure LSS+2617 220X SEM photograph of lock, using backscatter, showing pick

track.

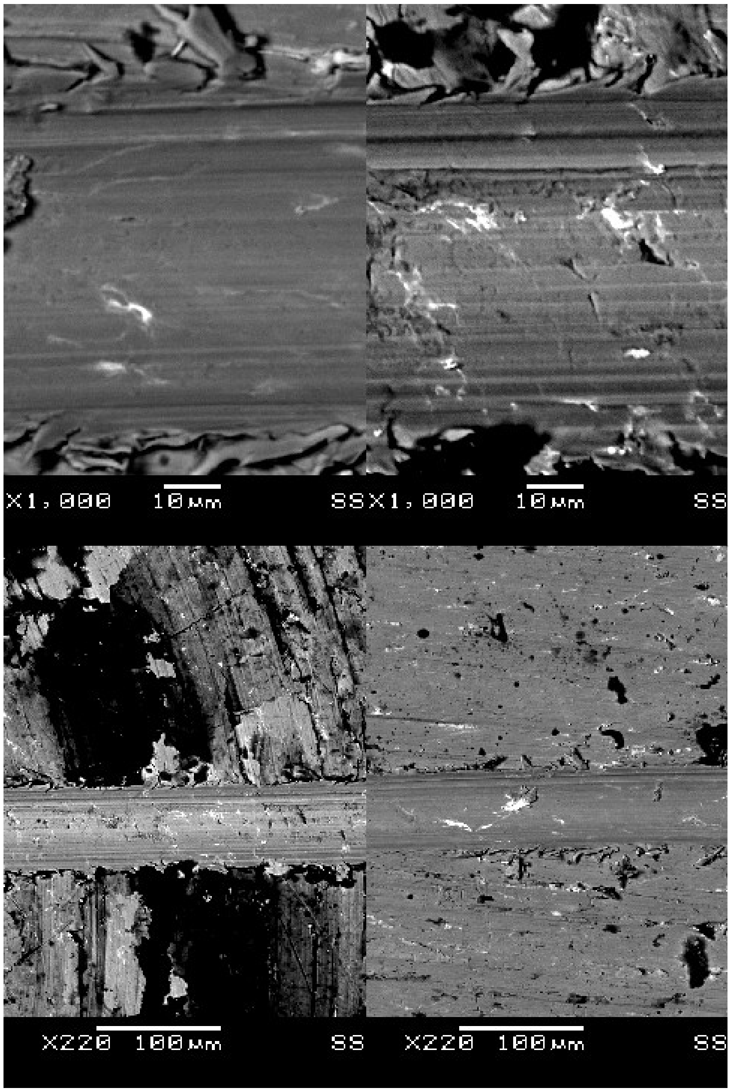


Figure LSS+2618 Composite photograph at 1000x (left) and 220x (right) of pick tracks on known sample and suspect lock. These marks were made by the same tool.

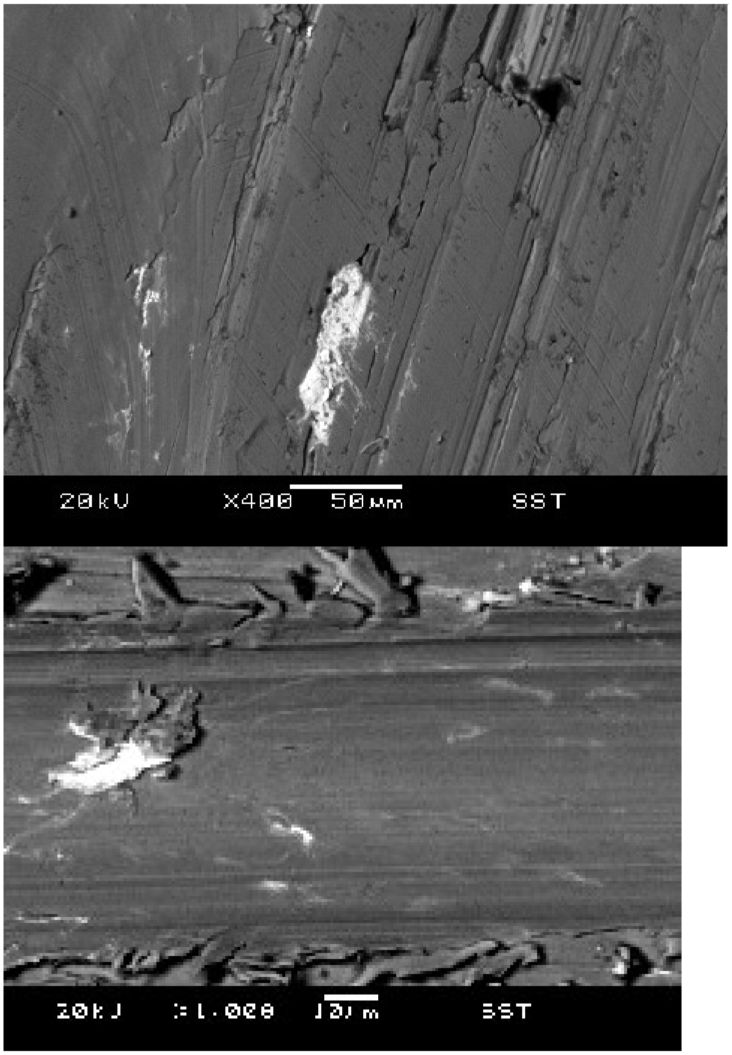


Figure LSS+2619 Photograph of internal surface at 400x and the same material at 1000x showing pick track.

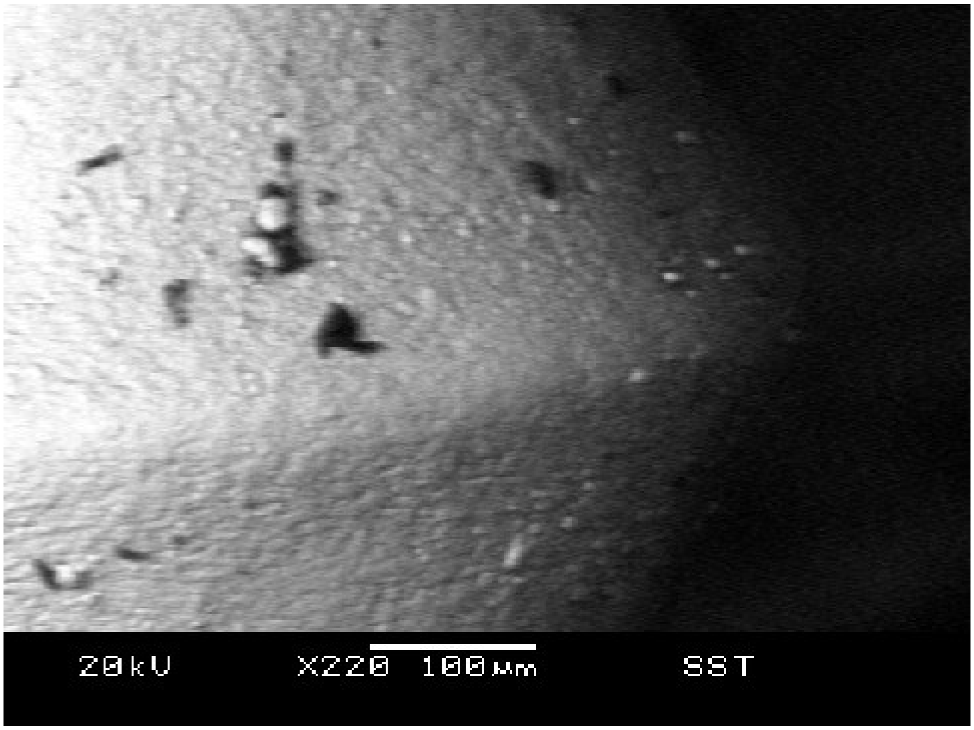
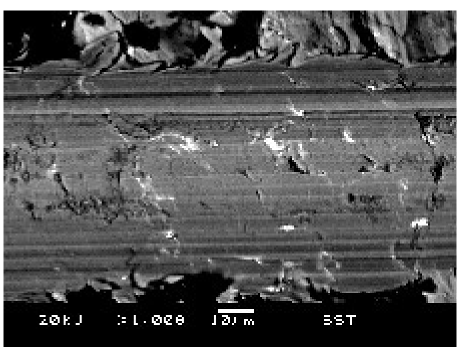


Figure LSS+2620 Photograph of the surface of the pick that produced the marks in all of the photographs, taken at 220x using backscatter. Note the curved surface. This pick was produced by acid etching of stainless steel.



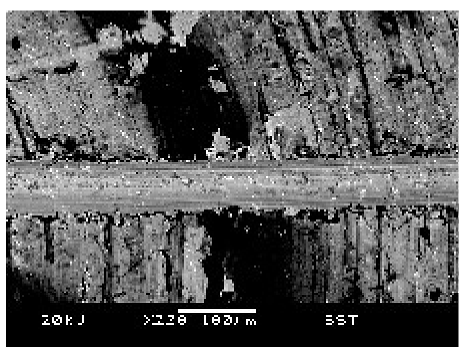


Figure LSS+2621 A photograph of a pick mark on a pin at 1000x (left) and 220x (right) using backscatter illumination.

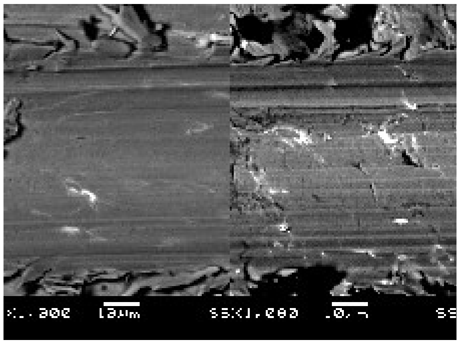


Figure LSS+22 Photograph of plug with pick marks and comparison with known sample made from the same pick.

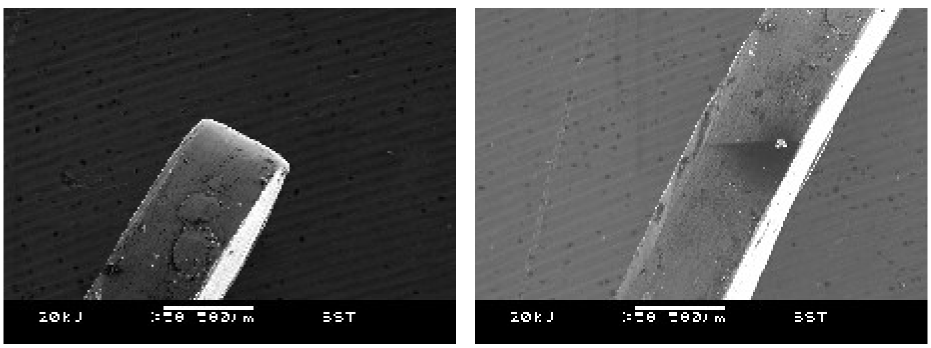


Figure LSS+2623 Photographs showing the surface of a pick at 50x using backscatter (left) and secondary illumination (right).

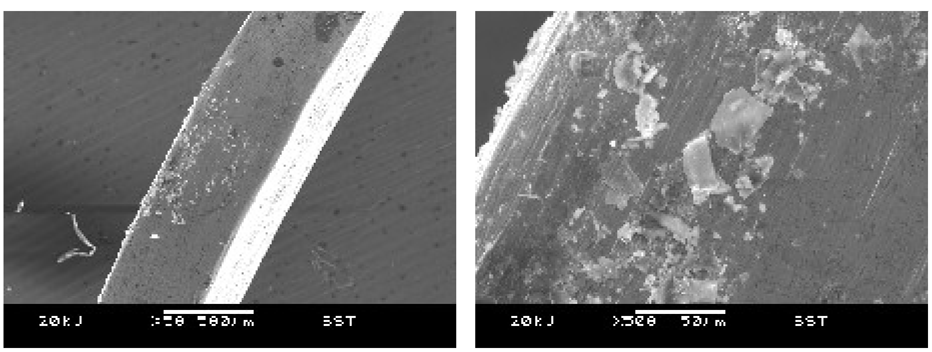


Figure LSS+2624 Photographs of pick at 50x (left) and 500x (right).

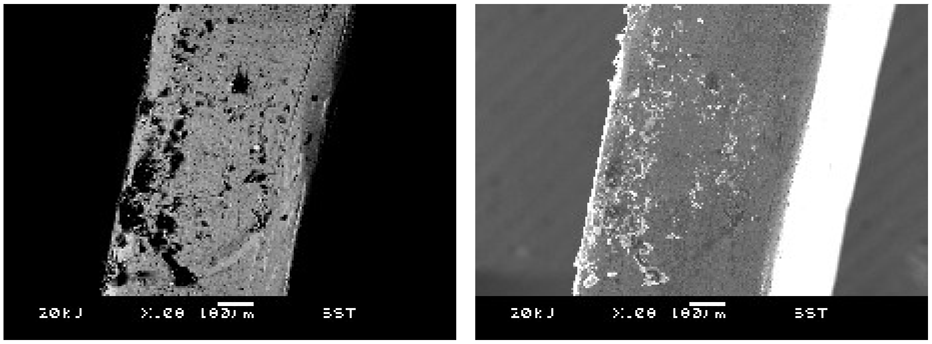


Figure LSS+2625 Photographs of surface of pick at 100x utilizing backscatter (left) and secondary (right) illumination.

26_2.4.1 SEM Issues Regarding Analysis of Pick Marks

There are a number of issues that will affect and control the ability to use a scanning electron microscope effectively, regarding the analysis of pick marks within a lock. These include:

- **Size and shape of the pick;**
- **Materials that the pick us made of;**
- **Materials that the plug are made of;**
- **Process used to produce pick: acid etch, stamping, grinding;**
- **Shape of pick and whether it is flat or rounded;**
- **Contact surface of the pick: curved, rake, ball, and how much contact with tumblers;**
- **How the pick us utilized: rake, individual pins, and possible obliteration of marks;**
- **Is it likely that the pick would rotate the tumblers;**
- **Skill of technician utilizing the pick;**
- **Amount of tension applied to the plug;**
- **Amount of upward pressure applied to the pick;**
- **Any aberrations on the pick surface;**
- **Any special coatings on metal within the plug or on the pins;**
- **Differing pattern of tumblers within the lock, which will control torque and necessity to apply pressure to each pin;**
- **How many times the pick contacted other surfaces;**
- **Skill of the technician in moving the pick vertically and horizontally across the pin surface;**

- **Special coating materials on the surface of the pick, such as teflon to diminish marking by bypass tools;**
- **Differs would affect number of passes required for picking;**
- **Use of mushroom or security tumblers;**
- **Use of master pins;**
- **Number of pins in the lock;**
- **Angle of attack of the picking tool, and whether that varies as the lock is picked;**
- **Whether the pick is utilized at 90 degrees or other angle, or the side of the pick makes contact with the pins;**
- **Geography of contact surface: flat, curved;**
- **Relative hardness of pick as opposed to pins or plug;**
- **Sharpness of point of contact of the pick;**
- **Prior lock picking attempts;**
- **Age of pins and wear patterns;**
- **Multiple techniques utilized on the same pins: raking, picking, snap gun;**
- **Have marks of different technique obliterated other markings;**

26_2.4.2 Issues Regarding Metal Transfer

There are several critical issues that will affect whether metal particles will transfer between the target lock and suspect pick tool. The issue becomes one of matching the specific characteristics of metal from an individual plugs and whether this can be isolated to one sample, or is generic to a type of brass form which most locks are constructed. Significant testing is required to determine if differentiation between locks could occur.

Although the likelihood of metal transfer is high between the lock and tool, the problem becomes whether the metal will remain on the pick surface long enough to be present for analysis. This is affected by the type of metal from which the tool is constructed, how it was stored, the amount and type of contact between the tool and internal components, and the geometry of the tool surface. Normally, one would expect fragments to be deposited on the pick. This is especially true in the case of a vibrating pick. Also, there may be metal fragments outside of the lock that can be matched to the pick tool.

Additional issues include:

- **Size of pick and type of contact surface: curved, rake, ball, diamond;**
- **Metal and polish;**
- **Relative hardness of the two metals;**
- **Whether metal fragments were deposited on the face of the pick;**
- **Whether there is any oil or grease which would retain fragments**
- **Pressure applied on the pick during bypass attempt;**
- **Angle of attack, digging out material from the plug;**
- **Would it be expected that material from the pick would be deposited on the plug;**
- **How the tool is stored;**
- **How the tool was carried;**
- **Was the tool wiped clean, either intentionally, or based upon how it was stored or carried;**
- **Is there a nickel or other coating or plating on the plug or the lock;**
- **Is there the possibility of plating deposits being left on the tool that transferred from the lock;**
- **Is there a potential of paint or dye transfer from pins to the surface of the pick;**
- **Is there lead or other foreign substances deposited on the pick from the lock, based upon irregularities in the manufacturing process;**

Use of a scanning electron microscope (SEM). Courtesy of Hans Mejlshede.

CHAPTER TWENTY-SEVEN: ANALYSIS OF KEYS

Forensic Examination: Keys

Master Exhibit Summary

Figure 27-4 Tool marks from tracing stylus
Figure 27-5 Speed and design of cutting wheel
Figure 27-6 The bitting of a key can be disguised
Figure LSS+2701 Schlage 922 wafer lock diagram and photograph
Figure LSS+2702 A milled blank is made to fit a restricted keyway

Bypass of a Schlage 922 series wafer lock. Courtesy of Don Shiles.

Metal filings at the scene of a safe burglary. Courtesy of Don Shiles.

Investigations may require a determination of whether a key has been copied. Courtesy of Hans Mejlshede.

Marks from key duplication. Courtesy of Don Shiles.

27_1.0 Introduction

Keys can provide extremely valuable and complex information about suspects, perpetrators, victims, connected locations, how they were cut, and the locks they fit. The criminalist or investigator may be called upon to conduct a forensic analysis of locks and keys for many reasons. These are classified according to primary information that can be developed and are discussed in detail throughout the chapter. The following checklist provides an outline of issues.

Keys and how they were Cut

- **Determine if keys have been recently cut;**
- **Determine if a key was cut by hand or machine;**
- **Determine if a key is a factory original or duplicate;**
- **Determine if a key has been copied;**
- **Evidence that a specific key machine produced a given key;**
- **Evidence that a generic type of key machine produced a given key.**

Keys and Tool Marks

- **Determine if a specific key could have been used, based upon tool marks within a lock;**
- **Determine if a duplicate key was used to enter a**

lock;

- Determine if a key opened a specific lock;
- Determine if a key was used to impression a lock;
- Identify metal transfer between key and lock;
- Identification of stamped letters, numbers, or logos on face of key;
- Identification of key used as abrasive on other materials;
- Identification of key as causing marks on other materials.

Identification of Locks, Keys, Suspects, Victims, Locations, Vehicles, and Property

- Identification of victims from keys;
- Identification of co-conspirators from keys in their possession or from common locks that they fit;
- Identification of possible suspects for a certain crime from keys in their possession;
- Location and identification of contraband, stolen property, evidence, or fruits of a crime;
- Tracing keys to specific locks;
- Matching suspects and keys with specific locations;
- Matching a key to a lock;
- Identification of illegally possessed keys;
- Identification of vehicles;
- Tracing and identification of locks;
- Identification and recognition of disguised keys;
- Identification of universal keys;
- Identification of foreign material on key to a lock;
- Trace unique, old, or rare blanks to vendor;
- Identification of metals transferred between suspect key and key ring or other materials with which the key came into contact;
- Identification of fingerprints, oil, blood, tobacco, paper, cardboard, paint, dirt, lint, fiber, hair, metal filings, salt, airborne particulate or other foreign substance on key surfaces with which the key or its bearer may have come into contact.

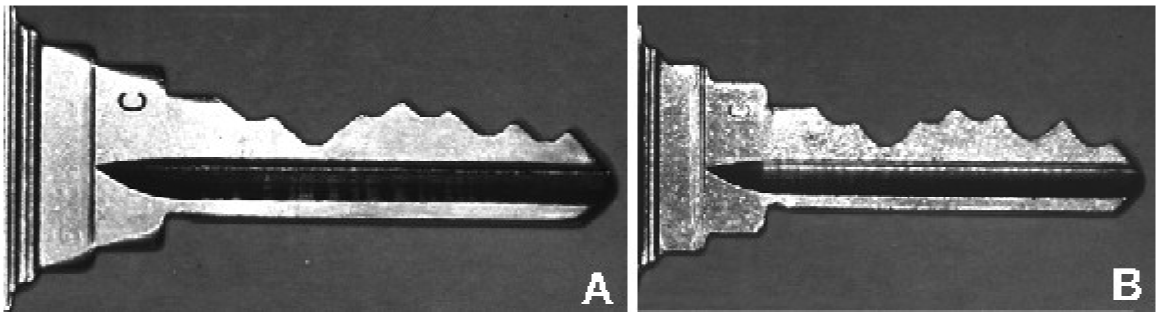
27_2.0 Keys and How They were Cut

In certain investigations, it may be important to know how keys were cut and to identify the cutting machine that produced the suspect key. Certain preliminary questions arise which follow:

27_2.1 Preliminary Questions

- **Is the key hand cut, machine cut, or stamped code cut;**
- **Is the key a duplicate or factory original;**
- **Are there sharp cuts on the key;**
- **Does it appear as if the bitting surface of the key would cause marking on lower pins;**
- **What are the ramp angles for each cut. Do they appear to follow industry guidelines as detailed elsewhere in this text;**
- **Are there steep cuts with sharp peaks, indicating that the key may have been cut by hand;**
- **Is each cut centered in the proper position directly under each tumbler. If not, hand cutting may be indicated. The key may also have been cut by hand during the impressioning process. Often, keys produced by impression will be irregular with respect to the center-to-center spacing between cuts and the width of each cut. Generally, a round file is used, often resulting in adjacent cut overlap;**
- **Was a factory original, original duplicate, or improperly obtained or produced duplicate used to open the lock;**
- **Are there scratches, shiny spots, or sharp edges on the key. This will generally indicate a recent duplicate;**
- **From what metal was the key produced;**
- **Is the key produced on a knockoff or original blank. Although a factory- original logo may appear on the key head, this may not be dispositive that the blank actually was manufactured by the vendor owning the logo. The author has seen many cases of counterfeit blanks that copied trademarked logos as part of the design;**

- **Is there any evidence as to the type of cutting wheel that was used to cut the key;**
- **Is there any data available as to what the factory used to cut original keys at the time the lock was shipped;**
- **Does it appear that the key was cut by code, or simply duplicated from another key.**



27_2.2 Manufacturing Process

It is useful to understand how key blanks are initially produced, cut, and identified by a typical manufacturer. The subject is also examined in **Chapter 8**. Keys and most domestic cylinders are usually made of #58 brass with up to a 99% content. Nickel silver, aluminum, Avional, and steel are also used. Brass is probably the most popular metal for wafer and pin tumbler locks because it is inexpensive and self-lubricating for longer life. Plastic polymers and other composite materials will become more prevalent in the future.

Nickel silver is favored for the more expensive locks in order to achieve high tolerance and security. The advantage is strength and hardness. Because it is a dissimilar metal to brass, it will experience less wear when used in conjunction with a brass plug. Some manufacturers use aluminum or an alloy of aluminum such as Avional (Silca). Avional is stronger and lighter than brass. Iron or soft steel that is cold-pressed and forged is also popular. Zamak, for poor quality locks such as mailboxes, is also used.

In the manufacturing process, keys are cut or stamped from strips of material with dies. They are then plated. In the future, the author believes that keys will be produced on small milling machines controlled by computers. Maintaining an inventory of thousands of blanks for each keyway and lock will be outdated.

Locksmiths will simply insert a piece of special composite material into the mill, enter the keyway design or optically scan a keyway, and the computer-controlled mill will produce the proper blank.

Factory cutters produce striations on OEM keys that are different than those on keys cut at the local hardware store. Cutting wheels are either single or dual sided. Angled cutters are also used for certain locks such as Medeco. End-mills and special drills are also utilized to cut certain keys, such as laser track.

An analysis of tool marks may identify:

- **How keys were cut;**
- **That a specific key machine cut a suspect key;**
- **That a key was cut by hand, by code punch, by manually operated key machine, or by an automated key-cutting system;**
- **That a certain key was inserted into a specific lock.**

Striations left by a cutter may remain for a very long time, depending upon the above- noted factors. See the discussion below for methods of identification. Striations may differ on the bitting surface of a key depending upon the following factors:

- **Whether the key is single or double-bitted;**
- **Number of active rows of tumblers;**
- **Position of the bitting on the key;**
- **Relative smoothness of the pins;**
- **Force exerted by the springs;**
- **Frequency of use of the key.**

27_3.1 Identification of Locks, Keys, Suspects, Victims, Locations, Vehicles, and Property

Keys, and the information they may provide, can be used in the identification of locks, suspects, victims, locations, vehicles, and property. Often, keys may be found on victims or suspects, at crime scenes, in vehicles, during the course of a search, or

in relation to other apparently non-connected cases. In each of these scenarios, a key may provide valuable leads. Sometimes, it is important to trace a specific lock from a recovered key. It may be necessary to know what type of lock the key fits, if it is a unique lock, and if the factory can provide any detailed information about its owner.

Perhaps a key is found on a suspect that might fit a storage locker. Information derived from that key may help identify a particular installation, which in turn will lead to its location. Keys for locks used in special industry applications should be viewed as suspicious when found on suspects or at crime scenes. Although these locks are prevalent in many industries, their keys are still relatively rare. Keys for the following applications should cause additional inquiry:

- **Banking;**
- **High-security safe and vault change-keys or long profile key;**
- **High-security lever lock keys;**
- **Mail and postal;**
- **Safe-deposit;**
- **Public locker;•High-security padlock (Chubb, Abus, Abloy);**
- **Vending (Ace, tubular, Tubar, axial keyways);**
- **Alarm control;**
- **Telephone;**
- **Secure key control and storage (real estate, automotive, and building lock boxes);**
- **Hotel dual-access or bypass (such as VingCard and Winfield);**
- **High-security (Medeco, Abloy, Assa, Evva, Schlage, DOM, Ikon, Mul-T-Lock, Sargent Keso).**

Many agencies maintain a criminal association and terrorist index to match keys to locks, suspects, location, and offense through the following criteria:

- **Lock manufacturer;**
- **Keyway type;**
- **Generic mechanism type;**
- **Code numbers;**

- **Keys that fit particular locks, especially those of victim;**
- **Evidence of replacement of lock;**
- **Broken key identification and match by:**
  - **Keyway;**
  - **Analysis of sections;**
  - **Code numbers;**
  - **Markings, logos, and other identifiers.**

27_3.2 Queries Regarding Identification

The following lines of inquiry will assist in the match of a key to its lock:

27_3.2.1 Basic Key Design

- **What type of locking mechanism does the key fit: warded, wafer, lever, pin tumbler, hybrid, or axial;**

- **Is the key single, double, triple, or quad-bitted. Is a special technology employed, such as rotating tumbler (Medeco), sidebar, laser track, magnetic, infrared, induction, or transponder;**

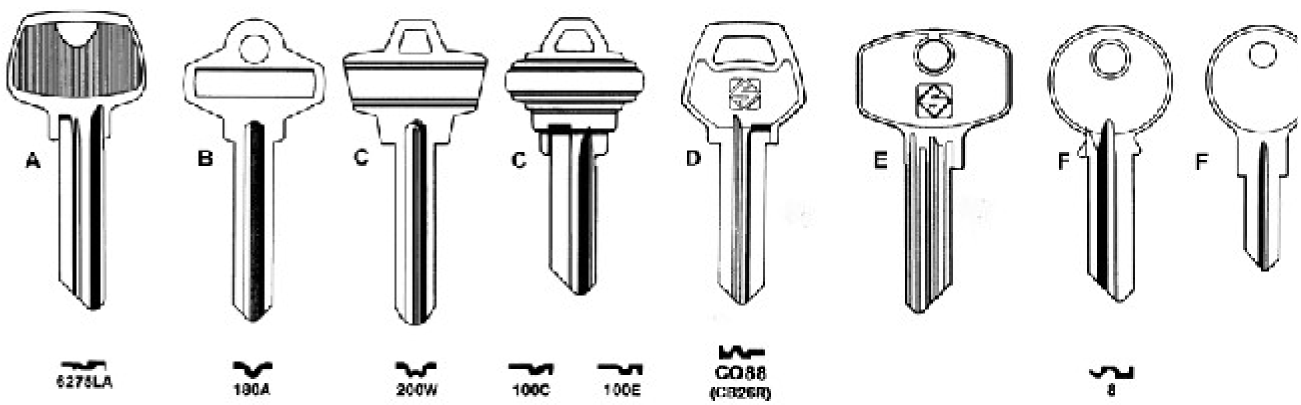
- **Does the blank number identify a particular lock;**

- **Has the derivation of all stamped numbers on blanks been obtained, including blank identification, code numbers, and internal numbers.**

If it is a steel flat key for use in padlocks, letter boxes, lockers, cash boxes, cabinet locks, lever locks, or safe-deposit locks, they are quite easy to duplicate, leaving little evidence to trace their origin. Blanks not intended for the suspect lock can be modified to work by cutting to size. A flat piece of metal may suffice. The length must be correct, the thickness and height close to the original. Generally, a 6” warding file can be used to cut these keys. An analysis of metal filings embedded in files or cutting wheels, if seized as the cutting instrument, may be helpful.

27_3.2.2 Lock Manufacturer

- **Who manufactured the lock. Does a specific manufacturer popular in the geographic area produce locks. Are the locks available. If so, from whom. Have many manufacturers produced locks of the same keyway. Does the key head provide any information, such as the lock manufacturer and keyway identification.**



In the above illustration (Figure 6-10), the key heads of different manufacturers are shown.

27_3.2.3 Key Blank Manufacturer

Certain vendors may carry OEM blanks for lock manufacturers. Thus, Silca produces original blanks for Medeco and many other lock producers. The blank manufacturer may point to the local vendor.

- **Who manufactured the blank. Generally, a manufacturer will stamp an identifying number on each blank, as well as offering a distinctive key head or logo;**

- **How many tumblers are in the lock for which the key fits. Is the lock turned to the left or right to open. Wear may increase in one direction;**

- **Was the key recently duplicated, determined from the wear on the serrations caused by the cutting**

wheel of the key machine.

This information may be derived based upon measurement of the suspect key against a factory original. This analysis may be difficult, but is possible.

Keys can also be evaluated to determine if they are cut following factory-established depth coding and spacing. This can serve to identify the key to a given manufacturer by looking up the difference between depths and consulting an HPC or Silca reference table. This information will also indicate if the key was code cut by machine originally, or by hand, and if the lock was pinned to factory standards. Perhaps a locksmith altered the pin-stack during rekeying. The ramp and valley angles for each cut can also be evaluated. This will provide strong indication of hand cutting, and may lead to the conclusion that the key was produced by taking the lock apart and cutting individually for each pin position.

Certain keys, especially for storage lockers, are very distinctive. American Locker, for example, has utilized a standard lock for at least forty years that is a hybrid conventional pin tumbler and axial mechanism. Guardian, Illinois, Chicago, and DuoLock are likewise very easy to identify.

27_3.2.4 Mechanism

- **What kind of lock does the key fit in terms of generic mechanism: warded, wafer, lever, or pin tumbler. How would the lock most likely be used: door, drawer, file cabinet, access control, padlock;**
- **Could the lock be an interchangeable type, such as Best removable core;**
- **Does the lock utilize a unique mechanism or principle of operation, such as a sidebar, rotating disc, dimple, or programmable function;**
- **Is the keyway special or unique.**

27_3.2.5 Keyway

- **How common is the keyway. When was it introduced, and by whom. Are there knockoff keyways. How old**

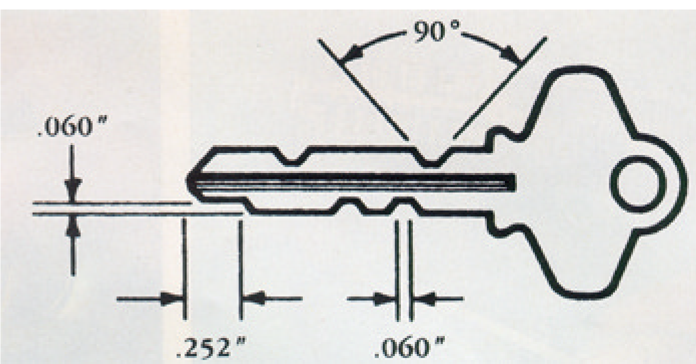
might the lock be;

- What is the potential number of keys that might be in existence, based upon the age and popularity of the lock, the number of pins, and total available depths (differs);

- Is a special keyway utilized. Is it restricted. What is the availability of blanks and key cutters for the keyway. Can any locksmith, hardware store, or vendor reproduce keys. If a restricted keyway, is it registered to a specific user, locksmith, or geographic area. If a special cutter, die, or procedure is required, who has that capability in a given area. This is especially relevant in the case of dimple, laser track, and sidebar keys that require special cutters;

Perhaps a key can be traced back to a specific locksmith in an area who sells very old series of locks. For example, the Schlage series 922 is fifty years old, but there are still millions in service. This is a very distinctive key, but not all locksmiths support the lock.

Bypass of a Schlage 922 series wafer lock. Courtesy of Don Shiles.



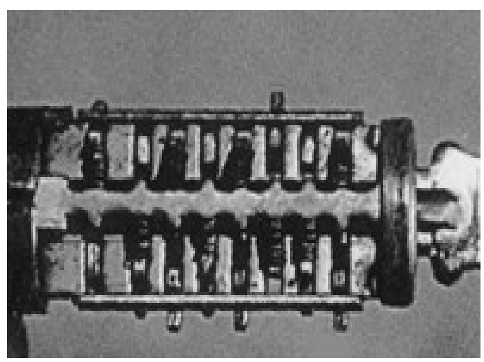


Figure LSS+2701 A Schlage 922 key is distinguished by its pattern of "cuts" and "no cuts." The lock utilizes a series of wafers of three different configurations.

Many shops will be able to identify locations where certain locks are used. They may also provide leads as to who may still stock such blanks. Certain locks are primarily used in business applications, such as Medeco, ASSA, Schlage Primus, and Sargent

Keso. Restricted use may provide a lead as to who services such locks.

27_3.2.6 Stamping on Key Head

- **Are there any letters, numbers, or warnings on the key head, such as "do not duplicate." If so, a check of locksmiths may identify where the key was cut.**

27_3.2.7 Key Code

- **Are numbers stamped on the key. If not, once the manufacturer and keyway is determined, an HPC or SILCA reference can be consulted to derive the direct coding for a particular key. That code can be given to the manufacturer, who may be able to determine who purchased the lock.**

Equally important, the direct code for any given lock can be determined and matched to a suspect key. If a burglary occurred at a given location and the keys to a specific lock were taken or cannot be located, then the lock can be disassembled and a key produced and entered into a database by code number.

If the lock utilizes a restricted keyway and the key still has factory-original coding, a manufacturer may be able to determine who the lock was sold to, in what system it is used, and other valuable information. This also applies to safes that are furnished with factory set codes. The following example is illustrative.

In one homicide investigation in which the author was involved, a wall safe was found at the victim's residence. The make and model was determined, and the factory was consulted. The preset combination was obtained that opened the lock. Use of factory-default numbers indicated that the safe had been recently replaced. The factory was able to advise that that model safe had been shipped to the victim's address. It was determined that the perpetrators had killed their victim, then burglarized the original safe, removed it, and replaced it with a new one, not bothering to change the factory combination.

27_3.3 Copy or Original

It may become relevant to determine if a key is a factory original or a copy. In certain instances, it may be equally important to learn if an original key has been copied. In one case, the author examined evidence involving the theft of Mercedes automobiles from rental car agencies. It was important to learn if the car rental keys had been copied in order to facilitate the thefts.

Investigations may require a determination of whether a key has been copied. Courtesy of Hans Mejlshede.

In that case, the original keys were examined for tool marks on the laser track surfaces for evidence of an automated key machine stylus moving across copied areas.

Key-cutting machines, as discussed in **Chapter 8**, will have certain unique characteristics. Each will have slightly different tolerances and tolerance errors in the duplication process. These errors may help identify a specific key machine as having produced a suspect key. Initial criteria to consider in making a determination if a key is a factory original or duplicate include:

- **Was the key produced on a factory-original blank;**
- **Is there easy availability of original key blanks used to produce a duplicate;**
- **Are original keys routinely supplied by the manufacturer, or are the locks keyed in the field;**
- **Does the manufacturer plate factory-original keys. If so, does the plating occur before or after the key is cut. If any remnants of plating are found on the bitting, the key is a factory original. Check the back slope of the bitting surface for such indication, especially on the cut closest to the bow;**
- **What characteristics of surface texture are present in the bitting surface. Of particular interest to the examiner will be the roughness or primary texture of this area. Texture is defined as the number of peaks per unit length and their average height. The examiner will see this as perpendicular striae running along the longitudinal axis of the bitting. Production processes, defined below, will**

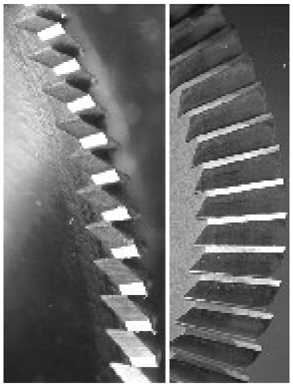
be closely related to the degree of roughness and visible striae.

Relevant production processes affecting key cutter characteristics and bitting striae will include:

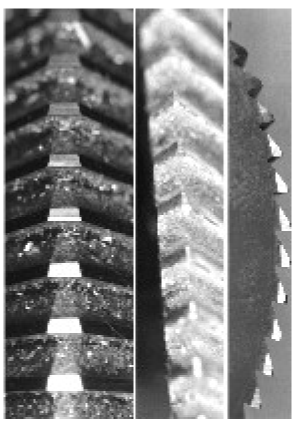
- **Machining operations;**
- **Production rate and quantity;**
- **Quality control;**
- **Cooling and lubricating during cutting;**
- **Movement of the key in relation to the cutting tool;**
- **Method of clamping the key;**
- **Positive or negative vertical cutting error;**
- **Skewed copying;**
- **Error in clamping angle;**
- **Broken or missing teeth in cutting wheel;**
- **Number of teeth in the mill cutter or cutting wheel per centimeter;**
- **Diameter of the cutting wheel;**
- **Alignment of guide;**
- **Speed of travel of the key;**
- **RPM of the driving motor for the cutting wheel;**
- **New or old cutting wheel and sharpness of cuts;**
- **Loose or unstable cutting wheel.**

27_3.3.1 Examination of Striae to Determine if Original or Duplicate

Examination of bitting surface will focus on the striae left by the cutting mill. Such striae will be directly related to the diameter of the wheel and teeth per centimeter. Assuming constant cutting speed and feed rate, a large diameter will result in higher cutting speed, and a greater number of “peaks” produced for a given area, or a finer resolution between cuts (less peak center-to-center distance).



The more teeth on the wheel, the less material will be removed by each during the cutting process. This will result in shorter amplitude for each peak. The result: there will be a finer cut pattern in the factory original key. If the examiner has a known factory original key to compare with the questioned duplicate, the determination can be made easily.



If a suspect key machine is examined, it is important to determine tolerances maintained during the cutting process. Silca, a leader in key machine manufacture, will maintain a minimum tolerance of .0075-.003”. A .02 mm variance per copy is acceptable. Silca will adhere to a tolerance of .001-.003” in producing blanks. Silca key machines can run ten generations before keys will fail to operate a lock.



Wear statistics for a given key and lock is very difficult to determine for many reasons. Wear will depend upon:

- **Metal used to produce the key;**
- **Material used in the plug;**
- **If the metals used in the key and plug are the same;**
- **Precision with which the blank was manufactured;**
- **How well the key fits in the lock;**
- **Whether there are foreign materials in the plug;**
- **If the lock is regularly lubricated;**
- **If the pin-stack opens precisely at shear line;**
- **How much torque is required to turn the key;**
- **The individual habits of the users of keys;**
- **Spring bias on each tumbler.**

Critical information to determine in such evaluations will include the following:

- **Does the key (or copy) appear to be handmade or machine cut. Good indication that the original was code cut, or produced by machine, is the accuracy of the depth of each cut corresponding to manufacturers specifications, the centering of cuts, and their shape. Indications that a key was cut by hand include irregular angles, too steep angles, multiple angles (such as two vertical ramps of differing angles), and differing widths of cuts. A hand cut key may be difficult to insert, remove, or operate in a lock, because ramp angles are too sharp.**

- **Are there stylus marks running laterally across the surface of the key, essentially in a straight line. Such markings will be present when automatic feed machines are utilized. A tracing stylus may be required when cutting high-security keys;**

- **Examine the key to determine how it was cut. By**

doing so, it may also be possible to extrapolate wear patterns on the bottom set of tumblers and whether a suspect key might have created them. This may be especially relevant where keys have jagged or sharp edges that may mark bottom tumblers;

- **Can an assessment be made as to whether the key has been recently duplicated and if the key is in fact an original, or a duplicate, or a duplicate original generated by code. Looking at two keys, it is always a question as to which was copied from which. This can be determined through precise measurements to determine subtle changes in ramp angles caused by errors in the accuracy of the tracing guide;**

Marks from key duplication. Courtesy of Don Shiles.

- **Are there clamp marks or distortions on the suspect key. Depending upon the location of such marks, this would indicate duplication rather than hand copying. An analysis of such marks may lead to a match between a key machine clamp, vice, or other securing device;**

- **Was the key burnished with a wire brush. This generally indicates machine cutting;**

- **Is the key an inexpensive knockoff, factory original blank, or blank produced by a licensed or high-quality vendor. Silca, for example, produces superior blanks, both as factory originals for certain lock makers, and as an individual blank alternate source for many locks throughout the world. Silca may, for example, produce slightly thinner blanks for certain locks, in order to insure a proper fit in the keyway. In contrast, cheap knockoff blanks, such as may be produced in Taiwan, China, and other Asian factories, will maintain poor tolerances, have profile errors, use more lead, and cause misalignment between blank and keyway. If a vendor does not maintain precise tolerances for its key blanks, then there may also be a greater possibility that the blank will score the sides of**

the plug when inserted, especially during impressioning. It is also more likely to break under the stress of normal use or impressioning.

- **Does the cutting machine use a single angled cutting wheel, or "V" angle;**

- **Do cuts appear to be made straight into the valleys of the key, thereby forming both sides and the ramp angles. This indicates factory code cutting;**

- **Has a key been simulated to meet depth and spacing requirements from metal, plastic, or other material. Remember, keys may be made to look quite different than the actual profile that fits a given lock. In the Falle variable key system, for example, keys are made from acid-etched stainless steel having only a few thousandths of an inch thickness. They may resemble the original key in depth and spacing only; there will be no keyway. These types of keys must be jiggled within the lock to work; they cannot simply be inserted as with a normal key. Remember that peaks, valleys, and ramp angles may all be altered, so that the key appears differently. If this is suspected, correct depth and spacing can be determined for a specific lock and the key evaluated against this criteria.**

- **What material was used to produce the blank: brass, steel, nickel silver, aluminum, or an aluminum alloy. Some manufacturers, such as Silca, have developed their own special metal alloys. If these can be identified, then so can the manufacturer;**

- **Does it appear that there is a tracing error on the suspect key. If there is a misalignment on the key machine between the tracing guide and the cutting wheel, then all cuts will be off by a certain dimension. It may be possible to determine if such an error has occurred and match such error with a suspect machine;**

- **Was there an alignment error in the way the original key was secured in the key machine that would either create an upward or downward angle in the copy. If the source key is clamped in the guide track improperly or there is an alignment error in the machine, then cuts will be stair-stepped, either up or down on the duplicate. This would result in a poorly fitting key;**

- **Is it possible to determine how many generations of keys have preceded the suspect key from the factory original. Are ramp angles or peaks wider, more rounded, less distinct, or disfigured. This would indicate several generations. Some key blank manufacturers have sophisticated equipment to read keys, regardless of generation, and produce a first-generation original. Silca, for example, has equipment that will laser-read a key, then correct any errors when generating a new one. These services would be available, if necessary from Silca.**

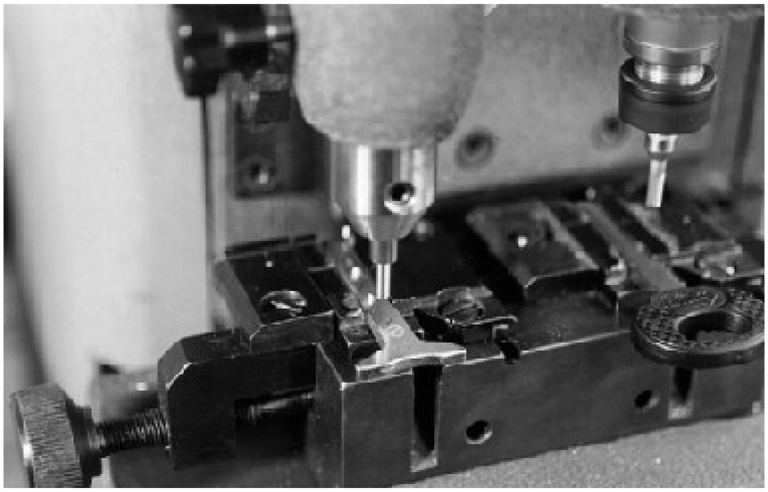
- **What is the surface appearance and texture of cuts. Depending upon whether an automatic or manual cutter was used, the surface at each cut may appear even or uneven. If a manually operated key machine made a duplicate, there is more likelihood of unevenness in cutting pattern on the bitting. This requires a comparison of the entire bitting surface, evaluating each tumbler position against all others.**

- **Can it be determined when metal plating of the key occurred. Sometimes keys are cut and then plated by the original manufacturer. Blanks, of course, are plated prior to the bitting being cut;**

- **Did the operator of the key machine align the two blanks correctly prior to cutting;**

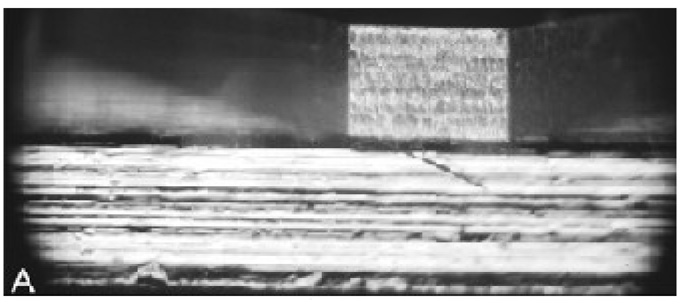
- **Do cuts appear smooth. If so, this would indicate a high RPM rotational speed of the cutting wheel and code cutting of the key. Silca, for example, cuts factory keys by code at 2200 RPM, in contrast with a**

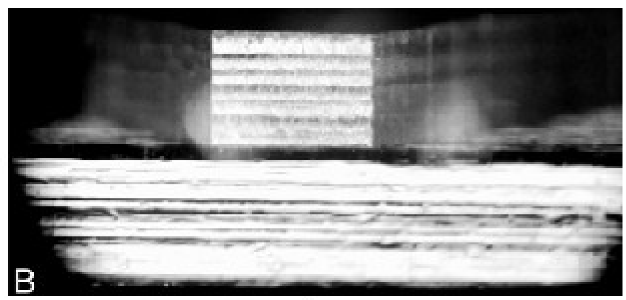
normal speed of around 800 RPM for conventional key machines used for cutting brass keys.

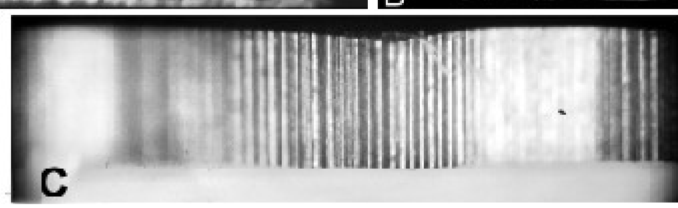










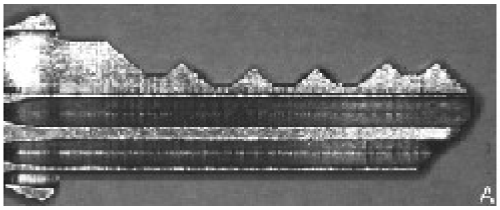


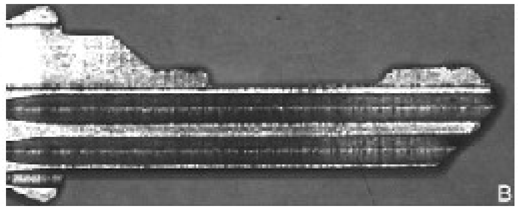
27_3.4 Keys: Substance over Form

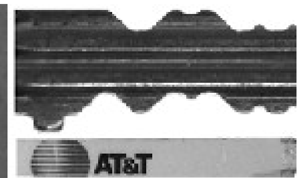
A working key is composed of four essential elements: keyway, bitting, depths, and spacing. **The correct simulation of these four elements will open a lock.** It is thus imperative that whenever keys are evaluated, substance must take precedence over form. That is, what the key looks like may not be as important as what the key does, functionally.

A key may not appear at all like the factory original. Keys can be made of any material, including metal, wax, metal foil, epoxy, thin stainless steel that has been specially cut or acid-etched,

wood, plastic, or clay.

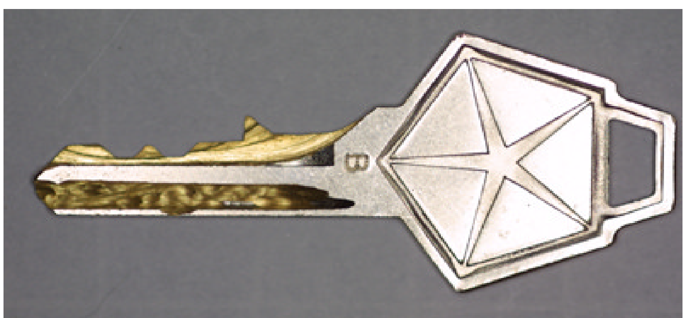
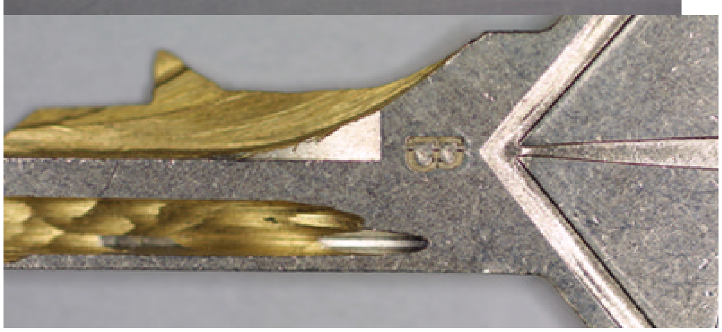


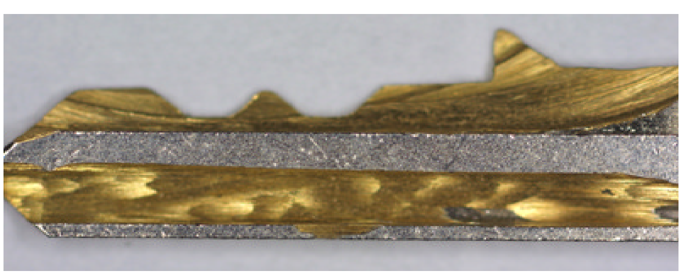




Exploded view.

Keys may have no distinguishable valleys or ramps. The position of valleys may be changed, causing the tumblers to ride on ramps. Extra cuts may be interspersed on ramps, making the key appear more complex than it actually is. There may be more cuts than there are tumblers within the lock. Cut order may be altered: there may be six cuts on a key, but only the first or last five are active. The keyway milling may be altered or a different sectional keyway may have been used.



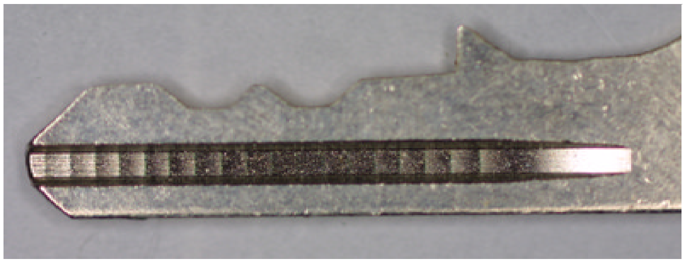


Figure LSS+2702 A Chrysler blank has been milled to fit a keyway on wafer locks that are used on hundreds of computers within a banking center. This altered key will open every computer in the system. Security officers were unaware of the problem.

27_4.0 Case Explanation from Beginning of Chapter 24

At the beginning of **Chapter 24**, seven relatively simple cases were presented. These demonstrate the diverse problems and evidence that may be encountered during the course of an investigation, where locks are an integral part of access. Other examples have been provided by experts in forensic locksmithing. Each of these scenarios will be briefly reviewed. They are not all-inclusive of course, but indicative of simple to complex indicia of bypass.

Case #1: Money is missing from an inner locked drawer that is contained within a safe during business hours. There are no signs of forced-entry. A day-lock keeps the combination lock from being opened.

There are two approaches: the lock on the dial may have been picked, if a standard wafer mechanism. However, often Medeco cam locks are utilized, making picking more difficult. A key may have been copied and used by the thief. However, often the simplest solution is to inquire where the key for the combination lock is kept. In many cases, it is left in a nearby desk. It is then a simple investigation to determine who had access. The other possibility is that the dial was rotated a few digits clear of the last number in the combination, never actually resetting the wheel pack. With the key for the day lock, the dial is simply turned back to the correct number and the safe can be opened.

Case #2: An apartment has been broken into. Property, including jewelry, is missing. A large insurance policy covers the loss.

There are tool marks on the face of the lock and within the keyway. Upon closer examination, it is noted that the marking of internal tumblers occurs on the first and second pin only. This is indicative of a fraudulent claim, where a screwdriver was inserted into the keyway and struck with a hammer to simulate picking.

Case #3: A lock shop has been burglarized in Paris, France. The insurance company believes that the burglary report by the owner is false, based upon the fact that the high-security locks could not be bypassed. In this matter, the Chief Forensic locksmith in France was consulted to buttress the premise that the locks could not be bypassed. He was able to demonstrate that in fact they could be picked. The claim was allowed. The owner was vindicated, notwithstanding that the manufacturer stated that their locks could not be bypassed.

Case #4: Property is missing from an office in a large complex. All employees who were thought to have had access to the area were polygraphed with negative results. A key system analysis was then conducted, pursuant to the material presented earlier in this chapter. It was determined that based upon the complexity of the master key system and the attendant cross-key combinations, that a key assigned to an employee in a different section would open the lock. He was confronted and subsequently confessed to the theft.

Case #5: Confidential information has been compromised from a computer. The keyboard is always locked at night or when not in use. An employee is suspected. Upon being polygraphed, the employee is cleared. It is verified that keys for other computers in the adjoining offices would not unlock this computer. The author was summoned to conduct the investigation. It was noted that the locks that blocked access to the keyboard were axial in design. Although it was obvious that they were a knockoff of the Chicago Ace, their security level was not immediately ascertainable.

Upon close examination, it was determined that in fact there were no tumblers in these locks. They were a simulation, made to **appear** as if they had pins. What they actually used were hard protruding pins that formed a crude keyway. The author demonstrated that with two paper clips the entire core of the lock could be depressed and rotated. A night janitor was identified as the culprit.

Case #6: Upon opening the store on Monday morning after a three-day holiday, there is money missing from the safe. There is no sign of forced-entry. The safe was located in view of the front window to discourage burglary attempts after closing.

The theft obviously occurred over the weekend; the manager is the prime suspect because he was the only individual having the combination. The lock is a Sargent & Greenleaf 6730, three number combination, with 1,000,000 permutations. After a long investigation it was determined that the lock was opened using an automatic dialer. The thief had learned the third number in the combination sequence. The TTI dialer will open one of these locks in less than an hour when one of three numbers if known. Although theoretically there are 1,000,000 permutations, in reality, there are only approximately 240,000 useable combinations.

Case #7: A theft of jewelry occurred in a hotel room safe at a very exclusive resort. There were no signs of forced-entry, either in the safe or door lock. The guest has been polygraphed, verifying the theft. Although these safes are not known for their physical security, they are utilized in rooms to protect valuables.

The particular safe had an electronic lock that utilized any commercial bank credit card to set the combination. The card was swiped through the magnetic stripe reader, and the account number on the card became the code to which the safe was locked. A magnetic card lock, utilizing barium ferrite spots, protected the door to the room.

It was determined that the burglars were quite sophisticated. The door lock was easily compromised through a decoding process of reading the location and polarity of the magnets. Once inside the room, the thieves had already determined that this particular type of safe utilized a security bypass scheme in case of lockout. They determined the combination for the bypass card, which would open any safe in the hotel. A duplicate card was created with a laptop computer and portable card encoder while the thieves were registered in the hotel.

27_4.1 Master Evidence Search Checklist

The following compilation summarizes covert methods of entry and trace evidence that may be encountered.

27_4.1.1 Methods of Entry

- **Picking of the lock;**
- **Decoding the lock;**
- **999 rapping of the lock.**

Presence and Transfer of Materials from other Locks

- **Impressioning (in general);**
- **Impressioning of dimple lock;**
- **Impressioning and molding of keys;**
- **Impressioning and decoding of locks;**
- **Recently duplicated key, by Machine or by hand, operated or inserted within the lock;**
- **Picking;**
- **Vandalism, interruption of entry attempt, sabotage.**

Additional Sources of Trace Evidence

- **Contact between bypass tools and lock components;**
- **Forced-entry techniques.**

27_4.1.2 Indicia of Entry

- **Lubricants and cleaners, including graphite, WD-40, oil, grease, cosmoline, gasoline;**

- **Carbon, metal foil, cellophane tape, electrical tape, wax, plasticine, type correct solution (White-Out), paper fragments, putty, Vaseline, soap, broken key or fragment thereof, broken key extractor, or parts;**

- **Wood fragments, clay, silicone, epoxy;**

- **Paint transfer on wards;**

- **Brass filings on bottom of pins; Brass fragments or particles, steel or stainless steel fragments or**

particles, gun-blue material transfer, metal particles at bottom of plug, dissimilar metal fragments present in plug;

Metal filings at the scene of a safe burglary. Courtesy of Don Shiles.

- **Toothpicks, glue, other foreign materials.**

PART B: General Introduction to Bypass

Silent Non-Destructive Entry

"To open one takes skill and knowledge, sensitive fingers, inventive ingenuity to contrive tools that will circumvent mathematics. This gives the locksmith the intoxicating feeling of using his skill to the utmost. When I confront a drillproof safe with dynamite triggers and the most exacting mechanism that has been contrived, I feel a shiver of expectancy down my spine, waiting for the moment when the bolts fly back and the door opens. Whatever may be inside--and the contents are often fabulous--it is never as stirring to the imagination as the moment when the lock gives."

In Unlocking Adventure, by Charles Courtney
CHARLES COURTNEY was a fellow countryman of A. C. Hobbs.

CHAPTER TWENTY-EIGHT: NEUTRALIZATION

General Introduction To Bypass

Master Exhibit Summary

No Exhibits

Discussion of different bypass techniques. Courtesy of Don Shiles.

Bypass of an American Padlock Series 700. Courtesy of Don Shiles.

Forensic analysis of gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

Marks on Ford wafer locks produced by gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

External bypass of a solenoid using a magnetic field. Courtesy of Don Shiles.

LSS303: Analysis of bypass techniques, by John Falle

LSS204: Brian Chan on the disassembly of a lock and derivation of the TMK

28_1.0 Introduction

This chapter surveys non-destructive covert methods to bypass locks, including picking, impressioning, decoding, and other forms of manipulation. The material in Chapters 28-31 has been organized according to bypass technique, rather than by specific type of locking mechanisms in order to minimize duplication of information. Certain materials in chapters 28-31 are restricted and only available in the Government edition for authorized law enforcement, government, and security services. This database provides detailed information of a sensitive nature. It includes instructions on the use of certain high-security bypass tools that have an extremely restricted availability, primarily to intelligence agencies. The Electronic Infobase provides complete patent information on picking, impressioning, and decoding tools described in this book.

The information contained in the following four chapters is directed to forensic investigators, intelligence and special operations units, locksmiths, and security specialists. The material will also be highly relevant for legal counsel that is charged with the responsibility of assessing the security of a lock and the liability for its failure. The data has been gathered over the past thirty years. It reflects not only the personal experience of the author but of the most skilled craftsmen and technicians worldwide. Some are in the business of covert entry, primarily involving government operations. Material has also been gleaned from thousands of patents reviewed by the author in the United States, England, Japan, Germany, Taiwan and other countries relating to bypass and manipulation tools and techniques. Many of these patents are referenced and contained in

the electronic edition.

Concerns regarding the printing of sensitive information in this book and other publications has always been seriously considered and evaluated by the author and others. That such knowledge may allow a person to bypass a lock and commit burglaries or other acts is outweighed by the need to know for those involved in the law enforcement, forensics, and intelligence communities. The dissemination of information regarding lock-picking, impressioning, and other bypass techniques is surely nothing new or unique. Books in the early nineteenth century provided detailed information on lock-picking and other forms of bypass. Notably, John Chubb (1850) and George Price (1856) wrote very revealing works.

What this book does is to provide the reader with the information needed to understand both traditional mechanisms as well as the most modern and sophisticated security technology incorporated into locks and how to bypass them. The text within the Government edition has a restricted distribution and is available to those with a need to know such information. To commit a burglary or otherwise use the information in this book to break the law can subject the reader to severe penalties. In a free society, liberty means choice. If the reader chooses to utilize the data herein for unlawful purposes, that is a personal choice that carries potential sanctions.

Locksmith supplies, videos, and extremely detailed manuals on every subject relating to locks may be purchased from a variety of sources. There is a great deal of information presently available regarding the bypass of locks, if one knows where to find it. This is especially true of patent offices worldwide. Lock picks and books do not make an expert in opening them. Practice, experience, and knowledge however, do. Even in England, where patents and the information they reveal are considered as state secrets, detailed data on the highest security locks may be found in Chancery Lane.

It is the author’s belief that publication of the information in this book will improve the security of products available now and in the future. Professional law enforcement and government agents, locksmiths, and security personnel should have the means to thoroughly evaluate a lock to assess its security. There is in fact very little information in this text about specific products and their bypass. Such information is included in the Government version where appropriate safeguards to distribution can be

imposed.

The modern locksmith is a skilled technician who understands the various technologies incorporated into today's locks. Unfortunately, there has often been an antagonism and protectiveness between the locksmith community and law enforcement regarding the release of information about bypass. Locksmithing is a full-time profession of experts. Lock-picking and covert entry is a specialization that does not make one qualified to fix locks. There should be no competition between the two disciplines.

The main purpose of this book is to tell the story of locks and how they are opened. They are utilized everywhere and in almost every culture. Their security is a constant concern because they protect every facet of society: its inhabitants, their property, and institutions. In the following chapters, we will learn how to circumvent that security.

28_2.0 Historical Perspective: The Development of Security Locks and Bypass Techniques

As has been noted elsewhere in this text, methods for bypassing locks are as old as the lock itself. The very nature of a lock invites its circumvention. It is the one single device that protects valuables from access by unauthorized persons. The art of lock-picking and those who have developed such techniques have always been the catalyst for the invention of countermeasures by the manufacturer. It should be no surprise that they have always outpaced such innovations.

Throughout modern history, lock-picking and safecracking contests have attracted world attention and competition between the pioneers in the business. During the eighteenth and nineteenth centuries, London and Wolverhampton were the centers for research, commerce, and industry involving locks and safes. Bramah, Chubb, Hobbs, and many others were the main participants in the quest for security and those that could defeat it. Their efforts, and of many of the other pioneers in this industry, contributed to the high level of technology available today.

Until fairly recently, making secure locks was quite a challenge. Prior to the convergence of many modern technologies such a metallurgy, high-tolerance manufacturing processes, electronics

and computers, this was especially difficult. Lock inventors had to start from nothing but a 4,000-year-old concept that originated in Egypt. The task was truly awesome. Bypassing each new mechanism was equally daunting for the lock picker. It has been a game of inventiveness, innovation, engineering, research, and wits. As will become evident in the next few chapters, that game will continue. Perhaps even at an accelerated pace.

Locks have been in existence prior to the time of written history. More than 4,000 years ago, a fresco discovered in an ancient temple pictured a lock. The Egyptians provided the basis for the modern pin tumbler, now the most popular security device in the world. Until the eighteenth century, locks offered little security and merely provided complicated inconveniences to burglars. As we shall see, until 1778 all locks could be bypassed.

Recent developments during the past quarter century have eclipsed all of the security enhancements occurring during the previous 4,000 years. The introduction of microprocessor technology and the inductive coupling of energy to make smart keys and locks have revolutionized the basic mechanical lock, and its ability to protect. There have been commensurate developments in the technology of bypass. Modern tools and devices are just as sophisticated and complex and utilize computers, radiographic technique, sound-signature analysis, space-age drilling materials, and extremely advanced metals and metallurgy in their design and operation. So, the technology of locks and their bypass continues.

There are certain pioneers, both early and modern, in this profession. Primarily in England and the United States, they are credited with revolutionary ideas in the both design and bypass of locks. A. C. Hobbs, Jeremiah Chubb (and the Chubb group), Joseph Bramah, Linus Yale (Sr. and Jr.), and James Sargent provided the foundation for current bypass technology. Modern pioneers, innovators, and inventors in this industry include Jerry Hoffman (HPC), Harry Miller (S&G), John Falle (Falle-Safe), Martin Newton, Bennie Wells, Nick Gartner (LaGard), Roy Spain (Medeco), S.A. McClean, Clayton Miller (Lockmasters), Mark Bates (MBA), Ken Dunckel and Skip Eckert (safe penetration and manipulation), and the design team at Mas-Hamilton. There are of course many others, but these are perhaps the best known for their contributions.

28_3.0 Introduction to Bypass

The art of lock-picking and the development of bypass techniques are as old as the first lock. The purpose of any lock is to restrict entry; it is axiomatic that someone will have a desire to do just the opposite.

What is a lock? Moreover, what is a key? As we have learned, a lock is a mechanism that comes in an infinite variety of sizes, shapes, and configurations. Its chief element is a bolt that can be shot into a staple or other recess. It is retained there until withdrawn by properly activating the locking mechanism. A key, in whatever shape and size, is simply a device for operating the mechanism within the lock in such a way as to control the bolt.

Locksmiths, from the time the craft first came into existence, have always been fascinated by the problems of security. The basic challenge has been to present the would-be thief with the most difficult obstacles to entry. There are many myths about opening locks. A very interesting book about Houdini entitled Believe (by Michael C. Tobias) may be of interest to the reader. Among the myths: that a blank key can open a lock; that wax or soap can be inserted into the lock to make an impression of the key; that all of the tumblers can be lifted to open the lock, that a special tool may be inserted, and by magic the lock is opened; that there is a universal master key or instrument for opening all locks; that there are skeleton keys; and that there is a universal picking tool.

These and many more tricks shown in the movies, make the whole process appear quick and simple, requiring little talent. Rarely is that the case. The author has picked thousands of locks, sometimes in seconds, more often requiring minutes. Sometimes, the simple locks will offer more difficulty than high-security bank locks. Then again, one may repeatedly attempt to pick a lock to no avail. After a five-minute rest, another attempt is made and the lock is opened in seconds. Bypassing locks is an art and a science that requires considerable practice, skill, and patience.

There are many labels to define the process of opening locks and safes in a manner not intended by the manufacturer, or in contravention of the "normal" mechanical activation. **Bypass** and **neutralization** are perhaps the most popular terms. In this text, the term "**bypass**" shall denote any process or manipulation that is employed to open a mechanical or electronic lock by tools, devices, and procedures other than intended or designed by the

manufacturer.

28_3.1 Security: A Simple Premise

The security of modern mechanical key and combination locks is primarily based upon the double-acting detainer principle. This requires that all discs, levers, or tumblers be lifted, rotated, or moved to precisely the correct level or position in order that the mechanism may be actuated. In addition, keyways, guards, wards, and other techniques may be utilized to block entry to the lock components by all but the correct key.

There obviously have been many variations. This involves the use of rotating tumblers, sidebars, telescoping pins, magnetics, optics, infrared, and the integration of other new technologies including induced fields, digital transponders, electronics, and computers. In essentially all mechanical locks, bypass requires that the action of the key or other actuating device be simulated or replicated. The ability to bypass a particular lock will depend upon nine primary factors:

- **Type of mechanism and inherent tolerances;**
- **Physical construction and measurements of the container holding the lock;**
- **Material and method by which the lock is affixed: If the lock is mounted on wood or other material that does not offer sufficient structural integrity, then it can be easily bypassed with force;**
- **Bolt-actuating mechanism, and capability of externally manipulating the active components to open the lock;**

External bypass of a solenoid using a magnetic field. Courtesy of Don Shiles.

- **Incorporation of special security devices within the locking mechanism that are designed to frustrate bypass, such as anti-drill pins and security tumblers;**
- **Number, structure, and design of tumblers, levers, wafers or discs: This is perhaps the most important information that can be developed in order to determine the best method of bypass. Such details will allow a determination of whether the lock is**

most susceptible to picking, impressioning, decoding, or drilling, and the likelihood of success. This information will also provide a means to visualize the internal components in order to translate touch and hearing into physical action;
- **Design of the keyway;**
- **Design and functionality of the key;**
- **Number of differs.**

Whether a lock can be bypassed depends on many factors, including its security rating. A comprehensive list of such factors can be found in **Chapter 29**. A detailed analysis of bypass potential is presented in the next three chapters and in **Chapters 24-25-26-27.**

28_3.1.1 Physical Components and Designs to Prevent Bypass

Within the lock, there are several principal components and designs to prevent or frustrate bypass. Although covered elsewhere in this text, these are summarized here. There are two primary means to make bypass more difficult: keyway profile, and the design of the device or means for obstruction or blockage of rotation of the plug or other bolt-actuating device. These are commonly described as wafers, levers, discs, or pin tumblers.

28_3.1.1.1 Keyway Design

The purpose of the keyway is to require the correct key to have identical properties, so that it may enter and turn inside the lock. The keyway wards prevent entry for all but the proper key.

28_3.1.1.2 Implements to Block Rotation

Locks with many mechanical designs have emerged during the past two hundred years, all with one common objective: to block rotation of a plug or other bolt-actuating device until the proper key is inserted. These have taken the form of levers, discs, wafers, and pin tumblers. Regardless of their size, shape, thickness, or number, they prevent movement of components until properly set by the bittings of a key.

28_3.2 Methods of Bypass

Discussion of different bypass techniques. Courtesy of Don Shiles.

LSS303: Analysis of bypass techniques, by John Falle

There are three primary methods of covertly bypassing all mechanical locks: **picking, impressioning, and decoding.** Other forms of manipulation may also be employed. Certain bypass techniques require disassembly of the lock; most do not. Understanding bypass procedures and the underlying theory of each method, coupled with sufficient practice, will allow almost anyone to become proficient at opening most locks.

In general terms, a lock may be bypassed or opened by the manipulation of active components, or by producing a key. In this text, techniques for bypass have been divided into three primary categories: **picking, impressioning, and decoding**, although impressioning and decoding are often in fact so closely connected so as to be indistinguishable. Although there are many techniques and procedures that can be employed to open a lock, all of them can be said to be subsets of one of the three categories listed above.

The following techniques, or subsets of them, are explored in detail throughout this text, and constitute the methods by which a lock or locking system can be compromised covertly. The summary does not include methods of forced entry.

- **Picking;**
- **Key picking;**
- **Impressioning;**
- **Mechanical bypass of security mechanism (such as comb pick or spiking);**
- **Injection of spray into the plug to freeze the top pins, then use heat to release bottom pins below shear line;**
- **Core shimming;**
- **Pin and cam technique;**
- **Pick and form technique;**
- **Stack probing of pin stack (length of pin stack determination. This can be done visually with an otoscope, and by viewing color coded pins);**
- **Sac probing (break point on short pins, visible decoding);**
- **Basic decoding of tumblers;**

- **Electronic decoding;**
- **Extrapolation and decoding of top level master key (TMK);**
- **Plasticine reading of levers;**
- **Automatic impressioning using pressure responsive materials;**
- **Step key and count back techniques;**
- **Shim wire decoding;**
- **Radioscopy (x-ray and Gamma ray imaging);**
- **Endoscopy (Use of borescope or otoscope);**
- **Belly reading;**
- **Scratch reading for levers (Use of borescope to view the length of wear marks on bellies of levers);**
- **Vibration techniques;**
- **Automatic manipulation of components by computer technology;**
- **Utilization of standardized access and control keys or combinations to enter other secure areas. Elevators, power panels, telephone company panels, alarm consoles and similar locations may employ standardized locks and keys. For example, all elevators in New York city are keyed alike, and all elevators in New York state, other than in New York, are likewise keyed alike;**
- **Combination of techniques.**

28_3.2.1 Picking

Picking involves a process of manipulating each moving component in a manner that simulates the action of a key or other actuating device. Many techniques are available to pick a lock, as well as a wide array of tools to accomplish the task. Picking is accomplished through the manipulation of individual pins or groups of tumblers using mechanical or electromechanical means such as conventional picks, rakes, pick guns, and “999” rapping keys.

All picking techniques rely upon cumulative tolerance and alignment errors between moving parts in a lock. As the gap between active components decreases, the difficulty of picking increases. All locks have a certain amount of space between plug, pins, shell, wafers, or levers. These gaps, coupled with slight misalignment of parts resulting from the manufacturing process, will allow a lock to be bypassed. The optimum exploitation of these errors differentiates amateur from expert.

28_3.2.1.1 Survey of Bypass Techniques: Picking and the Manipulation of Active Components

The following list provides a comprehensive summary of picking techniques:

- **Using a skeleton key;**
- **Using a mechanical vibration pick;**
- **Accomplish physical bypass of bolt mechanism;**
- **Pinning error, use of comb pick;**
- **Prying or defeating bolt by spreading, such as with desk lock;**
- **Rake picking;**
- **Key picking (jiggling of keys);**
- **Raking with a set of tryout keys or rocker picks;**
- **Rapping the lock;**
- **Rocking using computer picks;**
- **Use of snap-pick tool;**
- **Traditional picking;**
- **Use of tryout keys;**

Forensic analysis of gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

Marks on Ford wafer locks produced by gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

- **Use of a special pick tool to open and decode the lock, such as with tubular locks;**
- **Use of brush pick;**
- **Use of control key for removable core or interchangeable core lock;**
- **Use of shim to bypass lock mechanism;**
- **Use of vibration after removing springs, such as with the Briggs and Stratton sidebar lock;**
- **Utilize a cross-key combination;**
- **Vibration of special key inserted into the lock;**
- **Add wafers or pins to lock for later picking or entry;**
- **Celluloid to get around secondary bolt;**

- **Use of ice pick to manipulate the actuating cam or bolt.**
- **Electronic signature analysis;**
- **Radiographic imaging.**

28_3.2.2 Impressioning

Impressioning allows keys to be produced for locks without disassembly. The original technique was developed hundreds of years ago and involved the insertion of blank keys coated with wax or covered with carbon to sense the resistance of levers. Today, the process is essentially the same, except that the materials have changed. There are many ways to impression a lock. These include traditional techniques or the use of a special brass, lead, latex key, or hybrid key surface. Some rely upon the use of special substances to enhance tumbler marking. Materials such as carbon, metal foil, cellophane tape, electrical tape, wax, plasticine, grease, type-correct solution (White-Out), nail polish, putty, Vaseline, and soap may all be utilized. The technique depends upon the particular mechanism and personal preference.

Impressioning is a combination of picking and decoding. The process relies upon tolerance errors, and the ability to decipher information left on the bitting surface of a key. During the impressioning process, a blank key is inserted and manipulated. This allows a reading of the tolerance between plug and shell, and the position of a specific pin, wafer, disc, or lever. The advantage of impressioning is that a working key is produced at the completion of the process.

28_3.2.2.1 Impressioning Techniques

There are two primary methods of impressioning:

- **Tactile impressioning tool, such as foil and wax;**
- **Tactile impressioning of lock itself.**

28_3.2.3 Decoding

Decoding envisions and encompasses many techniques and procedures. It involves the acquisition and deciphering of data about active moving components within the lock that control configuration of the shear line. Both the lock and its keys can be decoded and compromised. Data for a given lock may be obtained

by various means, including:

- **Gaining physical possession of the key and copying it;**
- **Visually decoding the bitting, then utilizing that code for creation of a duplicate key at a later time;**
- **Viewing code numbers stamped on the key;**
- **Obtaining codes from an internal system list, from the locksmith who installed the system, or from the manufacturer;**
- **Impressioning;**
- **Use of a borescope to read the wafers, levers, or tumblers;**
- **Visual external decoding of the tumblers, especially if they are color coded by the pin manufacturer. There is no standardization of color coding, but an educated guess may be made as to pine length from its color;**
- **Use of a change key to extrapolate the top level master key;**
- **Disassembling the lock and measuring each pin;**

LSS204: Brian Chan on the disassembly of a lock and derivation of the TMK

- **Shim wire decoding.**

28_3.2.3.1 Decoding: Creating a Key for the Lock from Data

The following sources may provide direct code information that will allow a key to be produced by:

- **Code cutting after deriving the code by one of the following techniques:**
  - **Copy a key;**
  - **Decipher the key code from lock or tumblers;**
  - **Decode master key for entire system;**
  - **Decode combination using a depth gauge or key;**
  - **Extrapolate a composite master key in a positional system;**

- **Obtain factory or dealer data regarding codes;**
- **Make a silicone impression of the original, then decode or produce a molded copy;**
- **Measure the key with a micrometer;**
- **Trace the outline of a key for later reproduction;**
- **Obtain master key system listing or extrapolate the code for the TMK;**
- **Obtain or borrow a key;**
- **Obtain the code list for the lock;**
- **Photograph the key, then reproduce it;• Pick the lock, then examine with borescope to decode;**
- **Remove one lock, decode, and replace;**
- **Employ specialized decoding systems, such as magnetically reading the signature of the lock or measure tumbler lengths;**
- **Use of foil for impressioning;**
- **Visually decoding of the key or tumblers;**
- **Visually deriving code from one or more keys;**
- **Visually observe master key, then decode.**

28_3.2.4 Other Forms of Manipulation

Manipulation takes many forms and encompasses those techniques not constituting traditional picking, impressioning, or decoding. Manipulation is generally mechanical in nature and involves the alteration, exchange, addition or removal of active components. Modification of the pin-stack is a favorite technique, and generally involves two principal procedures: addition of master pins or the removal of pins. Both are designed to reduce pick resistance.

The removal of one or more tumblers and the exchange of security tumblers for conventional pins will make the lock easier to pick. The addition of one or more master pins, thereby increasing the number of shear lines, will also reduce pick resistance. Alteration of cams, removal of cylinder retaining screws, removal of springs, and similar actions can also make a lock more susceptible to bypass. Another technique involves the compromise of conventional master key systems by obtaining a change key and then decoding the TMK by sampling each chamber for each depth.

Bypass of an American Padlock Series 700. Courtesy of Don Shiles.

CHAPTER TWENTY-NINE: MANIPULATION OF COMPONENTS

Picking

Master Exhibit Summary

Falle.
Figure LSS+2925, Diagram showing order of picking, and the misalignment of the five chambers.
Figure LSS+2926 Plug partially picked.
Figure LSS+2927 John Falle comb pick set
Figure LSS+2928 Safe opening tools for lever locks
Figure LSS+2929 The theory of lock picking
Figure LSS+2930 The use of a comb pick
Figure LSS+2931 The MSC cross pick
Figure LSS+2932 The MSC Electropick allows controlled manipulation of pin tumblers.
Figure LSS+2933 MSC acoustic picking tool.

Figure LSS+2934 Kromer Convar lever lock
Figure LSS+2935 Kromer Novum lever lock
Figure LSS+2936 Stuv lever lock
Figure LSS+2937 Rosengrens ABN1 lever lock
Figure LSS+2938 Rosengrens RKL10 lever lock
Figure LSS+2939 Markings on levers to aid picking
Figure LSS+2940 Axial lock pick and decoding tools by A-1 and Peterson Manufacturing.
Figure LSS+2941 The Peterson pick tools for the Schlage Everest cylinder
Figure LSS+2942 A rake pick for a dimple lock
Figure LSS+2943 Picks can be concealed for covert operations

The theory behind the use of the 999 key, Courtesy of Hans Mejlshede.

The proper technique for the use of the 999 or bump key, Courtesy of Hans Mejlshede.

Residue may be present when a dimple lock has been bypassed. Courtesy of Hans Mejlshede.

Order of picking. Courtesy of Hans Mejlshede.

The use of pick guns and forensic analysis of locks. Courtesy of Hans Mejlshede.

Use of a pick gun requires skill. It also leaves forensic indications. Courtesy of Hans Mejlshede.

LSS201: MSC Assortment of tension wrenches, courtesy of Mahmod Abu Shanab

LSS201: MSC "Sputnik" bypass tool, courtesy of MSC.

LSS202: The use of the "bump key" or "999" key, by Hans Mejlshede.

Use of a bump key, by Harry Sher

Procedure to open a lever lock with the "drill and pick" technique. Courtesy of Harry Sher.

Picking Medeco locks. A discussion by Harry Sher.

A discussion regarding the impact pick gun, by Harry Sher.

How does impact picking work? Courtesy of Harry Sher.

Feel-picking individual pins, courtesy of Harry Sher.

Use of a plug spinner, courtesy of Harry Sher.

LSS203: Demonstration of the MSC cross pick on a lock with four rows of tumblers

LSS203: Demonstration of the MSC electropick on a profile cylinder

LSS203: MSC Acoustic picking tool demonstration

LSS204: Owe Bengtsson on picking lever locks and utilizing markings on the levers.

LSS204: Owe Bengtsson on picking the Kromer Convar lock

LSS204: Owe Bengtsson on picking the Kromer Novum lever lock

LSS204: Owe Bengtsson on picking the Stuv lever lock.

LSS204: Owe Bengtsson on opening the Rosengrens ABN1 lever lock.

LSS204: Owe Bengtsson on opening the Rosengrens RKL10 high security lever lock

LSS204: MSC Sputnik II with audio probe

“Whenever the parts of a lock which come in contact with the key are affected by any pressure applied to the bolt, or to that portion of the lock by which the bolt is withdrawn and shot, in such a manner as to indicate the points of resistance to the withdrawal or shooting of the bolt, such a lock can be picked. Where a key can enter, a false key, whether in key form or in the form of bent wire, can also enter.”

A.C.HOBBS

29_1.0 Introduction

This chapter is about covertly bypassing locks, using techniques commonly referred to as **picking**. Principles of picking, checklists for analyzing potential problems, various bypass techniques, and a description of general and special pick tools are presented. Information regarding warded, lever, wafer, disc, and pin tumblers locks is detailed so that the reader can become proficient at opening most mechanisms. Data will also be presented for certain types of hybrid locks such as sidebar, magnetic, rotating disc, tubular, and dimple, due to their wide acceptance. The majority of the discussion will relate to pin tumbler locks because of their popularity. However, most principles will be equally applicable to the disc, wafer, and lever. The differences in mechanisms and opening techniques will also be explored.

Although television and the movies have portrayed lock-picking as within the grasp of the common criminal, it really is not. For high-tolerance locks, it is a precision art requiring skill and practice. There are few universal rules: some locks are simple and some are exceptionally difficult. Others, including electronic, magnetic, laser-track disc, and sidebar, are virtually impossible to open. My intrigue with locks and picking began at age 15, when I opened my first pin tumbler mechanism and had my first key cut by code. From that time, it has been a continuing fascination and learning process. One has to marvel at the developments in the industry during the past quarter century. It is impossible to imagine what the next century will bring.

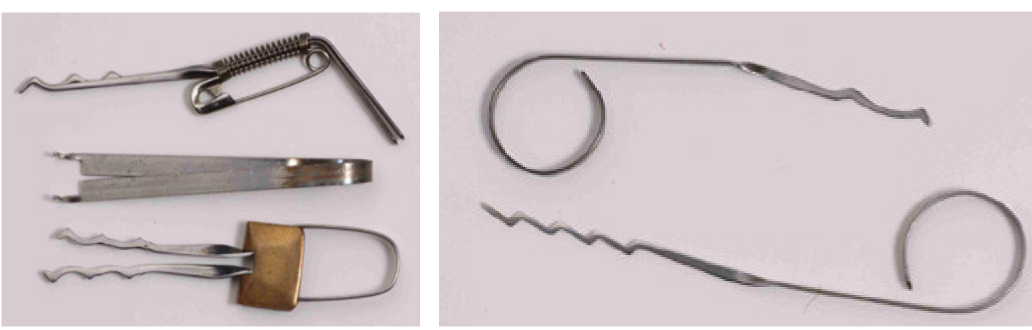


Figure LSS+2943 Special pick sets that can be concealed during covert operations, and thrown away if necessary. Courtesy of Barry Wels.

Modern locks, and specifically high-security locks, provide an extraordinary measure of security against many forms of bypass.

Having said that, one must take heart because most locks can be picked or decoded. It just takes a little more time, skill, and effort. From over thirty-five years of experience, I can attest that there is only one means to become skilled at the art: pick many locks of all kinds and in every possible situation. The only way to learn how to recognize and exploit defects within a lock is to practice.

This means practicing many times on the same lock as well as practicing on many different locks. Anyone can learn how to open desk and filing cabinets, but the ability to open a quality lock in under thirty seconds is a talent that requires a great deal of skill. It is gained through practice, coupled with mechanical sensitivity, physical dexterity, visual concentration, and the ability to think analytically. This chapter will teach that there is no "one" way to do it. Everyone develops preferences. Every instructor teaches slightly different methods, based upon personal experience. We all do things differently. If the basic premise of lock-picking is understood for each type of mechanism, then the reader will be able to succeed, albeit with persistence.

Many manufacturers have conducted the proper research and development necessary to produce secure locks. Although **all** manufacturers will represent their products as secure, in the author's personal experience, many have been quite the opposite. Just because the lock "looks" like it will be difficult to pick provides no barometer to its true security. A properly designed lock has the requisite security to make picking difficult and time consuming. That is what research and development accomplishes. Security tumblers, sidebars, magnets, false notches and gates, serrated levers, keyway curtains, and other refinements are all utilized to frustrate the process described in this chapter. Such devices and technologies are the product of research and development.

Manufacturers have been quite surprised by latent design defects that have not been found until years after a product is introduced and patented. Until discovery by a locksmith, government expert, or criminal, such defects are not obvious to anyone. Once discovered, of course, they often are so obvious as to be laughable. The author has always maintained that design engineers are skilled at making things work but not at breaking them. The issuance of a patent for a particular design does not guarantee security.

Finally, in the author's perspective from within the law

enforcement community, it is observed that there have been very few instances of dishonest locksmiths. It is indeed a noble profession of protection; it should receive the accolades it deserves. Few other groups of specialists are charged with such a responsibility and given such a wide array of tools to fulfill their mission. It is now a complex business, requiring the ability to open many different locks, sometimes in very difficult circumstances.

SECTION 1: Bypass and the Characteristics of a Lock

29_1.1 Locks Have Personalities, Too

Although skill and luck can play a significant part in bypassing a lock, there are many technical issues that will allow or preclude a successful opening. Certain characteristics will make a lock easier to pick, and others will present serious obstacles. Each lock has its own physical personality, resulting from differing mechanical features and defects that can help or hinder bypass. These traits can often be used to advantage during picking. To open a lock, its characteristics must be correctly assessed, responded to, and exploited using the proper remedy or technique.

The following discussion summarizes physical, setup, and mechanical characteristics that can affect how a lock responds to bypass attempts. Many common issues and problems can be remedied with skill, the correct tools, and proper techniques as outlined below. Consideration must be given to each of the following factors to assess whether a target lock can be opened and with what level of expertise and difficulty.

29_1.1.1 What Makes a Lock More Conducive to Picking

- **The suspect lock may be inherently easy to pick due to its design (especially if a wafer mechanism);**
- **The pin-stack configuration or combination may be extremely conducive to picking. That is, all**

tumbler positions may be close to the same depth, or a stair-step pattern may have been used;

- **Maison keying may be in effect. There may may only be two or three tumblers in the lock;**
- **Complex master keying may be employed, with many cross-combinations available;**
- **The lock may only have three, four, or five tumblers;**
- **No wards or obstructions in the keyway;**

- **The tolerance between plug and shell may be quite sloppy, due to:**
  - **Wear;**
  - **Poor manufacturing controls;**
  - **Because the top of the plug was filed by an amateur locksmith;**

- **The horizontal center-point alignment between chambers may be erratic, making picking easier. This means that all of the pin chamber holes in the plug/shell are not precisely drilled in a straight line. When the lock is picked, it will be easier to cause pins to set at shear line;**
- **No security tumblers are used;**
- **The perpetrator may be very skilled in lock-picking;**
- **All tumblers can be pushed, using a pocket knife, because each depth is close to the same level;**
- **Rocker picks can be utilized in a lock having a pin combination that matched the signature of the picks.**

29_1.1.2 Pick Resistance of a lock

- **Are high-security locks used. Does the lock carry a UL 437 or equivalent rating;**
- **What is the tumbler orientation of the lock (vertical or horizontal) and how does this affect pick resistance;**
- **Are security pins (serrated, mushroom, spool) employed. Are telescoping pins used for extra security;**

- **Does the lock utilize a paracentric keyway for added pick resistance;**
- **Have special pick or decoding tools or procedures been developed for this type of lock. Are there known picking or bypass techniques;**
- **Do locks utilize high tolerance components, factory original keys, and incorporate anti-pick features;**
- **Are high tolerances maintained between the plug and shell;**
- **Does the lock resist tumbler manipulation;**
- **Does the lock resist decoding techniques. Any chamber that allows slight lateral movement of the plug before pins are lifted can permit decoding of bottom pin lengths with a key blank;**
- **Does the lock resist impressioning;**
- **Will key jiggling be ineffective, due to high tolerances. Wide tolerances at shear line will facilitate jiggling, impressioning, and cross-combinations;**
- **Does the lock resist progressive compromise.**





29_1.1.3 Information from the Keyhole

The keyhole will provide some valuable information that can make picking easier and faster. The following observations should be made when planning an entry:

- **Type of mechanism (pin tumbler, wafer, lever);**
- **Possible number of tumblers;**
- **Design of keyway;**

- **Potential for visual decoding of tumblers;**
- **Special security features.**

29_1.2 (RESERVED)

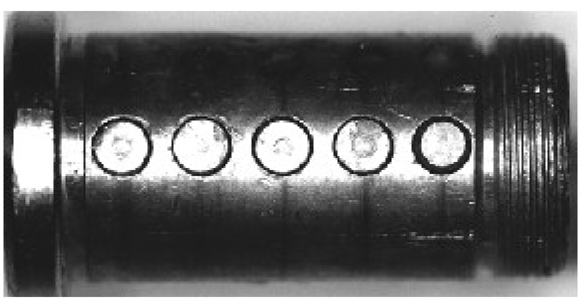
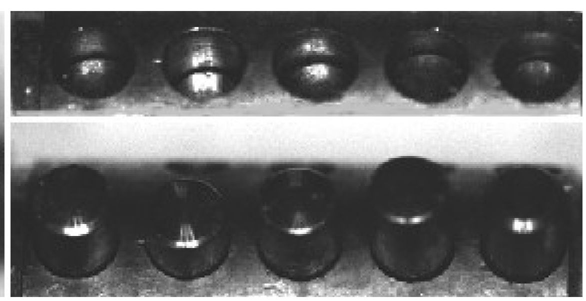
29_1.3 Lock-Picking and the Theory of Bypass

29_1.3.1 Introduction: the Basics

We begin our discussion of lock-picking by reviewing the most basic questions: **How does a key open a lock, what keeps the lock from opening, and why is it difficult to pick a lock?** If these concepts are thoroughly understood, then the actions of the key can be duplicated to effect the same result. The very essence of lock-picking, and indeed all forms of bypass, is an understanding of how a lock responds to manipulation and simulation of the use of the proper key.

29_1.3.2 How Does a Key Open a Lock?

A key is first inserted into the keyway. The protrusions on the side of the keyway are called wards. They restrict the set of keys that enter the plug. A cylinder can rotate when the proper key is fully inserted. The non-rotating part of the lock is called the shell. The proper key lifts each pin-stack, wafer, disc, or lever until the gap between the bottom pin and the top pin (or equivalent) is located at and forms the shear line or clearance. When all the pins are at shear line, the plug is free to rotate, thereby allowing the lock to be opened. An incorrect key will leave some of the **detainers** protruding between the shell and the moving component, thus preventing rotation.

29_1.3.3 What Keeps the Lock from Opening

Although the mechanisms of each classification of lock differ in

their operation, the theory of all mechanical locks is inherently identical. Regardless of design, the active internal components that control some form of boltwork are maintained in a locked position until some mechanical action or series of actions removes the obstruction and allows rotation or other movement. The obstructions are formed by the pins, levers, wafers, or discs. Removing this blockage involves the insertion of a key that rearranges and moves each of the obstructions to a common point, called a "shear line."

29_1.4 Cumulative Tolerance Errors

29_1.4.1 Introduction: Why is it Difficult to Pick a Lock?

Why locks are easy or difficult to pick is covered in detail later in this chapter. The short answer primarily involves tolerance errors. If a lock and its moving components (plug and pins) maintain a very high tolerance, meaning little space between parts, then the lock will be more resistant to manipulation. If all chamber holes have very close to perfect centerline alignment, ever more difficulty will be encountered. If security tumblers are added to the equation, the mechanism may present a serious obstacle to bypass. As the reader will learn, the question involves many complex issues. Understanding them will provide the maximum opportunity to successfully open a lock.

29_1.4.2 Tolerance

Tolerance errors are cumulative in effect, resulting from many factors. In high-quality security-rated locks, the plug and shell is made from brass bar stock or nickel silver. The pin chambers are drilled individually and reamed for a close fit. In contrast, poor quality knockoff locks such as produced in Asia are less expensive with commensurate poor tolerances. Maintaining tolerance is costly; there are no shortcuts. Cheap locks will generally display the following characteristics:

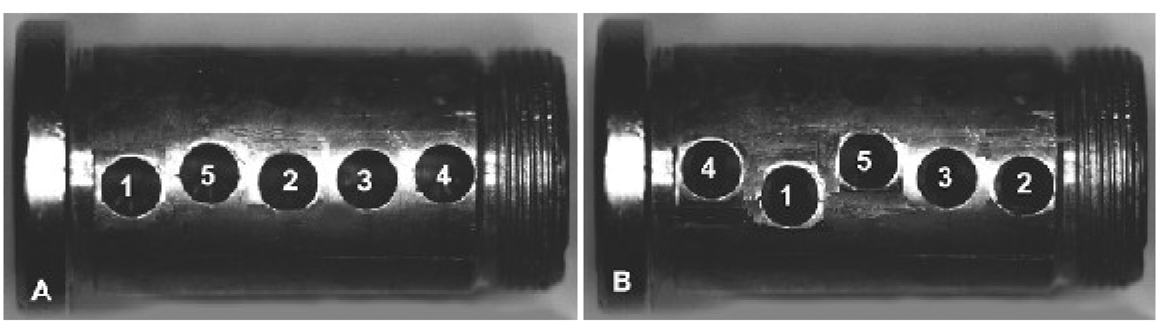
- **Have too much chamfer on the top and bottom of the pins;**
- **Use die-cast plugs and bodies with poor chamber alignment;**
- **Have oversized pinhole diameters;**
- **Allow too much clearance between the shell and plug;**

- **If brass is utilized, it will be of inferior quality to #58, (which is typically used in quality locks).**

The following tolerance errors are typical in a pin tumbler mechanism and will contribute to the ability to pick or impression the lock:

- **Plug and shell >.005”;**
- **Loss of bottom metal of keyway due to broaching <.0005";**
- **Flat at top of plug .005”-.015”;**
- **Chamfering pin chamber with a reamer or drill bit;**
- **Chamfering a pin;**
- **Pin chambers not all same diameter;**
- **Pin chamber centerlines not equal;**
- **Concentricity of chambers: roundness;**
- **Pin diameter and concentricity of tumblers;**
- **Master keying can create up to 2,000 or more shear lines because of cross-keying.**

Locks can be picked due to cumulative tolerance errors resulting from required clearance between moving parts. The poorer the tolerance between moving components, the greater the opportunity for setting pins at shear line. There is always a sliding allowance or tolerance. Any part that will slide past another moving component must be separated by a gap. The space allows the creation of a shear line; the opportunity to exploit that mechanical requirement permits bypass.



Order of picking. Courtesy of Hans Mejlshede.

Variations in alignment of active components caused by imperfections in machining and metal surfaces, drill bit and

broach wear, imprecise rounding, and other production stages make it possible to bind pins and other parts during picking. Tolerance errors occur at several critical points. These include:

- **Plug and Shell Gap: Free rotation of the plug requires tolerance between the plug and shell. A minimum of .0025″ is considered acceptable. This means that there will be at least .0025″ at any point between the plug and shell (a total of .005″ error), depending upon the position of the plug. If there is less tolerance, binding can occur; more will result in sloppy operation.**

A tolerance of .0025″ would be maintained assuming the plug rested in the center of the shell. In reality, the plug sets on the bottom, leaving .005″ at the top where the pins make contact with each other. The average tolerance between plug and shell is about 1/3 the depth difference between one cut. Thus, if the increment is .015″, then the tolerance will be about .006″, or slightly more than 1/3 depth. This number will range between .005″ and .010″. This also explains why poorly cut keys will often open a lock having low tolerances. The cumulative effect of the key-cutter and manufacturing processes of the lock will contribute to greater latitude with regard to shear line.

- **Broaching of keyway: Broaching is the process by which a keyway is created within a solid plug of brass. There are always slight variations in the formation of wards due to wear of the broach. Depending upon the manufacturer, broaching can be extremely accurate or quite sloppy. It provides an index as to the manufacturing quality controls and the cost and security of a lock.**

Broaching causes a small amount of metal to be lost at the bottom of the keyway in order to maintain the original plug diameter. Obviously, there is also a tolerance factor between the interaction of the key and the wards, so that smooth mechanical operation will result. If low tolerance is maintained in the broaching process, then the key will not index properly within the keyway, causing up to a 0.005″ error. This must be compensated for by the manufacturer at the plug-shell interface point (shear line).

- **Chamber tolerances: There are four critical factors involving tolerances relating to chambers:**

- **Plug diameter differential: The actual circumference of the plug varies longitudinally, creating differences in the shear line between plug and shell, and allowing pins to be easily trapped. This is called the effective diameter of the plug: it does not equal the true diameter. If the effective diameter is "true" across the entire length of the plug, then the gap between shell and plug will be constant, thereby creating a precise shear line.**

- **A flat surface at the top of the plug: It may be there by design or created by an amateur locksmith and can add 0.005"-0.015" tolerance error. Chamfering does the same thing. Thus, the difference between a flat and rounded mating of plug and shell can be critical with respect to pick resistance.**

- **Off center or misaligned chambers: This is the critical alignment error that determines which pins will set first. When the plug is rotated, the farthest out-of-center chamber will be first bound. Chambers are created by a process involving either individual drilling operations, or gang drilling. Gang drilling will produce results that are more varied. This is because of the use of different drill bits for each chamber. How often the drills are replaced is also relevant. Generally, each chamber is drilled individually for higher accuracy. Chamber diameter is generally maintained to ±.03 mm. In the case of Ikon, the pin diameter is 3.0 mm, and the chamber diameter is 3.2mm; thus, the pin-chamber tolerance is 0.2 mm.**

- **Concentricity or pin centers within each chamber: Internal lateral movement or play will provide another opportunity for pins to set at shear line. The error is caused by gang or sequential**

drilling. The drill bit changes by a microscopic amount during each penetration. High-security lock manufacturers such as Ikon maintain a vertical and horizontal center tolerance of .02 mm (.001”).

29_1.4.3 Tolerance and the Binding Effect: Setting a Single Pin within a Pin Tumbler Lock

Tolerance can be said to be the basic defect that enables all locks to be picked. It makes it possible to open a lock by lifting the pins, discs, wafers, or levers individually, thereby trapping (setting) them at shear line. Whereas a key lifts all tumblers simultaneously, the pick accomplishes the same task one at a time. In its simplest form, the procedure for opening a lock (one pin at a time) can be described as three sequential steps:

- **Apply a shear force in the form of torque;**
- **Find the pin that is binding the most;**
- **Force it up to the shear line.**

As the top of each lower pin reaches the gap between plug and shell, the plug will rotate slightly; the top pin will then be trapped above the shear line. This procedure is called **setting a pin**. Opening the lock simply requires that all pins be set. The most difficult aspect of picking a lock can be the determination of the first pin that binds, or the pin that is binding the most. It is essential to understand the relationship between applied torque and the force required to lift each pin. This is necessary in order to appreciate and utilize the mechanical sensations generated during the picking process.

29_1.4.4 Forces Exerted Upon Pins

There are four primary forces that are exerted on driver pins during picking and which must be overcome through pressure applied by the pick:

- **Friction from the sides of the pin;**
- **Spring-bias force from above the pin;**
- **Contact force from the lower pin;**
- **Elastic deformation of pins.**

29_1.4.4.1 Binding Friction

The binding friction is proportional to how hard the top pin is being scissored between the plug and shell; it is a function of the applied torque. It is axiomatic that the more torque presented, the harder it will be to move a pin. To make a pin move, pressure must be applied that is greater than the sum of the spring and friction forces. When the base of the top pin reaches the shear line, the physics suddenly change. The friction binding force drops to zero and the plug rotates very slightly until stopped by another pin binding. Now the only resistance to the vertical motion of the pin is the spring force.

After the top of the lower tumbler enters the gap between the plug and shell, a new contact force is created from the bottom pin striking the shell. This force can be quite significant and will cause a peak in the pressure required to move the pin. If the bottom pin is pushed further into the shell, it creates a binding friction just as the top pin originally encountered. Thus, the amount of pressure needed to move the pins before and after crossing the shear line is about equal. Greater torque increases the required pressure. At the shear line, the pressure increases dramatically due to the lower pin striking the shell.

29_1.4.4.2 Spring Bias

Spring bias increases slightly as pins are pushed into the shell, but the difference in force is negligible and essentially of no consequence. A pin will not move without the application of enough pressure to overcome the spring bias.

29_1.4.4.3 Elastic Deformation

The mechanics of lock-picking occur in distances that are measured in thousandths of an inch, where metals behave like springs and very little force is necessary to deflect or deform metal components. When that force is removed, the metal will spring back to its original shape and position. Deformation can be used to advantage to force several pins to bind at once. For example, the application of heavy torque may aid in setting more than one pin at a time by deforming the surfaces with which the pins bind. This is especially useful where tolerances have been maintained with respect to chamber bores and their center axis. Added torque can skew the centerline of all chambers, causing tumblers to set.

Torque actually places a twist in the plug that causes the front to be deflected further than the rear. With light torque, the back of the plug stays in its initial position. When increased, the front pin chambers bend or deform enough to allow the back of the plug to rotate, causing the rear pins to bind. With the extra torque, a single stroke of the pick can set several pins simultaneously.

Exerting excessive torque can also cause problems. When the torque is great, the front pins (and plug holes) can be deformed severely enough to prevent them from setting correctly. For example, the first pin can **false-set low.** Too much torque can deform the bottom of the top pin and prevent the bottom tumbler from reaching the shear line. This circumstance can be recognized by the lack of give in the first pin. Correctly set pins feel springy if they are pressed down slightly. A falsely set pin lacks this springiness. The solution is to press down hard on the first pin. Torque can be reduced slightly, with the attendant risk that other pins will then unset. It is also possible to deform the top of a bottom pin when scissored between the plug and shell above shear line. When this occurs, the pin is said to be **false-set high.**

29_1.5 Definitions

Certain terms define physical characteristics and mechanical operations relating to lock-picking.

Balanced Driver

A balanced driver requires that the dimensions of the pin-stack (driver and lower pin) be computed and adjusted so that the overall length remains constant. This is required in order that keys with high bittings will operate smoothly, and bypass by comb picks will be prevented.

Binding of Pins

Pins are said to bind during the lock-picking process. Binding is caused by an opposite rotational force being applied to the pins to trap them in the gap between plug and shell (shear line). Binding theoretically should occur in the order of pins farthest out of center alignment between the chambers of the plug and shell. This is referred to as the "order of picking."

In theory, only one pin will bind at one time, requiring

individual manipulation. In succession, the next farthest pin out of alignment will bind. As each pin is picked, it is trapped at shear line.

Breaking Point

The breaking point occurs where lower and driver pins are split, allowing creation of the shear line.

Comb Pick

A tool that resembles a comb, having the same number of teeth as there are chambers within a pin tumbler lock. The device will allow all lower pins to be raised above shear line, thereby creating a new shear line by which the lock can be opened.

Lock Pick

A pick is a device that is usually made of spring steel with a thickness of .032” or less, and is used to enter a keyway and manipulate the active components of a locking mechanism. Picks have many different designs in order to accomplish specified tasks during bypass.

Order of Picking

The order of picking refers to the sequence in which the tumblers, wafers, discs, or levers are set. It is dependent upon tolerance errors in chamber bores and their overall alignment, plug diameter, and other mechanical features. Theoretically, pins will set in direct relation to their deviation from centerline of the plug. The pin most out of alignment from the centerline of the bores will set first. However, this is dependent upon elastic deformation and the amount of torque applied during picking. Pins may actually set in any order, but will do so based upon tolerance errors.

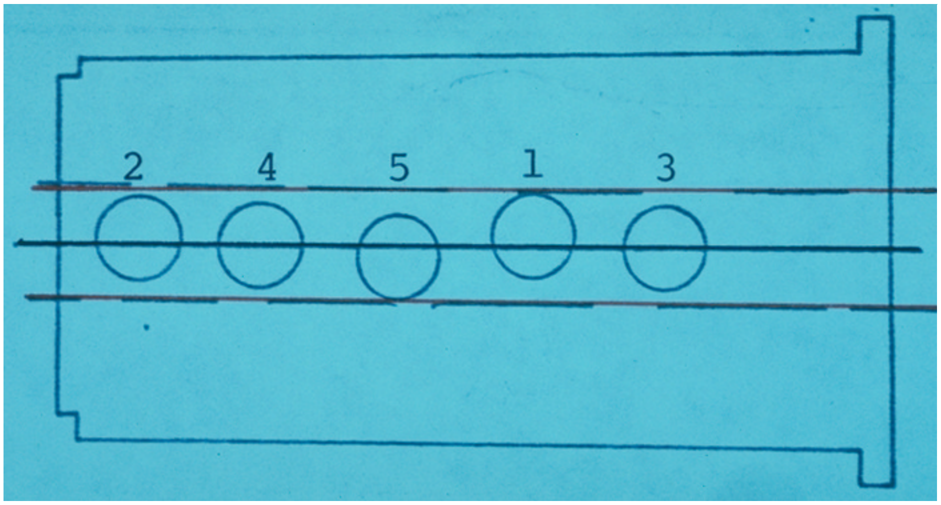


Figure LSS+2925, diagram showing order of picking, and the misalignment of the five chambers. Courtesy of Illinois State Police, Bill Sherlock.

Plug

The terms “plug” and “core” have the same meaning. A plug is the active component within the lock that contains detainers and is rotated to actuate a cam, bolt, or other mechanism.

Shear Line

The shear line is created by the gap between the plug and shell. It is the precise point where tumblers, wafers, or discs are “set” allowing rotation of the plug.

Sidebar Lock

A lock incorporating a sidebar mechanism, generally consisting of a secondary locking pin that must be retracted into the plug prior to rotation. This mechanism appears in both disc and pin tumbler locks. The sidebar was originally developed by Briggs and Stratton for automobiles and was introduced in the United States in 1935.

Setting a Pin

A pin, lever, or disc is “set” when it is trapped at the shear line by being physically stopped from protruding into either the shell or plug.

Tang

The tang of the torque wrench is that part which extends at right angles from the body of the wrench and is inserted into the plug.

Tolerance

Tolerance refers to the gaps, measured in thousandths of an inch, between moving and fixed components within the lock.
Lock-picking relies upon tolerance variations and cumulative errors.

Torque

The rotational force that is applied to the plug or tumblers during the picking process is known as torque. Its purpose is to exploit the binding affect of moving components. A torque wrench is employed for this process.

Torque Wrench; Turning Wrench

A device used in conjunction with a pick that provides the turning motion to rotate the plug and bind and set the pins, wafers, discs, or levers during the picking process.

Wedging

Opening a lock with a comb pick generally requires the use of a wedge to obtain sufficient pressure to drive all tumblers above shear line. The wedge is placed underneath the pick to provide leverage, allowing the springs to be crushed when the tumblers are elevated. Sometimes, enough pressure is applied to drive top pins out of the lock. High-security locks such as Medeco use setscrews to hold drivers in place. Otherwise, brass retainers can be forced out of position.

999 Rapping

This technique allows cylinders to be opened rapidly by inserting a specially cut blank that applies equal pressure against each lower tumbler. It simultaneously causes shock waves to the driver pins, thereby bouncing the driver pins above shear line momentarily.

SECTION 2:

Preliminary Considerations Prior to Picking a Lock: An Overview of the Successful Bypass

29_2.0 Introduction

To successfully open high-security and certified locks, planning, reconnaissance, experimentation, and a great deal of practice is often required and recommended. Especially in covert operations, time is generally of the essence. This means that the entry team must know the target lock: its specifications, differs, unique designs, idiosyncrasies, and special security features. Preparation is the key to success. Unless the entry team has opened the target lock on prior occasions or has had extensive experience with the same mechanical design, the chances of a rapid and successful opening will be greatly diminished, even with the most sophisticated tools.

The notion that high-security locks are bypassed by simply walking up to them, inserting a pick and tension wrench, working for a few seconds, and the lock is open only happens in the movies. Rarely is it the case in real operations. High-security locks are designed to be difficult and time consuming to open. That is the essence of UL 437 and other such standards. There are many issues to consider prior to actually beginning the process of picking a target lock. They relate to general considerations pertinent to all locks, specific problems that may arise or be caused by a particular mechanism, and detailed planning of covert openings.

The author, prior to an entry, always mentally reviews the following checklist. Most of the considerations are routine and automatically factored into the overall analysis of the lock in terms of its capability to be bypassed. It is important, especially for the novice, that the points raised in this section be fully understood and considered. Failure to resolve each issue can make lock-picking immensely more difficult or impossible.

29_2.1 General Considerations

- **Identification of the target lock:**

    - **Type of mechanism;**
    - **Number of pins, wafers, levers, or discs;**
    - **Likely direction of rotation of the plug.**
- **Are special tools required to pick the lock, or have special tools been developed for such purpose;**
- **Does the mechanism incorporate more than one type of locking system;**
- **Does the lock appear to be new or old; in good condition, or worn;**
- **Is the lock located inside or outside;**
- **What is on the other side of the door, and does that pose a danger;**
- **Why is the lock being opened;**
- **What is the familiarity with the lock and prior experience;**
- **What is the preferred method of picking;**
- **Can the cylinder be picked, or is it one that has been certified UL 437 or similar rating that will make the process very difficult, time consuming, or impossible;**
- **Is the lock operable;**
- **Can each pin, wafer, disc, or lever be manipulated with a pick to determine their number, whether each can be moved, and if each is spring biased;**
- **Should the lock be lubricated prior to picking. If the lock is going to impressioned, the answer is no. Otherwise, it may be wise to use graphite, LPS, solvent, aerosol cleaner, spray oil, ether, electronic contact cleaner, silicon sprays, automotive cleaners such as Gunk or carburetor solvents, or other non-lubricating spray cleaners to wash the keyway and pins. Dirt or grit makes picking difficult. WD-40 probably should not be used to clean a lock because of its ability to absorb water. When it mixes with graphite, it can cause difficulties.**

29_2.2 Planning the Bypass

- **What is the ultimate goal:**
    - **Surreptitious entry, one time only;**

   - **Generation of a key;**
   - **Multiple entries;**
   - **Remove, decode, and replace the lock;**

- **Examine the keyway to determine:**

   - **Room to work;**
   - **Clearance for movement of a pick;**
   - **Identification of the best pick to use;**
   - **Identification of the preferred tension wrench;**
   - **Where to place tension wrench;**

- **What method(s) of picking will be attempted;**
- **Which pick and tension wrench will be used as primary tools;**
- **How much tension is generally required for this type of mechanism;**
- **Is there another way to open the target lock;**
- **Are keys or key codes available;**
- **Can the lock be impressioned, and would that be easier and more advantageous than picking;**
- **Will keys be needed for the lock after entry;**
- **How much time is available to open the lock;**
- **What is the projected time that will be required to open the lock;**
- **Is there a way to bypass the locking mechanism without picking the lock;**
- **Is it possible to drill and replace the lock;**
- **Can the lock be decoded, either visually or through the use of a special tool such as the Falle-Safe Pin Decoder;**
- **If the lock is to be opened surreptitiously, be certain to return the plug to the locked position and verify that fact.**

29_2.2.1 Potential Difficulties that may be Encountered

Potential problems can be encountered depending upon many variables, often unknown until an actual attempt at picking is

begun. Problems may be both of a physical nature (to the lock and operative) and psychological. Depending upon the circumstances and constraints involved in the operation, the technician may be under high stress to perform. Such factors as time, danger, visibility, complexity of the lock, prior experience in opening the target lock or similar mechanism, risks of interruption, and consequences of being caught all must be considered.

- **Does the lock carry a high-security or certified rating;**
- **Does the lock utilize unique high-security features such as rotating tumblers (Medeco); rotating disc tumblers (Abloy, Abus); magnetic tumblers (EVVA, Chubb, Miwa); pick resistant lever tumblers such as used in safe-deposit, telephone, and vaults; sidebar (Assa, Schlage, Ikon, Evva, Medeco, Briggs and Stratton); multiple rows of pins used in dimple locks (Keso, DOM, KABA); high-security telescoping pins (Mul-T-Lock, Keso, Kaba);**
- **Is the manufacture known to utilize security tumblers.**

29_2.2.2 Choosing Lock-Picking Tools

Especially for the beginner, how to choose the correct lock-picking tools can be a difficult and confusing question, partly because commercial kits generally contain up to 100 separate items. The selection of which pick and tension wrench to use is based, at least in part, on the following criteria:

- **Type of lock mechanism;**
- **How the lock is mounted;**
- **Picking method to be used;**
- **Size and complexity of keyway;**
- **Pin, disc, wafer, or lever configuration;**
- **Required amount of torque;**
- **Bolt-actuating mechanism;**
- **Personal preference.**

Personal preference is perhaps the most relevant of all factors. The author utilizes only two or three different picks and a

couple of tension wrenches for most locks. The favorite is a long, combination hook-rake pick without a handle. A double-ended pick is very convenient for switching during the bypass process. Often, more than one pick is used to open a specific lock.

Some experts prefer picks with handles; others do not. Many claim that there is a loss of sensitivity. That may be true, but the author uses both rubber-coated picks and ones that are not. If picking many locks, a handle is preferred. Without a covering, fatigue can be a problem. Handles or rubber covering also allows the pick to be held like a pencil, very light-handed. Remember that the object is to feel the pins; anything that facilitates this is acceptable. Pick tips should rarely be broken. If they are handled properly, they will not break. This is especially true of the newer etched stainless steel varieties.

29_2.3 Eight Steps to Successful Bypass

In the author's experience, there are eight critical stages to successfully bypass a lock. These occur after acquiring the general proficiency in manipulation, and the understanding and ability to apply the techniques of lock-picking to a given mechanism. These stages are:

- **Understanding and mastering the fundamental theory of all bypass techniques. These involve the manipulation of active components that directly control the rotation or movement of a plug, cam, or other actuating device. Lock-picking theory encompasses:**
    - **Tolerance errors;**
    - **Knowledge of the design and use of bypass tools;**
    - **Determining which tools will best accomplish a successful opening, and knowing how to use such tools properly;**
- **Understanding the mechanical characteristics and theory of operation of the target lock;**
- **Analyzing the condition and design of the lock, plug, keyway, and active components;**
- **Assessing the factors that will make the lock easy**

or difficult to open;

- **Consideration of special entry conditions, limitations, hazards, or constraints;**
- **Familiarity with special bypass techniques that have been developed for a target mechanism;**
- **Determining which tools will best accomplish a successful opening and knowing how to use such tools properly;**
- **Applying one or more techniques that are most likely to open the lock, taking into account all of the information known about the target lock, bypass techniques available, and the skill and expertise of the operative.**

SECTION 3: Picking Locks

The Process of Picking

Feel-picking individual pins, courtesy of Harry Sher.

Picking simulates the action of a key. The following generic description of the process is applicable to most disc, wafer, and pin tumbler locks. Information for specific locks is presented later in the chapter. The process described below applies equally to manipulation of individual pins and rake picking, although the focus is on conventional procedures (also known as feel-picking). The technique is different for raking, but the theory is the same. The **procedure** is different when mechanical impact devices are used.

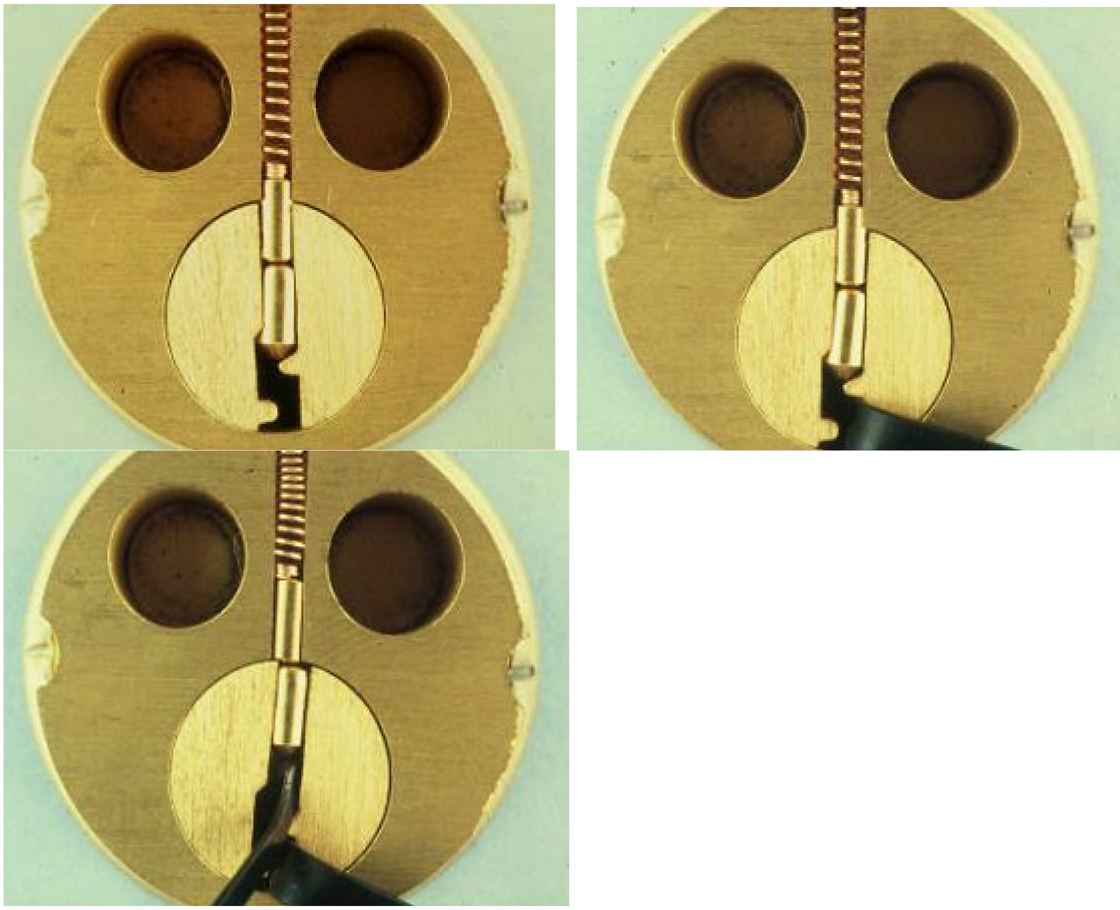


Figure LSS+2929 The process of lock picking requires the application of tension to the plug. A pick is then inserted to raise each tumbler, in order to bind it at shear line. Courtesy of Medeco.

The actual sequence of physical steps involved in picking and opening any lock, and more particularly a pin tumbler lock, require three distinct operations: **the application of torque, the manipulation of each tumbler, and the actuation of the locking mechanism.** If the lock fails to open, then the operative must **assess obstacles** that prevented a successful bypass, select different tools or techniques, and make another attempt.

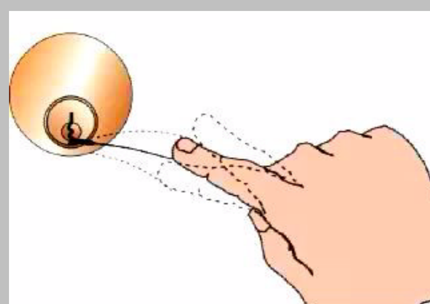
29_3.1 Theory: Apply Torque

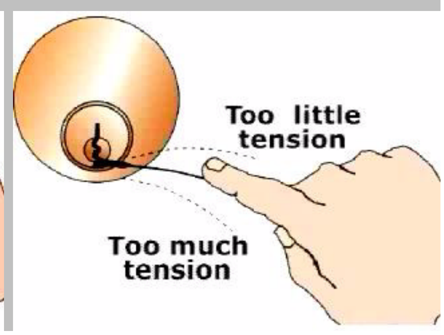
- **Provide varying amounts of tension, based upon:**
  - **The type of lock;**
  - **Experience of the operative;**
  - **Feel and sensory information from the lock;**

- Trial and error during the picking process;
- Once all tumblers are trapped at shear line, rotate the plug.

29_3.1.1 In Practice: Using the Tension Wrench to Apply Torque







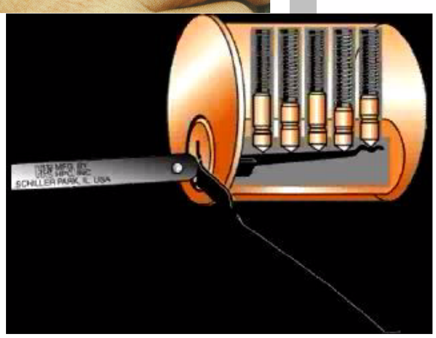








Figure LSS+2901 Methods of application of torque with the tension wrench. Courtesy of HPC Interactive Learning Series.

- **The application of torque allows the tolerance errors of a lock to be exploited in order to set pins at shear line. Often, too little or too much tension is applied, making picking difficult or impossible. During the picking process it may be necessary, as pins set, to increase or reduce tension to specific pins already picked. This is called correction tension. Properly applied, the procedure allows tension to be lessened or increased without affecting those pins that have already set. The technique is especially useful when security tumblers are encountered;**
- **The placement of the tension wrench within the keyway is a matter largely of personal preference, although the location of the wards is certainly a factor. The best place for the torque wrench, from the standpoint of control, is at the top of the plug. Because the torque is at the center axis, there is more room to manipulate the pick. Canting of the plug, causing binding, does not occur. Be certain that the wrench is actually applying torque to the plug;**
- **The properly designed wrench can be inserted at the top of the keyway. Ideally, the wrench should present not only a rotational force but also forward pressure against the plug to maintain its position. The tang will be shorter than the distance to the first pin;**
- **If the wrench is inserted at the bottom of the keyway, be certain that the tang does not dig into the soft brass. If this occurs, burrs can be**

created that may cause the plug to stick;

- **Inspect the keyway to select the proper tool. The tang should be snug when torque is applied. If the wrench is too narrow, it will slip. If too wide, it can require too much room;**
- **When inserting the tension wrench, do not interfere with the movement of the tumblers. Enough room is required to move a pick both horizontally and vertically. The tension tool can be placed at the top or bottom of the keyway, depending upon the design of the wards, vertical clearance, and required picking tools. Be certain that the tool does not contact any of the pins, nor restrict access to the keyway;**
- **When holding the wrench, use the index finger and not the thumb, to apply tension. The index finger is more sensitive; use of the thumb can result in the application of too much pressure;**
- **Begin with a light tension and increase as required. Initially, featherweight tension, approximating the weight of a penny, often works best;**
- **Apply torque to the plug so as not to wedge the bottom of the keyway. It is a common error to apply tension at an angle, thereby binding the bottom of the keyway. Different tension may be required to pick each tumbler;**

- **Tension is not a constant but a variable, dependent upon many factors. A heavy tension is required, especially in some high-tolerance locks. This can only be determined by feeling the spring bias upon each tumbler, then determining the order of picking. Once that order has been decided however, the actual tension required to pick the lock may be slight;**
- **The object in applying torque is to bind only one pin at a time. Too much torque binds more than one pin and can make the lock impossible to open;**

- **Torque should be applied based upon the type of lock and the feel of the tumblers. The application of tension is in large measure a personal preference. Some locks pick better with a featherlight torque; others require very heavy turning pressure. Begin**

with a slight tension;

- **The correct application of torque will result in the plug turning slightly as each tumbler is picked. Generally this is progressive, although when security tumblers are employed such turning will only be for a few degrees;**
- **Learn how to change picking tools while maintaining tension on tumblers that have already been set. This requires that constant tension be applied while switching tools;**
- **Learn how to switch tension wrenches while maintaining a constant tension. This is a bit more complicated and requires that a second tension wrench or small screwdriver be employed to maintain the position of the plug while a new wrench is inserted;**
- **When rake picking, often the tension must be varied slightly without releasing pins that have been set.**

29_3.2 Theory: Manipulate each Tumbler

- **Simulate the action of a key by individually raising each tumbler to shear line. Try to determine the "order of picking";**
- **Whereas conventional picking raises each tumbler in a specific order based upon tolerance errors and misalignment of the chamber bores, raking is the random simulation of the depth of each pin. Try raking the lock. Try picking and raking;**
- **Feel each tumbler at shear line;**
- **Split each tumbler at shear line, and retain the driver above the gap between plug and shell.**

29_3.2.1 In Practice: Manipulating with a Pick

- **The lock will tell you how it needs to be picked and the order of picking;**
- **Analyze the keyway. The pick must be able to meet each pin. There must be space to move the pick and to insert a torque wrench without touching the pins. If the keyway wards are slanted, then insertion of a**

pick at an angle will almost always result in a tumbler being raised;

- **A thorough understanding of the principles of the lock will insure successful bypass;**
- **In order to successfully pick any lock, manipulation of short pins next to long pins and long pins next to short pins must be possible with the selected pick tool;**
- **How far pins must be raised is determined by the length of the bottom pin;**
- **Do not use the pick as a lever. Generally, minute hand movements are all that is required to manipulate tumblers;**
- **Determine if the lock is mounted upside down;**
- **Decide the best place to insert the tension wrench;**
- **Determine which way the plug turns. Generally, mortise dead bolt cylinders mounted on left hand doors will pick counterclockwise (clockwise with right- hand doors). Usually, the bolt must go in the opposite direction of the doorjamb;**
- **Insert the pick into the keyway to verify that there are no obstructions;**
- **Test each spring for bias. Difficulties in picking can result from weak, broken, or missing springs. If there is a problem, try introducing a cleaning or lubricating agent. Heavy springs are generally easier to pick;**
- **Run the pick to the back of the keyway lift and lower the last tumbler;**
- **Count the total number of tumblers in the plug. The number of pins must always be determined in order to provide a reference during picking and to understand the potential difficulty of the task;**
- **Determine the condition of the pin-stack by running a half-diamond pick through the plug to test each pin. Make sure that each pin moves freely and is not sluggish. Oil or grease may have been used that can cause such a condition. Graphite will also cause problems in a humid environment or damp climate;**
- **Make certain that there are no foreign objects in the keyway or jammed pins, master pins, or a loose**

cam. A lodged pin may be cleared by trying one of the following:

- **Spray lubricant: run a blank or rake pick through the lock, then remove and clean;**
- **Compressed air: Do not use your mouth unless you like the taste of solvent;**
- **Bellows (used for enemas);**
- **Try picking: pins may be jammed at shear line;**

- **Select an insertion point for the tension wrench, and verify that there is room for the pick to move without restriction;**

- **Determine the order of picking. Conventional picking requires manipulation of one tumbler at a time. There is no set order, although it is preferred to pick from the back to the front. As each pin is set, there is an absence of spring bias upon that tumbler;**

The term "order of picking" refers to the alignment and tolerance of the bores or chambers with respect to centerline. The bore that is the farthest from center will theoretically be picked first. The next farthest bore would be picked second. Such order would continue, setting pins closer in alignment to the theoretical centerline of all of the bores.

Some locks will pick easier in one direction than another, especially if the pin chambers are not in perfect alignment. The same condition will occur when using a key. Depending upon the bolt works, this may or may not be an obstacle.

- **Select the appropriate tension wrench, based upon keyway design, clearance, type of bolt-actuation system, and personal preference, and apply tension;**
- **An absence of spring bias upon a pin does not mean it is set. Too much tension may have been applied, lodging the pin in the shell. Generally, as each pin is picked there will be an absence of spring bias on that pin. However, this does not mean that the tumbler is at shear line;**
- **If it is an interchangeable core lock and the**

control core is inadvertently picked, the assembly can be removed and the bolt actuated. Otherwise, the plug may be picked again to the conventional shear line;

- **Try raking the lock as an alternative to picking;**
- **Try a combination of picking and raking; the author often utilizes both procedures in one session;**
- **Try picking in opposite direction;**
- **Verify that the applied torque is sufficient to overcome the resistance of the bolt works;**
- **If a security tumbler is encountered, alter the amount of applied torque to set the pin. Release tension slightly, to attempt to set that pin;**
- **After a sufficient number of contacts with each pin during one picking session, release the tension and try again;**
- **If physical or mental fatigue or frustration causes a problem in acquiring sensory information, rest for a few minutes; it is amazing what a short interval can accomplish. Often, one can try to pick a lock for several minutes without success. After just a short break, the lock can be immediately opened;**
- **If the plug is picked in the wrong direction, use a plug-spinner to rotate in the opposite direction while maintaining a picked status. It is suggested that a screwdriver or tension wrench be inserted while manipulating the plug-spinner. If done correctly, the plug can be reverse-rotated without dropping any drivers into lower chambers.**



Figure LSS+2902 The use of the HPC Flip-it tool. The plug-spinner is a spring-loaded device that can spin the plug in the opposite direction without allowing driver pins to drop into lower chambers. This is especially useful if the plug s picked in the wrong position. To operate, the spinner main spring is wound; the tang is inserted into the keyway, and the spring is released. Photographs courtesy of HPC Interactive Learning Series.

Use of a plug spinner, courtesy of Harry Sher.

29_3.3 Theory: Actuate the Bolt, Cam, or other Locking Mechanism

- **Rotate the plug to the unlocked position.**

29_3.3.1 Practice: Retracting the Bolt

- **The bolt may require more torque than anticipated, causing the inexperienced technician to believe that the lock cannot be picked or that the plug has been picked in the wrong direction. This is especially true in the case of padlocks because of shackle pressure;**
- **It is sometimes necessary to switch tension wrenches, or use a screwdriver to turn the plug in such cases;**
- **Try to learn which way the plug is required to turn to retract the bolt;**
- **Look for a very slight rotation, indicating that the lock is in fact picked.**

29_3.4 Theory: Assess Obstacles to Successful Bypass

If the lock does not open on the first attempt, evaluate:

- **Was the lock actually picked, but the plug could not be turned due to the resistance of the bolt mechanism. Could this resistance have been misinterpreted as picking in the wrong direction;**
- **The plug may appear only to turn in one direction; this may be due to worn tumblers;**
- **Spring-bias error caused by broken, compressed, wrong spring, or too heavy a spring;**
- **Not enough room to move a pick, resulting in lifting more than one tumbler at a time;**
- **Wrong style of pick;**
- **Wrong picking technique;**
- **Secondary locking pin, restraining plug from turning;**
- **External mechanical problem which stops plug from turning;**
- **High tolerance between plug and shell;**
- **Too many tumblers;**
- **Long tumbler next to short tumbler;**
- **Made an error in counting the number of tumblers in the lock;**
- **Which way is the lock easiest to pick;**
- **Could any of the tumblers be felt when they set;**
- **Are security tumblers used? If so, in which positions;**
- **Did all but one tumbler appear to set? If so, a security tumbler was not picked;**
- **Could the order of picking be determined;**
- **Adapt torque and picking technique as required;**
- **Change picking technique from conventional to raking;**
- **Pick the lock an adequate number of times, utilizing techniques adapted to the specific situation;**

Difficulties caused by operator error:

- **Could each tumbler be felt during picking? If not:**
  - **Too much tension;**

- **Too little tension;**
- **Lock was picked in wrong direction;**

- **Pick and rotate to 180° and inadvertently drop one or more drivers into the bottom of the keyway;**
- **Pick in wrong order and release one or more tumblers by forcing lower pins into upper chamber.**

29_3.4.1 Practice: Correcting Errors in Picking

- **There are few errors that cannot be corrected during bypass attempts;**
- **If an error is made, simply attempt to determine both the problem and remedy. Often, errors will be complex, so it may be necessary to change several techniques;**
- **If a set pin is floating, there will be no tension;**
- **Some pins will set quite easily;**
- **If a pin is lifted against spring bias and it does not set, a release of tension will cause the tumbler to be forced downward;**
- **If a pin is set, gravity will cause the pin to fall but there will be no spring bias exerted against it;**
- **Sometimes, no pins will set. This can be caused by:**
  - **High tolerance;**
  - **Picking in the wrong direction;**
  - **Security tumblers;**
- **The tops of all bottom pins may be rounded to match the surface of the plug in order to create a closer fit, such as in the Mul-T-Lock;**
- **There may be a short pin below a long pin in the plug;**
- **There may be a bottom pin trapped above shear line;**
- **If a dimple pin tumbler lock is picked such as a Kaba, extreme caution must be exercised not to pick and rotate more than 20°. To do so may result in one or more tumblers falling into the keyway.**

29_3.5 Personal Comments and Observations About Picking

29_3.5.1 General Issues

The theory presented in this chapter provides the fundamentals to successful bypass. However, many issues can only be resolved through experience and practice. The following comments are of a general nature relating to difficulties experienced during picking.

- **The cost of the lock generally relates to its ease in picking. Cheap locks do not generally contain high tolerance components;**

- **Patience is required to pick some locks; it is a fact of the trade;**

- **Vary the tension, tools, and picking techniques. Locks generally may be opened using a variety of tools and procedures;**

- **Multiple attempts may be required. It may be necessary to pick a lock one or more times in order to effect an opening. The time required to pick any given lock can vary from five seconds to thirty minutes or more. Luck definitely plays a factor in the ability to open a lock;**

- **The time required to bypass a lock can be affected by additional issues, including:**

  - **Pressure that the operative is experiencing regarding the "window of opportunity";**
  - **Hazards that may be encountered;**
  - **Security or complexity of the lock;**
  - **Experience of the operative;**
  - **Importance of the assignment;**
  - **Fatigue;**
  - **Other factors.**

These matters should not be ignored when planning a covert operation.

29_3.5.2 Sensory Perceptions During Picking

Two basic questions are always asked by new students to bypass: **What sensations and information is felt during picking, and what is the lock supposed to feel like during the process.** The ability to feel and imagine what is happening inside of a lock is the primary critical skill of the accomplished lock manipulator. Sensory data is complex, and dependent upon many factors. An integration of the skill of the operative with the physical characteristics of the lock is required.

Essentially, what we feel is a very slight increase in the rotation angle as the correct sequence of tumblers is trapped at shear line. This “turn error” or added play is generally less than .002”. Sometimes an almost imperceptible click or snap is also heard or felt as each pin sets.

29_3.5.3 Specific Difficulties That may be Encountered when Picking Pin Tumbler Locks

Many difficulties can arise when picking a pin tumbler mechanism. Critical problems include:

- **Bad springs;**
- **Cold weather;**
- **High tolerances;**
- **Rotating tumblers (sidebar);**
- **Jammed plug, caused by dirt, residue, broken spring, stuck master pin;**
- **Mechanical jam;**
- **Damaged plug from warping caused by attack;**
- **Broken pick lodged in keyway;**
- **How the lock is mounted, resulting in access difficulties, limitations on freedom of movement for the insertion of pick and tension tool, and restrictions on rotation of plug;**
- **Security tumblers;• One or more tumblers at false shear line;**
- **One or more tumblers raised above the shear line;**
- **Jammed master pin;**
- **Mechanical jam that prevents plug from rotating although plug is actually picked;**

- **Physical fatigue and loss of sensitivity.**

29_3.5.4 Locks That are Master Keyed

As detailed in **Chapter 11**, most locks within a business, hotel, apartment, or large complex are master keyed. Depending upon the keying system and the characteristics of the lock, multiple keying levels can make picking a great deal easier. Master pins or spacers are utilized to create added shear lines and thus provide many more opportunities to set each pin. Generally, only two or three wafers will be used unless the system is extremely complex.

Often, a tumbler position having a spacer can be identified by feeling two clicks as the pin is lifted. However, if the wafer has a smaller diameter than the driver and lower pin, then there will be a springy region as the spacer passes through the shear line, because the pin will not bind. In many cases, the master pin is larger than the driver and lower pin. This situation is recognized by an increase in friction as the pin passes through shear line, and a more positive response when the pin is set.

Master pins can also cause serious difficulties in a plug where the chamber holes have been beveled, especially if heavy torque is applied. In this situation, the spacer can twist and jam at the shear line. In certain cylinders, it is also possible for the wafer to actually fall into the keyway if the plug is rotated 180°. To prevent this occurrence, place the flat side of the pick in the bottom of the keyway **before** turning the plug too far. If a master pin or driver does enter the keyway, thereby preventing the plug from turning, the flat side of the pick can be used to push the offending pin back into the shell.

It may be necessary to manipulate the torque wrench during this procedure to relieve any shear force that is binding the spacer or driver. If that fails, try raking the drivers with the pointed side of the pick. If a spacer falls into the keyway completely, the only option is to remove it. A hook-shaped piece of spring steel works fine for this, though a bent paper clip will work just as well unless the spacer becomes wedged.

SECTION 4: Ways of Bypass

Specific Methods of Bypass

29_4.0 Introduction

There are several universally recognized and accepted methods of bypassing a lock through the manipulation of active components. The techniques that are covered in this section include:

- **Conventional picking of individual tumblers;**
- **Rake picking;**
- **Rocker picking;**
- **Picking through the use of impact tools, such as snap guns and vibrating devices;**
- **Comb bypass.**

These standard techniques will not work with certain high-security and certified locks, including sidebar, rotating tumbler, special lever-tumbler mechanisms, and certain vending machine locks. Data regarding the bypass of these and other specialty locks is covered later in this section, and in **LSS+/^{x} CD/ROM.**

29_4.1 Conventional Picking

This discussion will focus on picking the pin tumbler lock, but in general is equally applicable to the disc, wafer, and lever locks. Specific techniques for bypassing these mechanisms are presented later in this chapter. The reader is directed to the preceding section for a detailed examination of the theory and practical aspects of bypass. Picking is actually a combination of individual manipulation and raking of some or all of the tumblers. Often, one or more pins are individually picked; then all of them are raked until the lock opens.

Almost all locks that have some form of shear line and tolerance errors can be picked. However, patience and skill are required to pick not only high-security locks, but some of the less expensive ones as well. Lock-picking relies upon a **negative locking theory**; the vertical binding of pins to block rotation always occurs, until the tumbler is lifted to the correct height. In contrast, impressioning relies upon a **positive locking theory**. It is desirable that the vertical binding of tumblers always occurs except when raised to the correct height.

The cost and security rating of a lock is only a general index to its pick resistance. Sometimes, even the most expert craftsman

is unable to open a lock regardless of cost or complexity. Often the use of different tools, a change in tension, variance of technique, or simply a short rest can mean the difference between a successful bypass and failure. Picking a lock in the conventional fashion is a rather straightforward procedure. That does not mean it is simple, but it can generally be done "by the numbers." As noted elsewhere, picking is based upon cumulative tolerance errors.

To pick a lock, the correct order of out-of-tolerance pins must be determined. That is, those pins that are farthest out of alignment on an imaginary centerline longitudinally across the plug will be bound first. It is a matter of physics. With torque applied to the plug, the pin that deviates the most from center alignment will be the first to be contacted when scissored between the plug and shell. The primary function of torque is to bind pins at that point where they are wedged at shear line. The "trick" in picking locks is to correctly determine the order in which the pins do in fact bind, then to cause each one to "set" at shear line and remain there. When all pins are so set or split (with the drivers residing above shear line and the bottom pins below the break), the lock will open because there is nothing to prevent rotation of the plug.

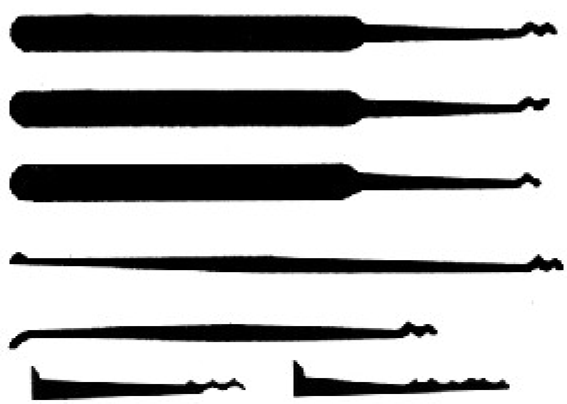
In its simplest theoretical form, lock-picking requires that **the correct order of picking be established; the proper torque be applied; each tumbler be lifted to shear line; and those pins which have been picked are retained in that position.** A detailed analysis of each of these procedures is presented in other sections so there is no need to repeat the material here.

Obviously, there are many obstacles between the beginning of this journey when the pick and tension tools are inserted into the keyway and the end of the trip when the lock is opened. Such matters as tolerance, keyway design, security tumblers, pin-stack configuration, master keying, locking mechanisms, and other issues can vastly complicate the procedure. Regardless of the type of lock, the theory is always the same. A. C. Hobbs, quoted in the introduction of this chapter, was precisely correct almost 150 years ago in his assessment of locks that could be picked.

29_4.2 Rake Picking

The technique known as raking or scrubbing is a shortcut for the traditional and more methodical means of picking a lock. Raking, when done properly, will open many locks quickly unless there is

a large difference between tumbler lengths. When raking a lock, no specific tumbler is targeted for manipulation; the rake is gently or vigorously moved across the pins, depending upon many factors.



In the author's view, much less talent and training is required to rake a lock, but the chances of success, especially with the more difficult locks, are greatly diminished. Having said that, however, raking may also make it easier to determine which pin sets first. Proficiency in raking does not require the same level of sensitivity, feel, and touch that is developed by a real practitioner.

Raking will always open **some** locks. Picking will generally allow bypass of **all** locks. Often, locks are picked **and** raked to accomplish a bypass. Raking can be analogized to driving a car. An inexperienced driver has no problem driving on a straight road. However, any turns, bends, or obstacles may cause difficulties, especially at high speed. So it is with raking.

A lock with similar bitting depths for all tumblers or a stair-step pattern with no security tumblers and poor tolerances will be easy to open. When, however, any of those parameters change, the inexperienced operative or one with little training in the real art of lock-picking will have trouble. Rake picking in many cases may allow rapid determination of which pin sets first, especially where all pins seem to bind and exhibit the same friction or resistance to movement.

Raking should place just enough pressure upon all of the pins to overcome the spring bias and binding forces exerted upon them, but not so much as to exceed the collision force of the lower pin traversing the shear line. Any pressure within this "window" will

suffice. In practice, any pick can be used for raking, although an actual rake pick may be preferred. The tip is run across the tumblers from back to front several times. This may raise some or all of the pins to shear line. If that does not occur, the pick may be moved slowly across each tumbler or each may be raised individually, often with varying tension. It must be remembered that raking is random action, with less precision than conventional picking. It really is the rapid manipulation of each tumbler.

As the pick passes over each pin, it will move that pin to the shell but not **through** shear line; the shell will block the movement of each tumbler unless too much pressure is applied. So, the trick is to apply **just enough pressure** and to allow flexibility in movement of the pick, so that it will ride over a pin when that pin is blocked from vertical movement at shear line. If any tumbler is forced into the shell, then one must start over. During rake picking, if the proper torque is applied and the proper pressure placed on each pin, the plug will rotate slightly as each tumbler sets. Concurrently, the driver will be trapped above shear line and the lower pin will fall to the bottom of the keyway. It is recommended that light then heavy tension be used, at least by the beginner.

In theory, one stroke of the pick over the pins will cause the lock to open, and sometimes that is indeed the case. In practice, at most one or two pins will normally set during a single stroke, so several passes are required. Thus, the pick is moved over the pins several times while the amount of torque is adjusted according to feel. Depending upon the lock's mechanical characteristics and those of the pin-stack, pins will tend to set in a particular order. The theory of why pins set is covered elsewhere in this chapter. Generally, a lock can be raked as a result of the misalignment between the center axis of the plug and the axis upon which the holes were drilled.

If the axis of the chamber holes is skewed from the centerline, then the pins will set from back to front when the plug is turned one way. Likewise, they will set from front to back if the plug is turned the opposite direction. Most locks will have this skewing error. Although raking can allow rapid opening, it still requires practice to become proficient. Many characteristics will inhibit the ability to open a lock in this fashion. In such cases, individual pins can still be raked.

29_4.2.1 The Procedure to Rake Open a Lock

This procedure is a generic description that is applicable to most disc, wafer, and pin tumbler locks. Information for specific locks is presented later in the chapter.

- **Insert the pick and torque wrench into the keyway. Without applying any torque, withdraw the pick to assess the spring bias on the pins to insure that there are no obstructions in the keyway, and to count the number of pins;**

- **Reinsert the pick, then apply a slight tension. As the pick is removed, apply upward pressure to the pins just slightly greater than the minimum force necessary to overcome the spring bias;**

- **Gradually increase the torque with each stroke of the pick until pins begin to set;**

- **Now keeping the tension fixed, rake back and forth over those pins that have not set. Be very careful to allow the pick to ride over set pins. This is the essence of raking: only apply enough tension to depress pins that feel springy or differently than pins that have already lodged at shear line. If no additional pins set after several passes, pick each pin individually or release the torque and start over, repeating the process;**

- **Once the majority of the pins have been set, increase the torque and rake with a slightly increased force. This will generally cause those remaining tumblers to set.**

29_4.2.2 General Rules and Principles for Rake Picking

There are a number of general principles and rules to successfully bypass a lock by raking:

- **Rake picking does not target any specific tumbler but rather applies force to each in a random fashion;**

- **The function of the rake pick is to randomly simulate the bitting of a key while applying sufficient torque to set each pin at shear line;**

- **The force applied to tumblers may be varied as the rake is passed across their surface. The range of force will depend upon many factors and include both gentle and vigorous motion;**

- **The pick must be free to come into contact with all pins;**

- **Light tension is generally preferred when first raking a lock to set any possible pins and to feel the status of all tumblers;**

- **After the first rake, one of three conditions will exist:**
  - **Pins are in an original position, not bound, at rest;**
  - **Pins are bound, but not set;**
  - **Pins are set;**

- **Remember: pins will only pick one at a time;**

- **Pins should be raked two or three times. If the lock does not open, then the tension should be released, listening to hear how many tumblers were probably set (indicated by clicking or snapping upon release). If pins did not set, then generally the cause is either too little or too much tension;**

- **Raking is generally accomplished on the outward stroke (removal of pick) rather than on the inward stroke;**

- **Often, tension must be varied during the picking process from slight to hard without losing control of the plug. This can be a tricky procedure, because there is a very slight range of torque that**

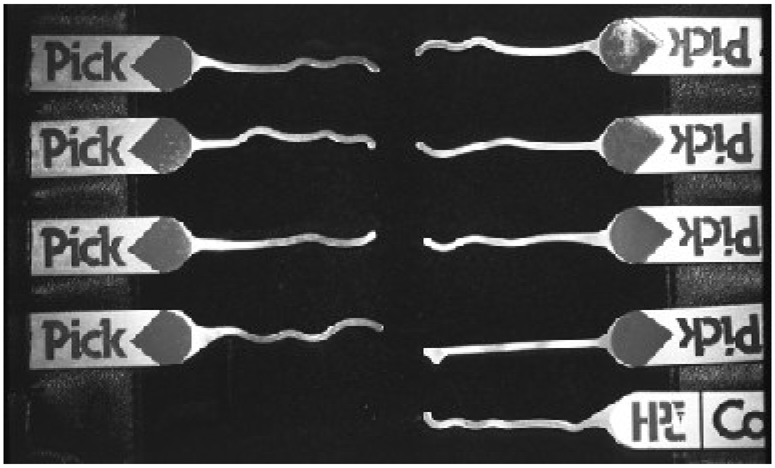
will retain set pins at shear line. For the beginner, the best learning exercise is to mount locks on a board and rake with only two or three tumblers inserted.



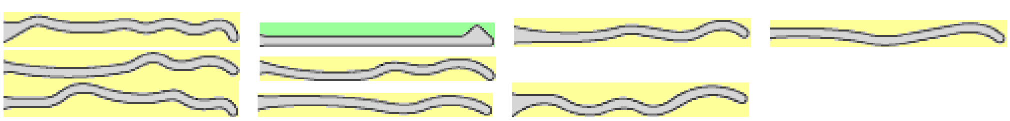
Figure LSS+2903 The pick must be free to access each pin individually without disturbing the position of adjacent pins. In the diagram, a rake pick has been inserted so as to reach the last tumbler. The photographs demonstrate how the pick is moved in and out of the lock. Courtesy of HPC Interactive Learning Series.

29_4.3 Rocking Open a Lock with Computer Generated Rake Patterns

A slightly modified approach to raking employs specially designed picks in a process called **rocking**. The procedure is different than raking, in that each pick in a series or set has a carefully designed signature of varying depth simulations. Rocker picks are not, strictly speaking, rake picks although there are some design similarities. They are often complex in shape and generally double-sided.



The procedure for this type of bypass requires that a pick be inserted fully into the keyway, then lifted and rocked in a vertically angled motion while applying torque. The theory is that at some point, random motion of the pick and the selected bitting pattern of the tool will lift each tumbler to shear line. Both sides of the pick should be utilized; light tension is recommended. HPC and other vendors produce rocker picks. The HPC Israeli designed series (HPC COMP-1) contains nine picks within the set and simulate various tumbler combinations, determined from computer modeling. These picks can be quite effective for opening certain locks. Various signatures are shown below.



29_4.4 Bypass Using Impact Tools

Use of a pick gun requires skill. It also leaves forensic indications. Courtesy of Hans Mejlshede.

A discussion regarding the impact pick gun, by Harry Sher.

How does impact picking work? Courtesy of Harry Sher.

There is a class of lock-picking tools that rely upon the generation of a mechanical shock or impact applied to the base of all tumblers simultaneously in order to bounce drivers into the shell for a brief window of time. These tools can be loosely categorized as impact guns or tools and are primarily designed for pin tumbler locks. Included in this definition are

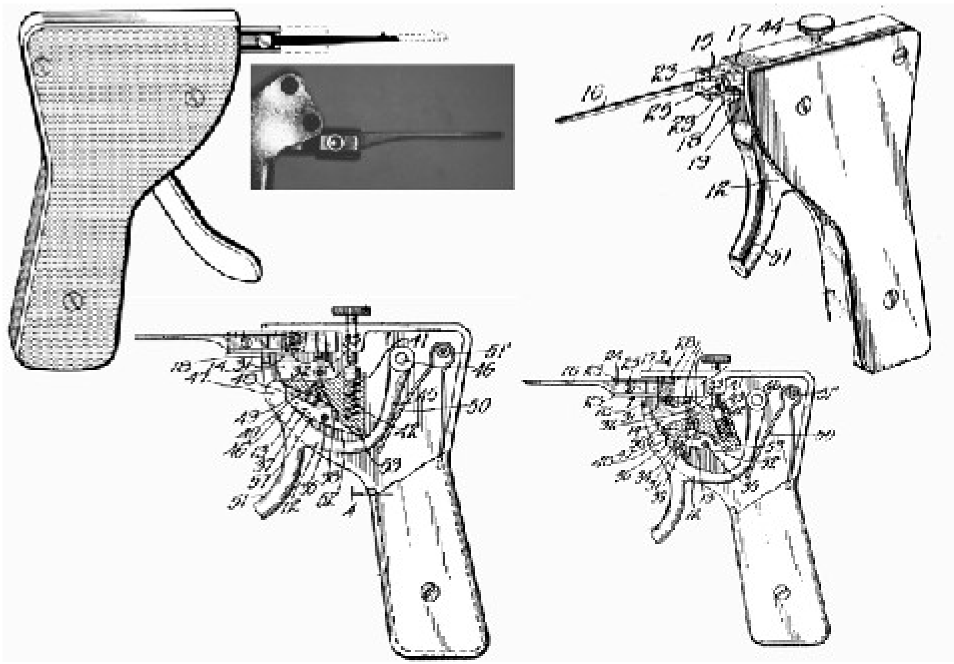
mechanical devices such as manufactured by HPC that transmit energy through a steel tip. The energy is generated by the operator pulling a spring-loaded trigger that moves the tip vertically. Depending upon the tool, the tip-travel and spring tension can be adjusted.

Vibration picks can be classed in the same general family. They utilize an electric motor to generate movement and different oscillations at the tip of a spring steel wire or blade. These tools can be quite effective in opening locks, especially those having security tumblers. However, they do require some practice and will not allow everyone to use them effectively. The author prefers conventional picking or raking and considers impact tools as gizmos and shortcuts to mastering the art of bypass.

Many law enforcement agents utilize impact tools because they have not acquired the traditional lock-picking skills that are customarily developed by a professional locksmith. Although these tools will open many locks, they are in the view of the author "gimmicks." They still require talent and an understanding of their working principles. They offer the promise of instant success without learning the complex theoretical and mechanical underpinnings so necessary to operate in today's security environment. Any competent criminal will usually install high-security locks in their homes, offices, safes, storage enclosures, and anywhere else that will contain the evidence or the fruits of their crimes.

Sophisticated criminals have a far greater ability to afford the best in security hardware. Impact-type tools may open some of these locks, but they should only be viewed as one tool in the arsenal of the covert entry team. These devices should never be thought of as "the" entry tool, nor should be relied upon in such instances. Pick guns, in many forms, have been the subject of U.S. patents. As early as 1927, percussion and violent rotational force was employed as a means to open pin tumbler locks (**1667223(259)** and **1639919(260)**). See also Epstein and his 1923 patent for a impact producing implement (**1450435(261)**), and (**1403753(262)**) by the same inventor in 1922.

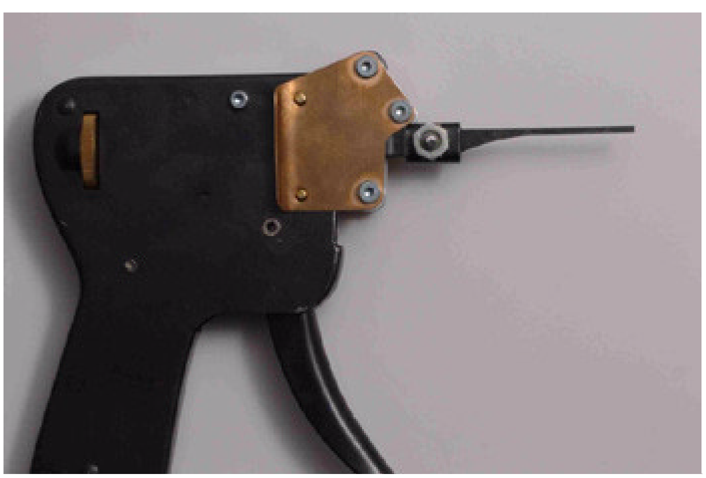
29_4.4.1 Snap Gun Construction



Exploded views 1, 2. There are many different tips available for the HPC pick gun.

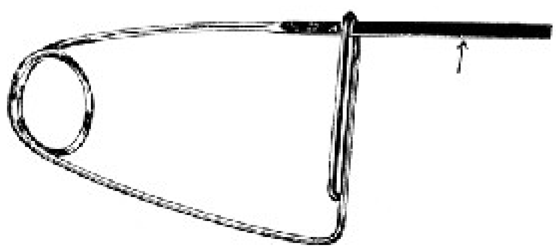
 **The use of pick guns and forensic analysis of locks. Courtesy of Hans Mejlshede.**

Mechanical snap guns generally are constructed with a pistol grip, trigger, and removable blade that is either straight or angled. The tool is operated by placing the blade under the pins and squeezing the trigger. This causes a spring within the pistol to retract and release, violently moving the blade in an upward direction.



This pick gun is unique, in that the blade can be reversed for use on European profile cylinders. It was developed by Kurt Zuhlke.

Other similar tools operate on the same principle but have slightly different designs. A piece of wire fashioned as a spring can be as effective as the electric vibrating gun, detailed below. It appears that the first snap guns were patented by Wakstein and Hanflig in 1934, then by Segal in 1943 and Miskill in 1951, (**1944006(263)**, **2309677(264)**, **2565254(265)**). See also Wakstein (**1977362(266)**).



29_4.4.2 Theory of Operation

All impact tools operate upon the same principle and which is discussed elsewhere in this text. Essentially, energy is applied to lower pins that in turn is transmitted to driver pins. If done correctly, in terms of force, angle of contact, and consistency between all pins, then all drivers will for a brief period, float or reside **above** the shear line. If a rotating torque is applied during this brief interval, then the plug can be turned.

The actual physics of the tool is based upon Newton's Third law of motion. The snap pick has been used by locksmiths since at least 1934, when the first patent appears to have been granted for such a device (**1944006(267)**, **2565254(268)**, **2309677(269)**). Snap guns cannot be used as a conventional picking tool; they are designed to act upon **all** tumblers at one time, rather than individual pins. Several factors determine whether the lock will respond to this type of manipulation:

- **The shape and design of the keyway will control how the tip makes contact with the tumblers and its vertical freedom of movement. The pick must be able to move without obstruction. Paracentric keyways**

can pose a serious problem;

- **The thickness, condition, and length of the tip of the impact tool must be correct. The tip cannot be distorted or bent and must be long enough to make contact with each tumbler. The tip material must be thin enough to move about freely in the keyway just below the pins. There can be no sharp edges or burs on the tip or along its surface;**

- **The vertical orientation of the tip must be correct so that the center of each pin is struck, rather than the sides or chamber walls. The position of the pick and its angle of attack is critical;**

- **The pick strikes the pins, causing them to bounce. It does not vibrate or oscillate as with an electric vitiation tool;**

- **The condition of the springs in each chamber will determine how each pin moves and what force is required;**

- **The length of the tumblers, their metal content, and weight will determine how much force is needed to move them above shear line;**

- **The precise time when torque is applied will determine if the plug can rotate or if one or more tumblers are caught in the lower chambers;**

- **The presence of foreign materials such as dirt, oil, or debris can affect or retard the ability of pins to freely move within each chamber.**

See the description in **Chapter 26** for added information.

29_4.4.3 General Rules and Principles for the Use of Impact Pick Tools

There are a number of general principles, guidelines, and rules for the successful and proper use of impact picking tools.

Failure to follow these guidelines will result in increased difficulty in opening locks or the inability to bypass certain mechanisms. This discussion primarily applies to snap tools, although the principles are similar for electric vibrators.

- **Impact tools present a totally different method for bypass. The tools cannot be used to manipulate each tumbler individually. Do not attempt to pick each pin;**
- **When squeezing the trigger, do not move the gun up, down, or to the side;**
- **The blade must strike all pins at the same time. An offset blade, which requires holding the gun at 90°, are quite difficult to control. The top of the blade must be exactly parallel to the shear line, with no sharp edges or burs;**
- **If a thinner blade is required due to the design of the keyway, then material should be removed from the tip;**
- **The angle of attack must be 90° ±4°. The blade cannot be successfully used in a slanted keyway. There can be no angled upward pressure on any pin; the strike must be from below the center-point of the tumbler;**
- **The tip strikes the pins, transmitting a reaction to abutting tumblers. The pins do not actually vibrate or oscillate. The tip cannot be distorted or bent;**
- **The intensity and range of movement of the tip must be adjusted depending upon the bias placed on the tumblers by their springs;**
- **The pick should not be wiggled or jiggled in the lock. It does not work that way;**
- **The sides of the keyway nor back of the plug should ever be touched by the pick tip;**
- **The correct amount of tension must be applied precisely at the moment that all pins are above shear line. Do not apply too much tension or the pins will bind. Begin with a slight tension, then increase it as required. A standard tension wrench or the blade of the tool can be used to create rotational force. The application of tension is critical to the success of the process. Too much**

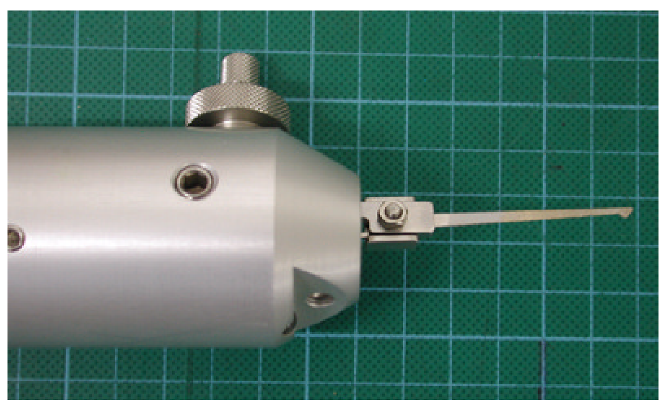
torque will result in a binding of both bottom and top pins and will prevent the top pins from being bounced above shear line. Too little tension will result in both bottom and top pins being moved by the force from the vibrating tip. The optimum torque will bind the bottom pins, but not the top pins, allowing the shock from the pick to be transmitted through the bottom pins, but not moving them.

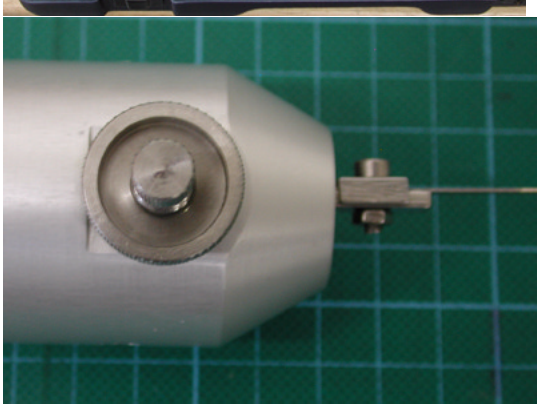
- **Do not apply tension prior to a release of energy from the gun;**
- **The active motion of the pick is in the upward direction; no tumblers are picked during the downward stroke or below the pick.**

29_4.4.4 Electric Vibrating Tools

Many companies produce vibrating pick guns. The design allows the tip to move at various frequencies or intensity. MSC produces a well engineered tool that allows a variety of different tips to be inserted. An LED provides illumination to the surface of the keyway.







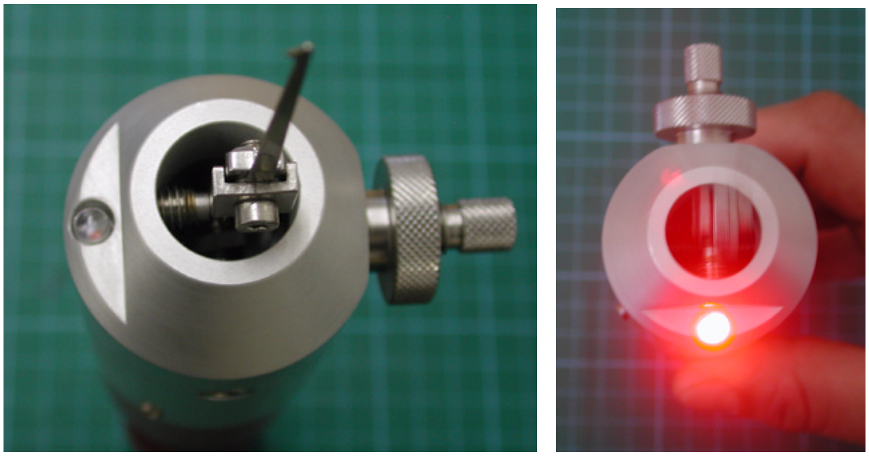
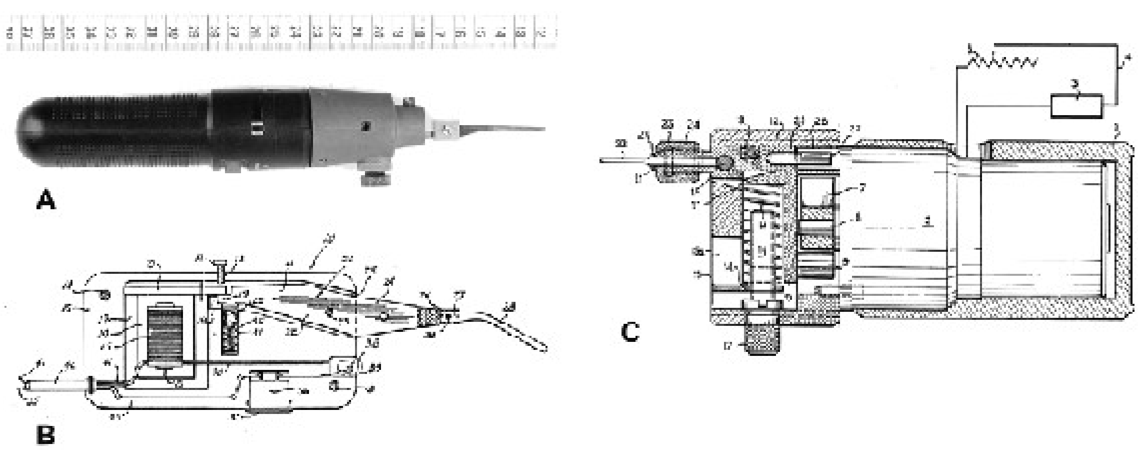


Figure LSS+2932 The MSC Electropick allows controlled manipulation of pin tumblers.

LSS203: Demonstration of the MSC electropick on a profile cylinder

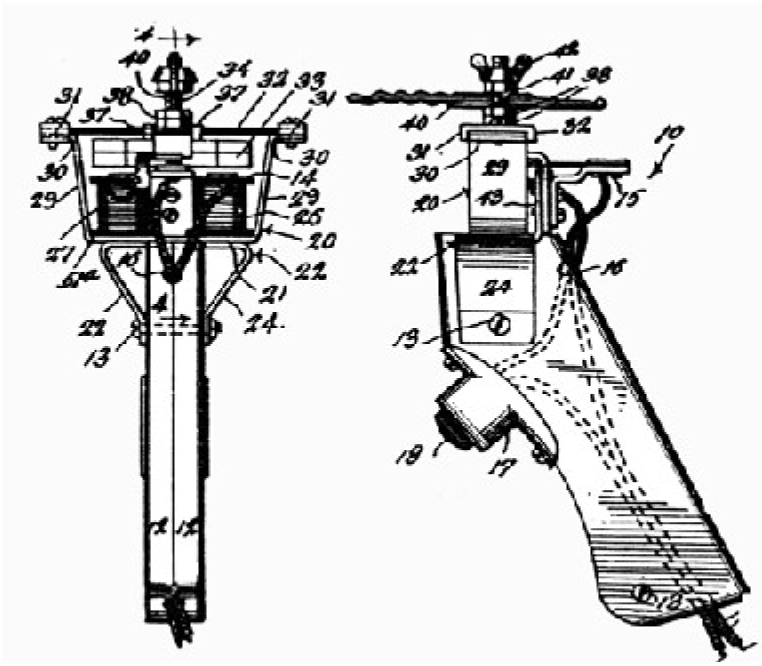
The HPC tool creates oscillations of varying intensity, depending upon blade setting. The tool's operation is based on the same theory as the snap pick, with slight variance.





Exploded views 1.

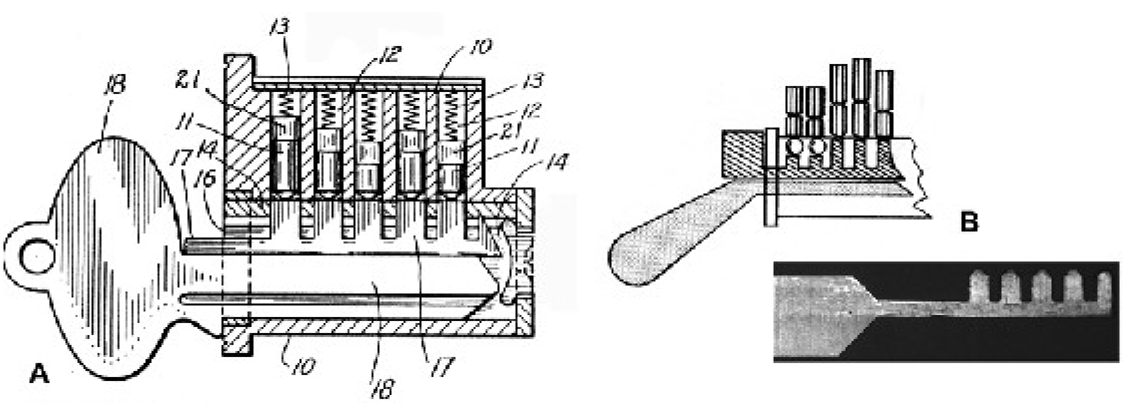
To bypass a lock, the blade is inserted into the keyway to contact the base of the tumblers. The fundamental difference in operation to the snap tool is that tension can be applied while the lock is vibrated, so that the tool resembles an automated rake pick. In the alternative, pins can be vibrated and then torque applied as with the impact tool. Torque can also be applied with a tension wrench or the blade of the tool itself. This tool can be extremely effective in opening some locks, with little or no experience with bypass. Two electrically powered snap pick guns have been patented in the United States: one driven by a solenoid (in 1979), and an earlier version controlled by an electromagnetic coil (in 1966) (**3264908(270)** and **4156375(271)**).



Exploded view.

29_4.5 The Comb Pick

The comb pick has probably been in existence for over a hundred years. Its success relies upon a manufacturer's failure to utilize balanced drivers in pin tumbler locks, thereby creating the ability to force all lower pins above the plug. When this occurs, the teeth of the comb will in effect create a new shear line.



In the properly pinned lock, each pin-stack has the same length. That is, a short bottom pin will have a correspondingly longer driver. If the bottom pin is for a deep cut, then the driver

will be that much shorter.

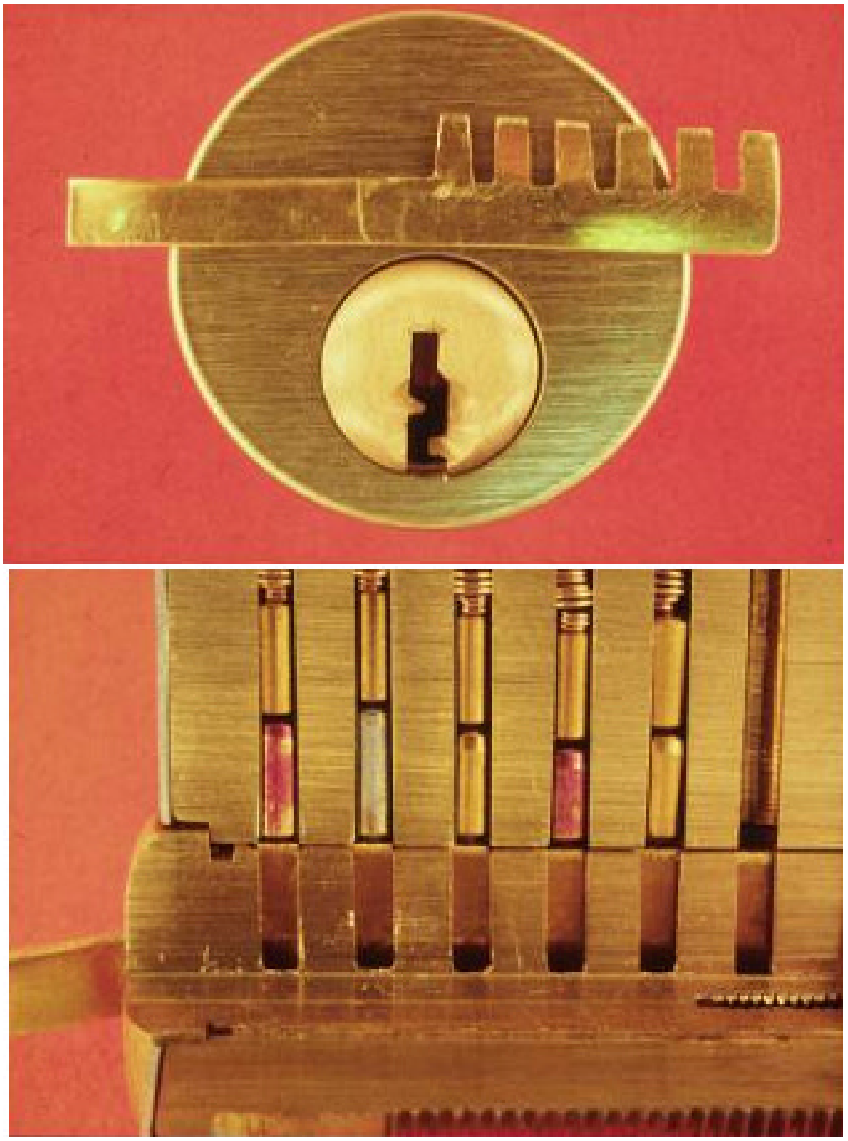


Figure LSS+2930 photographs showing how the comb pick creates a new shear line. Courtesy of Medeco.

The overall length of the pin-stack is computed by adding the length of a compressed spring and all pins within a chamber. The pin-stack must be longer than the vertical dimension of the upper chamber. If not, then all pins in the stack can reside in the top chamber, and there will be nothing to keep the plug from rotating. A U.S. patent was granted for a comb pick in 1936 (**2064818(272)**). Corbin locks manufactured from 1902 to the mid-1960s were particularly vulnerable to comb picking because they utilized a .116" ball bearing in each pin chamber to reduce

wear in high traffic cylinders. The comb pick would utilize the bearings to create a unique shear line and thus presented a serious security issue.

29_4.6 Shimming Open a Lock

As described elsewhere in this text, shimming using a fine wire can open a pin tumbler lock. This practice is utilized for three distinct procedures:

- **Lock disassembly where no key is available;**
- **Decoding of the lock using the Falle-Safe Pin Lock Decoding system;**
- **A method of forced-entry that requires drilling a tiny hole in the front of the lock.**

The theory underlying all shimming procedures is straightforward. A very thin wire with a thickness of between .0015" and .002" is inserted between lower tumblers and drivers, at shear line. The shim splits the pins, mirroring the physical characteristics of the correct key. Depending upon the technique, the shim can be inserted from the back of the cylinder for disassembly, from the front of the cylinder for covert entry, and from the base of the pins to decode their length.

29_4.6.1 Falle-Safe Decoding System

The Falle-Safe Pin Lock Decoder is described in Chapter 31. It is a sophisticated and highly precise tool, originally developed for use by government intelligence agencies. It allows the insertion of an extremely fine shim wire between the pin tumblers and their chamber walls to measure the exact length of each lower pin.

29_4.6.2 Drilling and Shimming

This procedure requires that a very small hole be drilled through the front of the cylinder, corresponding with the precise location of the shear line. An extremely fine wire is then inserted, while a pick is used to raise each tumbler (from front to back) to shear line. The wire is forced between upper and lower pins until it reaches the last pin. At that point, a shear line has been created by the wire: all drivers are above the wire, and all lower pins are below it. The plug can be turned and the bolt actuated. The pin lengths can be measured while the

lock is in the picked position to allow generation of a key. The hole can then be filled, erasing any trace of the procedure.

29_4.6.3 Lock Disassembly

Often, a cylinder must be disassembled for which the keys have been lost. Although this practice has been detailed elsewhere in this book, it will be summarized here. It is in fact the exact same procedure as employed when **drilling and shimming** described above with slight modification. The theory underlying this technique is that a fine shim wire can be forced between top and bottom tumblers to create a shear line. The wire is inserted into the gap between plug and shell from the **rear** of the lock after the cam and retaining screws have been removed. The operation requires two actions: insertion of the wire with a constant pressure applied to it, and the raising of each tumbler in succession, from the rear of the lock forward using a blank key.

Shims may be purchased or they can be produced by cutting mainspring wires from watches and clocks. Often, a curved tip is easier to insert between pins. The author prefers a shim having a width of at least .0625." If the end becomes damaged, it is simply cut with scissors. Security tumblers, except for serrated ones, can be shimmed in the same fashion. However, remember that some pins may be found in upper chambers. To shim open the lock, the following steps must be accomplished:

- **Insert the wire at shear line from the rear of the lock;**
- **Advance the shim until it contacts the first pin-stack and apply pressure. Do not apply too much pressure, however, or this can prevent the bottom pin from falling, or the tip of the shim can be deformed;**
- **Insert a blank key completely into the plug;**
- **Remove the blank slowly until the wire catches at the split between top and bottom pin. Feel the pin as it scratches the side of the shim. The minute gap between top and bottom pin can be felt;**
- **Move the blank back and forth, if necessary, to manipulate the pin that is to be split by the shim. Do not move the blank forward when manipulating a single pin. The blank may, however, be withdrawn**

slightly and then pushed back into a position to move the pin up and down. If an attempt is made to insert the blank to raise a pin that has already been split, the shim will be deformed or dimpled and may be difficult to remove;

- **It is sometimes difficult to lodge the shim between pins. It may be necessary to raise and lower a pin several times with just the right pressure in order to lodge the shim at shear line;**
- **As each pin is split, the shim will move forward across the plug: the blank will not be able to move as far toward the cam;**
- **When the last pin has been split, turn the plug at least 20° and remove the shim;**
- **Withdraw the plug with a following tool.**

29_4.6.4 Picking with a Blank Key

A blank key can be utilized to open some locks, much the same as if a shim were inserted to the rear of the plug. The theory is that a slight torque is applied as a blank is slowly withdrawn. As it moves across each tumbler, the lower pin will drop to the bottom of its chamber if the right amount of tension is applied. A major European lock manufacturer was quite embarrassed to learn that one of their profile cylinders could be opened in like manner with one hundred percent repeatability by using a blank key. Upon being notified of the problem after the locks were released to different customers, an investigation revealed that one manufacturer in the group was pinning the plug, while another inserted springs and top pins into the shell. The cylinder and plug were mated at one of the factories and repinned with the correct combination for a specific customer. The pinning by two different automated facilities was done for efficiency. Unfortunately, the diameter of the top and bottom pins were slightly different, although the diameter of the chambers was correct, and sufficient to allow proper vertical movement. The author tested one of these locks and found it to be extremely easy to open within a few seconds.

29_4.7 Multiple Tumbler Sets and Cross Picks

LSS203: Demonstration of the MSC cross pick on a lock with four rows of

tumblers

Locks may contain multiple bitting surfaces to provide added protection against picking. A number of picks have been developed to manipulate all of the rows of tumblers at one time, much like a rake pick. MSC in Hamburg, Germany makes a pick to open three and four rows of pin tumblers. As shown in the video demonstration, the pick is raked across the pins simultaneously while tension is applied.

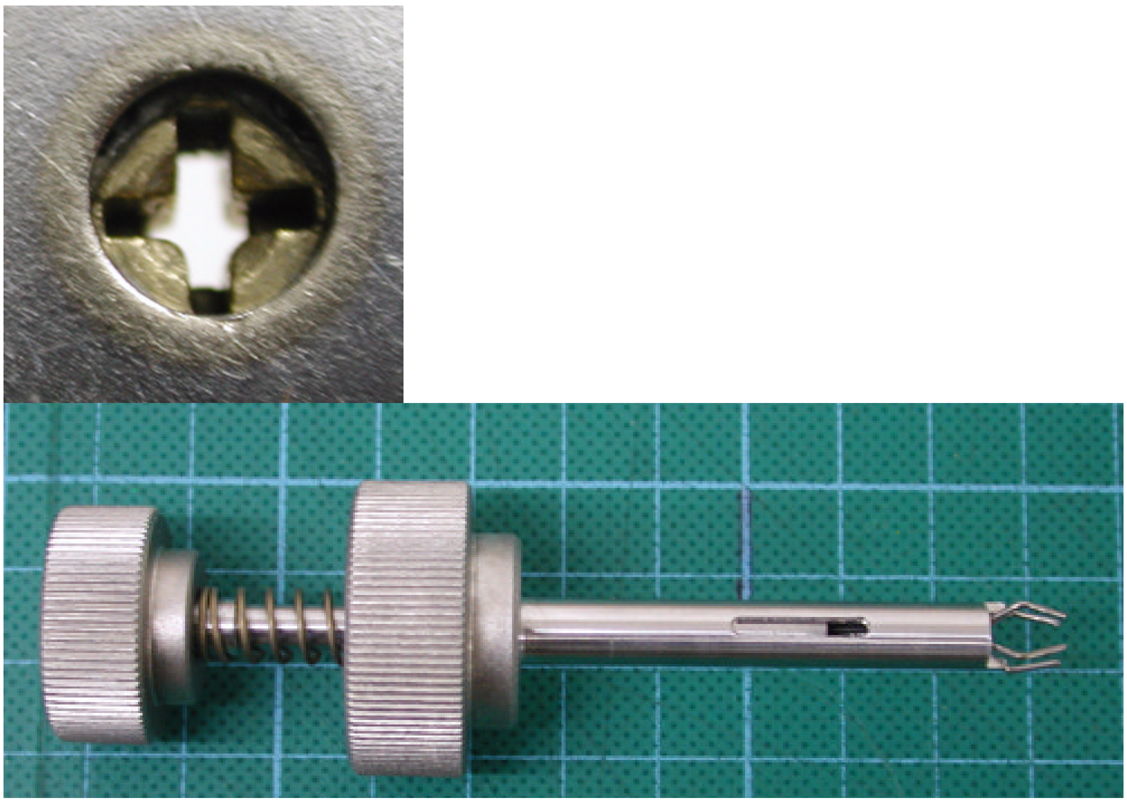


Figure LSS+2931 The MSC cross pick has four protruding wires that make contact with each row of tumblers, as shown in the lock. Each set of pins is manipulated at the same time.

SECTION 5: Skills Acquired

Developing Lock-Picking Skills

29_5.1 The Basic Skills

It should be obvious to the reader that picking a lock is a

complex process encompassing many variables. Although with practice most obstacles are overcome more or less automatically, one must develop specific skills by addressing each unique mechanical characteristic. Lock-picking skills require a great deal of time to perfect. Knowing the theory of bypass is a small step in acquiring competence in the art. A. C. Hobbs was one of the greatest lock pickers. He summarized the characteristics required of one who wishes to be effective at bypass:

- **Ingenuity in the development of tools;**
- **Able to assess the invisible anatomy of a lock mechanism;**
- **Patience and persistence;**
- **Fundamental knowledge of the internal workings of the lock;**
- **Self-confidence.**

Hobbs felt that one must also have an inborn skill, delicacy of touch, and an ability to memorize numbers and calculate permutations. Finally, he stated that the expert must be able to accumulate knowledge about people's minds and the way that they think. The author recommends certain exercises to hone skills, especially for the beginner. It is much like learning to fly an airplane; one practices stalls, dives, climbs, adjusting to wind and other variables in order to become proficient. Lock-picking is no different.

The exercises outlined in this section should be completed in short sessions; they can be fatiguing, with diminishing results. After a few minutes, fingers can become very sore and a resultant loss of concentration will occur. If the ambient temperature is either hot or cold, even more difficulty can be encountered. It is also recommended that for the beginner, a lock having only two tumblers be mastered first in the practice exercises; then slowly, more tumblers are added until a six or seven-pin lock can be opened. Locks should be mounted on a practice board or door so that variance in picking techniques and tension can be mastered. Picking cannot be learned by holding the lock by hand during actual tumbler manipulation because such does not simulate real conditions.

To learn about the lock and its mechanical configuration, it is recommended that the plug with lower pins be held in the hand. Run a hook-pick through the keyway, thereby demonstrating how each pin is raised to shear line and the minimal effort required

to do so. This technique will provide a feel of the pins and the movement of the pick inside of the lock. Practice by moving each of the pins to shear line. A cylinder with one pin (such as a Schlage 923) should then be used. Start with one long pin in the #3 position. Light tension is applied. Learn the feel of one pin and spring.

Remember that much of picking is a state of mind, believing that the lock can be bypassed. A five-pin lock with one tumbler set becomes a four-pin lock. When a lock is approached, a great deal of analytical thinking may be required to successfully bypass the mechanism. Certain things may be known from prior experience, industry reports, or knowledge of fellow craftsman.

As previously noted, each lock has its own special characteristics that will affect the ease with which it is opened. The recognition and exploitation of "personality traits" of a lock separates experts from amateurs. Locks will talk about themselves: they will provide feedback to diagnose traits. It is then a matter of relying upon experience to decide on the correct approach for a successful opening. This process may occur in seconds or may require some planning. In high-security bypass scenarios, it is always best to practice on sample cylinders before attempting an actual opening. This is especially true if sophisticated decoding methods are employed.

The novice will generally underestimate the analytical effort that is a necessary part of lock-picking. Incorrectly, they often think that the pick opens the lock, and that the torque wrench is a passive tool that simply places the required tension on the plug. In truth, many factors and forces come into play during the process.

29_5.1.1 Basic Skills: Lock-Picking and Hand Coordination

Mastering the correct method to move the pick over wafers, discs, levers, or pins is surprisingly difficult. This is because of the requirement to maintain a fixed position or path for movement, independent of the amount of force to be exerted. Lock-picking requires the application of a relatively fixed force that is independent of the position of the pick. However, that force may instantly vary, depending upon the feedback (resistance) received from each pin. That feedback is based upon feel and sound. A great deal of practice is required to acquire this skill.

29_5.1.2 Basic Skills: Lock-Picking and Analytical Thinking

Because the internal components cannot be seen during lock-picking, their position must be visually reconstructed from the information gathered from sound, touch, smell, and vision. That mental image is the key to successful bypass. Lock-picking consists of the exertion of pressure to move active components (discs, wafers, levers, tumblers), and the coincidental application of torque upon the rotating plug, in order to bind the pins and trap each of them at shear line. A number of training exercises can enhance the ability to successfully bypass a lock. These are detailed below. At all times while picking a lock, one must:

- **Know what is happening inside of the lock;**
- **Know when a pin is binding;**
- **Know when a pin-stack is not bound;**
- **Know when a pin-stack is set.**

29_5.1.3 Bouncing the Pick

This exercise enhances the ability to move the pick over tumblers with a fixed pressure while sensing the resistance of each pin. Learning how to hold the pick so that the exerted pressure is controlled by the fingers or wrist rather than elbow or shoulder is most important. Focusing on the tip of the pick and where it is making contact is of equal significance.

Generally, three fingers are required to hold, balance, and control movement of the pick. Which fingers are used is a matter of personal choice. One popular method is to utilize two fingers to provide a pivot point, while another provides vertical leveling and pressure. The pick may also be held like a pencil. With this method, the wrist generates the pressure; the shoulder and elbow provide the force to move the pick in and out of the lock. The wrist should not be used to move the pick **and** apply pressure.

An excellent way to learn the feel of a pick tracing the contour of the pins is to move the rake over the tumblers of a picked lock, with the plug being slightly rotated. The pins cannot be extended into the shell, so the pick must adjust to the contour of their height to shear line. Rapidly moving the pick in and out

of the keyway will cause a rattling sound to be heard and felt. It is this same feeling that will indicate that a pin has been set. Failure to hear or feel this rattle will indicate a falsely set tumbler.

29_5.1.4 Setting Picking Pressure

One of the problems for new students is learning how much pressure to apply during picking. Although such pressure will vary, there is a range of force that must be learned. Initially, the novice will apply pressure only on the outward stroke when the pick is being removed. With practice, pressure can also be applied on the inward stroke.

Minimum force can be considered as that which is required to overcome the spring bias on the first pin, without any torque being applied. This can be felt by applying pressure against the pin with the flat side of the pick. Remember that the spring force increases as the pin is depressed; the number of pins with which the pick comes into contact also becomes greater. Initially, no torque should be applied. Exert enough pressure to press each pin into the shell. Each pin should spring back as the pick moves past. There is an associated snapping or clicking sound and springiness. Count the number of pins as the pick is withdrawn.

Maximum pressure is achieved when all pins are depressed and torque is applied. This is a variable, because the amount of tension is directly proportional to required lifting pressure. This exercise will define a “pressure window”, within which the pick must be manipulated.

29_5.1.5 Torque: How Much, When to Apply It, and to Which Pins

The purpose of the pick tool’s first contact with each pin is to receive information about the lock and its quirks. An analysis of that information allows the torque to be adjusted, causing the pins to set at shear line. It is the torque wrench that opens the lock, based upon the proper manipulation of each tumbler. Beginners may fear applying too much tension and doing damage to the lock. It is impossible to apply a force that will shear pins. Thus, there is no harm in applying either too little or too heavy a tension, other than in creating frustration at not being able to open the lock.

Varying the torque as the pick moves in and out of the keyway is one method to get around several picking problems. For example, if the middle pins are set but the ends pins are not, one can **increase** the tension as the pick moves over the middle pins. This will reduce the chances of disturbing those correctly set tumblers. If a certain pin doesn't appear to lift high enough as the pick passes over it, a reduction in torque may remedy the problem.

Torque control during picking is a real skill; it requires a great deal of sensitivity, practice, and hand coordination. There is no set answer as to how much torque to use for a particular lock or type of mechanism. Each practitioner will develop certain preferences for each kind of lock. That insight can only be gained through practice. The application of torque during picking is the opposite of the rotational force applied when using a key. In the former, tension is first applied, then pins are raised to shear line. In the latter, the key is first inserted and all pins properly aligned, then torque is applied.

29_5.1.5.1 Establishing Picking Torque

Torque must be properly integrated with pressure to be effective. This exercise will teach the range of torque needed to properly set tumblers. The minimum torque will be just sufficient to overcome the friction of rotating the plug within the shell until stopped by the pins. Note how much torque is required to move the plug, even slightly, before the pins bind. This force can be rather high for locks that have been left out in the rain and for padlocks. Maximum tension may be simulated by pushing all pins into their chambers with the flat side of the pick, then applying the rotating force necessary to bind all pins in this position after removal of the pick. Depending upon the stiffness of the tension wrench and its twist configuration in the tang, it may not be possible to hold all pins.

Too much torque and pressure create the situation described above, where the lower pins are pushed too far into the shell and the torque is sufficient to hold them there. This case would indicate over-picking; the moving of pins past shear line and freezing them there with too much torque. The window or range of picking torque can be determined by gradually increasing the tension while raking the pins. Some of the pins will become harder to move. Gradually increase the torque until some of the pins set; they will lose their springiness. While maintaining fixed torque, continue raking to set other pins.

Defining the window of minimum and maximum tension is difficult to learn. These exercises should assist in establishing those limits. In all of these procedures, an appreciation of the minimum tension required to bind one set of pins and trap them at shear line, as well as a determination of the order of picking, is the goal.

29_5.1.5.2 Step 1: Single Pin Cylinder

The author recommends the following procedure in order to learn how to apply tension and the correct degree of torque. Remember, luck does not play a part in learning about torque; skill and practice does. Initially, configure a lock with only one set of tumblers. Use a cheap cylinder with a wide keyway and poor tolerance, such as an inexpensive Kwikset. Low tolerance will make it easier to feel the pins bind. A cylinder with one pin-stack is the lowest common denominator. The first lesson to learn is the required tension that is sufficient to bind one tumbler. Enough tension must be applied to learn:

- **The feel of pins reaching shear line;**
- **How to place the tension wrench;**
- **How to move the pick inside the keyway;**
- **How to hold the pick and tension wrench in concert;**
- **The minimum amount of torque required to bind a pin;**
- **How to vary the tension. Apply less and less tension until the minimum amount of torque that will bind a pin is determined.**

29_5.1.5.3 Step 2: A Cylinder with Two Pins

Setup a cylinder with two pin-stacks about the same length. Feel how much tension is required to bind **one** set of pins. Then, identify the stack that is binding. One pin will always bind first. This is called the **order of picking**.

- **Pins will always pick in a specific sequence unique to each lock. The pins are actually setting based upon the misalignment of the plug and shell;**

- **Determine which stack is not binding. It will be noted that very little pressure is required to move this set of pins and that they will return to their**

original position when the pick is withdrawn;

- **Identify which pin-stack has been picked. Run the pick around the pins and internal chamber walls of the set pin-stack. Feel pins at shear line;**
- **Remember that the application of too much torque will bind both pin-stacks in our two-pin lock, thereby preventing picking in the proper order;**
- **The same degree of tension that bound the first pin will also trap it at shear line;**
- **Disassemble the lock and vary the pin lengths and position. Specifically, set the two-pin lock for the following different configurations denoted by a long pin = 0; short pin = 1: 00, 01, 10, 11.**

As the lock is picked for each of the above pin configurations, learn what is felt when:

- **A pin-stack that is picked; no pressure is felt;**
- **A pin-stack that is not set; feel spring bias.**

29_5.1.5.4 Step 3: A Cylinder with Three Pins

Place three pin sets in the cylinder and vary according to the following configuration: **000, 001, 010, 011, 100, 101, 110, 111.** It is very important that each permutation be picked. The length of the pins should also be varied so that on a one-to-ten scale, the short pins should be a **1, 2, 3,** or **4,** and the long pins, a **7, 8, 9,** or **0.** There is no shortcut to this learning procedure. With this exercise, four added lessons must be mastered:

- **Sequence of picking;**
- **Which pin-stack is being manipulated;**
- **Feeling of each pin-stack binding at shear line;**
- **How to place the pick in contact with only one pin at a time.**

29_5.1.5.5 Step 4: A Cylinder with Four or more Pins

Switch to a higher-tolerance cylinder such as a Schlage, Yale, or Sargent having a more complex keyway that is paracentric in design. It is suggested that the **Yale 8** or Schlage **923C** be utilized. It will be noted that it becomes harder to sense pins that are set. The 923C can be a very tough lock to pick, and thus makes an excellent training tool. At this point, the pin lengths should be varied, different tension wrenches employed, and various picking techniques should be utilized. This will allow a feel to be acquired for the relationship between torque and pin pressure.

29_5.1.5.6 Step 5: Add More Pins to Cylinder

Add more pin stacks to the cylinder. Practice with different tension wrenches. Vary the torque.

29_5.1.6 Identifying Set Pins

It is very important to identify which pins are set. This can be felt by a slight give or rotation of the plug that actually increases as the number of pins are set. When first making contact with the pin, it can be pushed down a short distance with a slight pressure. It becomes hard to move after traversing to shear line and being stopped by the shell.

Rotational torque and vertical pressure are directly proportional: the more torque, the more pressure is required to lift and set a pin. If too much tension is applied, the pins will be scissored between plug and shell and trapped in the upper chambers.

Falsely set pins can be remedied by pushing them down farther or by slightly releasing torque allowing the pin to pop back to the original position. Pins will set differently depending upon direction of rotation of the plug.

A determination must be made as to which pins are setting and their location (front or back). **This is perhaps the most important skill in lock-picking**. Many novices will falsely assume that the snapping of pins, which can be heard upon release of tension, indicates the number of tumblers that were set. This sound may or may not indicate this information and cannot be relied upon as an accurate indicator.

29_5.1.7 Turning the Plug

Two problematical questions can be encountered during lock-picking regarding plug rotation: which way does it turn and how far.

29_5.1.7.1 Which Way to Turn?

It can be very frustrating to spend a long time picking a lock, only to discover that the plug was turned in the wrong direction. There are generally no rules except common sense in this regard. A plug turned in the wrong direction will often rotate freely until it hits a stop, or until it rotates 180° and the drivers enter the bottom of the keyway. It may also be necessary to turn the plug more than 180° if that is required to fully retract the bolt. The bottom of the pick tool can be placed at the base of the keyway to keep all tumblers even with the outer diameter of the plug.

The extra resistance that is encountered when the plug engages the bolt works can also mislead one. This may be misinterpreted as a stop, falsely indicating that the lock has been picked in the wrong direction. In fact, some bolt mechanisms when engaged will present an obstacle to turning with a torque wrench because the leverage is not as great as with a key. The bolt defines direction of turn for the plug mechanism. There are some general guidelines, but in the case of cylinders, the hand of the door must also be taken into account.

Characteristically, inexpensive padlocks (such as manufactured by Master) will open if the plug is turned in either direction. In contrast, Yale padlocks will only open if the plug is turned clockwise. Likewise, locks in doorknobs, desk, and filing cabinets tend to open clockwise. When rotated in the correct direction, the plug will be stopped by the pins; so, the barrier will feel mushy with the application of heavy torque. When turned in the wrong direction, the plug will be stopped by a metal tab that will exhibit a solid feeling.

If the lock is picked in the wrong direction, a plug spinner may be use to rotate the plug in the correct direction. This device is spring-loaded and will actually place a very strong spin in the desired direction. Its purpose is to turn the plug so quickly that driver pins do not have an opportunity to drop into lower chambers. In practice, the pick and torque wrench is removed from the keyway and a small screwdriver is inserted to retain the position of the plug. Then the spinner is placed in

the keyway and spun in the desired direction while holding the screwdriver steady. The screwdriver is removed and the spinner is then released, rotating the plug in the correct direction. The torque wrench is reinserted.

29_5.1.7.2 How Far to Turn

The companion question to which way to turn the plug is how far to turn it? Desk and filing cabinet locks generally open with less than a quarter turn. Locks that are separate from the doorknob tend to require a half turn to open. Dead bolt lock mechanisms can require almost a full revolution to open. Turning a lock in excess of 180° can cause difficulty because the drivers may enter the bottom of the keyway. In certain cases, it will be impossible, due to mechanical limitations or stops, to turn the plug past a certain point.

29_5.1.8 Broken Picks

Beginners often break picks and wonder why. The causes are many and often occur when learning to bypass locks. Picks are rarely broken by experts, although it does happen. Typically, picks fail due to the following reasons:

- **Improper handling during bypass. The pick should be used as a pencil, not as a lever or wedge;**
- **Pins are bound, and excessive force must be applied with the pick in an attempt to raise them because too much tension has been used;**
- **Inexperience in trying to raise a picked pin against the shell;**
- **Pins may be bound very tightly on their own due to broken springs, dirt, contaminants, or oil in the lock.**

29_5.1.9 Gravity

Picking action will be affected by gravity, which in turn is directly influenced by the orientation of the springs. A lock with springs at the top will react differently than one with the springs at the bottom. With upward spring bias (springs at bottom of lock), gravity holds the lower pins out of the way once set. This will allow for much simpler manipulation of pins that have not been picked to shear line and the testing of pins that

have not set. Spring bias from above will allow gravity to pull the lower pins down after the top pin catches at shear line. Once set, the bottom tumbler is easy to lift.

29_5.1.10 Pins Not Setting

A failure of one or more pins to set during raking, even with an increase in applied torque, is generally caused by a tumbler that has a false-set, thereby prohibiting the other pins from setting. Consider a lock whose pins prefer to set from back to front. If the farthest pin false-sets high or low, the plug will be prevented from rotating enough to allow the other pins to bind.

It is often difficult to recognize a false-set pin, because the springiness of the front pins makes it hard to sense the small give of a correctly set back pin. The main indication is that the other pins will not set, unless extreme torque is applied. If this situation is encountered, try releasing the torque and starting over, concentrating on the rear-most pins. Often, slight tension and moderate pressure or heavy torque and heavy pressure will be effective.

29_5.1.11 Loose Plug

The plug is held in the shell by being physically wider at its front and by having a cam on the back that is bigger than the hole reamed into the shell. If the cam is not properly installed, the plug can move in and out of the lock slightly. On the outward stroke of the pick, when a pulling force is exerted, the plug will actually shift slightly. When this occurs, the driver pins tend to set on the rear of the plug holes rather than on their sides. If reverse pressure is applied, the drivers will unset. This problem can be used to advantage by simply applying pressure on the outward or inward stroke of the pick. Alternatively, a torque wrench or finger can be used to prevent the plug from moving forward.

29_5.1.12 Pin Diameter

When the pair of pins in a particular chamber have different diameters, that pin-stack will react oddly to pick pressure. As the pins are lifted, picking pressure can be resisted by the binding friction and spring force. Once the driver is above the shear line, the plug slightly rotates until some other pin binds. If the lower pin is small enough and the plug did not rotate very far, the pin can enter the shell without wedging at its edge.

Some other pin is binding, so the only resistance to motion is the spring force. The pin will not set.

The pin feels normal at first, but then the plug binds and the tumbler becomes springy. The narrow lower pin can be pushed all the way into the shell without loosing its springiness. When the picking pressure is released, the lower pin will return to its initial position, while the large driver catches on the edge of the plug hole. The critical difficulty caused by a large top pin is that the lower tumbler tends to lodge in the shell when some other pin sets. Imagine that a neighboring pin sets and the plug rotates enough to bind the narrow lower pin. If the pick was pressing down on both the smaller, lower tumbler and the pin that set at the same time, then the narrow lower pin would be in the shell and would get stuck there when the plug rotates.

29_5.1.13 Beveled Holes and Rounded Pins

Some lock manufacturers may bevel the edges of the plug holes or round off the ends of the lower pins. This can reduce wear and help or hinder picking. There is generally a larger give, or tolerance in the travel of lower pins at shear line. The distance between the point at which the top pin catches on the edge of the plug hole, and the height at which the lower pin contacts the shell is greater when the plug holes are beveled or the pins are rounded. While lower tumblers are moving between those two positions, the only resistance to motion will be the force of the spring. There won't be any binding friction.

A plug with beveled holes requires more tumbler movement during bypass than a lock without such treatment, because the driver pins set on the bevel instead of on the top of the plug. The plug will not turn if one of the drivers is caught on a bevel. The lower pin must be contacted again with the pick to push the top pin up and off the bevel. If a lock is encountered with beveled plug holes and all the pins appear to be set yet the lock will not open, sometimes it is helpful to reduce tension and continue picking each pin. Lessening the torque will make it easier to push the drivers off the bevels. If pins unset when this happens, try increasing the torque and picking pressure. Increasing picking force, however, may jam some lower pins into the shell.

29_5.2 Security Tumblers

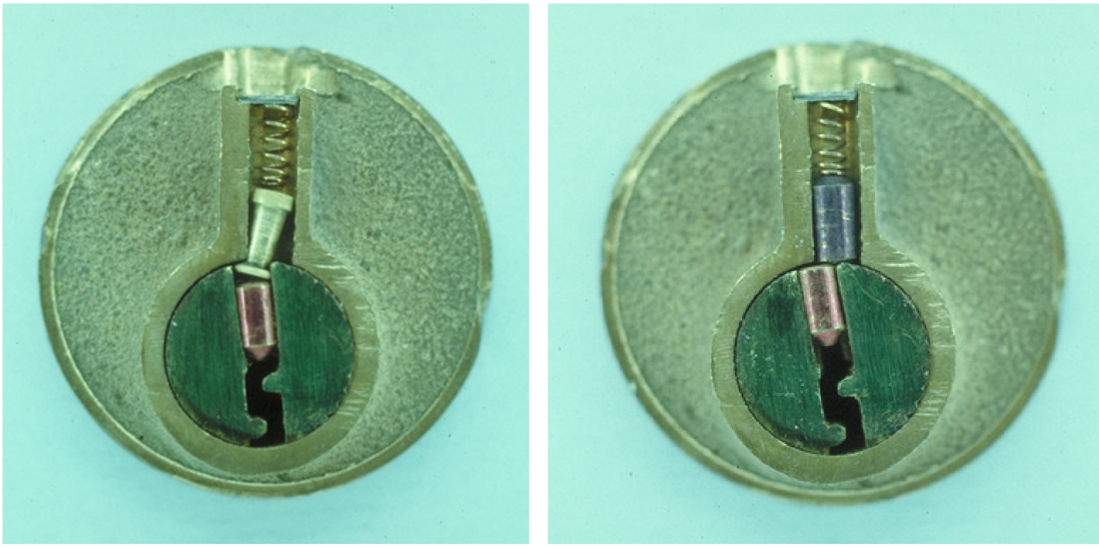
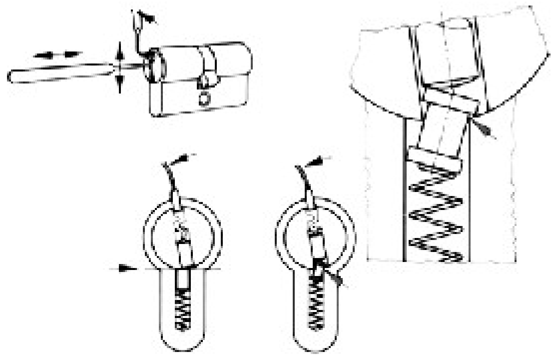


Figure LSS+2926. A lock (left) with a mushroom tumbler caught between plug and shell. The lock (right) has a slightly rotated plug, which occurs during the picking process as pins align at shear line. Courtesy of Illinois State Police, Bill Sherlock.

There are two primary means of increasing the security of a pin tumbler lock: design a complex paracentric keyway and employ security tumblers. Lock manufacturers routinely incorporate special drivers or lower tumblers in one or more chambers to frustrate picking and impressioning. The most popular shapes are mushroom, spool, conical, and serrated designs. Generally, spool-shaped pins refer to top drivers; mushroom shapes are found in bottom chambers. Each tumbler has a unique shape to facilitate false setting at shear line.

Especially in high-security locks, one to three chambers will have lower or upper security pins. These tumblers are even placed in certain padlocks, such as Abus and American Lock Company. Security tumblers will never be placed in all chambers, because the keyway would be off-center and difficulty would be encountered when inserting and removing the key. Neither is a tumbler placed in the first position, closest to the front of the lock.



Serrations can be added to pins in both top and bottom chambers, as well as the chambers themselves. Serrated master pins are rare and will not be utilized if the thickness of the wafer is less than .125”.

“S” pins are extremely effective, because they can create false shear lines both above and below the actual shear line. If the bores are tapped, serrated tumblers are very effective. However, they are extremely easy to impression. This shape was invented by Yale over 100 years ago; the first patent was granted on June 27, 1865 and was reissued in 1878.

The primary purpose of each of these modifications is to cause the pins to false-set low or high. They will allow the plug to rotate slightly, generally from 6º-15º, and prevent further setting of pins. These drivers can inhibit certain picking techniques, but generally will only make picking more difficult.

If, during the picking process, the plug stops turning after a few degrees and none of the pins can be pushed up any further, then it is likely that security tumblers are in place. The lower tip or other portion of the driver, or top of the lower pin has wedged at the shear line. Applying a light torque and upward pressure to each pin can identify the chambers containing security tumblers. Those positions with special tumblers will often exhibit a tendency to bring the plug back to the fully locked position. In the case of mushroom tumblers, raising the lower pin pushes its flat top against the tilted bottom of the mushroom driver. This results in the driver straightening, which in turn causes the plug to **counter-rotate.**

In order to pick locks with modified drivers, incorrectly set pins must be recognized. A mushroom tumbler, for example, will not have the springy give of a correctly set driver when the pin is set on its lip. Picking a lock with security tumblers

generally requires the use of a lighter torque, often with almost a feather touch and heavier pick pressure. The correction of tension during picking may also help.

The adjustment or correction of torque while manipulating each security pin must be quite precise if other tumblers are to be retained at shear line. The correct tension tool must be utilized for this exercise to allow maximum control of the plug. Raising the lower pins too far into the shell is preferred to not exerting enough pick pressure. In fact, another way to pick these locks is to lift the pins as far as possible, and then apply very heavy torque to hold them there, while releasing each one. This is called reverse picking.

29_5.2.1 Bypassing Security Tumblers

There are three methods of bypassing security tumblers: **conventional picking, impact picking, and reverse picking**. The following general rules apply to all techniques for neutralizing security pins.

- **Determine if security tumblers have been installed and if they are in the upper or lower chambers;**
- **Standard pins will pick first, because they have a larger diameter. The order of picking can thus be determined;**
- **Test to determine which is a special tumbler. The ones that cause rotation of the plug when lifted are security pins;**
- **Determine if serrated pins are used and, if so, whether the chamber walls have also been serrated;**
- **When the cylinder rotates slightly during picking, it is certain that the remaining pins are most likely security tumblers;**
- **Once standard pins have all been picked, maintain tension and bypass the security tumblers while still keeping the other drivers above shear line;**
- **Use more pressure and tension to raise security pins. They will cause the plug to rotate counterclockwise. If this procedure is not done correctly, all standard pins will release;**
- **Pins may be vibrated and moved back and forth to raise them. If one of the standard pins releases, try to pick it back without losing the other pins**

that have set;

- **Security tumblers will not pick in any particular sequence;**
- **Raking security tumblers is often effective using a very light turning force or a pick gun;**
- **When picking serrated pins, remember that bottom, driver, and chamber walls may all have the characteristic. Also, remember that all chambers may be pinned with serrated pins. They may be observed by visually examining the keyway. Serrated pins cannot be released with tension, thus they can be quite difficult to pick, especially when the chambers are likewise scored. An impact gun may be the best option for bypass.**

29_5.2.1.1 Conventional Picking of Mushroom Security Tumblers

To pick security pins, select those chambers that are so pinned, then use light tension to raise each tumbler. If the tension is correct, the mushroom pin can be forced above shear line without losing the other pins. The controlling factors are: wear in the mushroom pin, chamfer around the pin chamber in the plug, width of shear line at the chambers, and rounding of the lower edge of upper chamber.

29_5.2.1.2 Impact Picking of Security Tumblers

An impact gun can be quite effective when picking special pins. This is because the problems associated with the bypass of all security tumblers (with the possible exception of serrated) are eliminated. It will be recalled that the impact technique bounces all pins above shear line momentarily. The primary design of security tumblers is to cause trapping falsely at shear line. This procedure is ideal, because it circumvents the principal design function of the pin. It is recommended that a tweezers wrench or special round tension wrench be used for this procedure, such as manufactured by HPC. Use very light tension.

29_5.2.1.3 Reverse Picking of Security Tumblers

Reverse picking is a technique used to manipulate security

tumblers. The practice requires that all tumblers be raised above shear line with relatively heavy tension. Then, each tumbler is released, to drop below shear line. Use a raking action to manipulate the lower pins while slowly lessening the tension. This will diminish binding friction. The vibration of the pick and spring force causes the bottom pins to slide down to the shear line. A variation on this procedure involves the use of a rake pick combined with medium tension to raise above shear line, then release all tumblers.

A half-diamond pick can also be used with security tumblers to accomplish reverse picking. All pins are lifted simultaneously above shear line with the bottom side of the pick. Tension is then applied. The diamond tip is then used to let each tumbler drop. This is a very difficult procedure to successfully accomplish.

SECTION 6: Tools used in Bypass

Bypass Tools

29_6.0 Introduction

A variety of simple to sophisticated picking tools can be purchased from vendors in the United States and Europe. An example of a commercial kit, produced by the Falle-Safe Securities Company, is described below.

Lock-picking tools can be subdivided into two primary categories: picks and tension wrenches. The first classification includes conventional picks, sophisticated computer-designed picks, rakes, and specially designed pick tools for each kind of locking mechanism.

Tension or torque wrenches are produced in a variety of sizes, shapes, and configurations: some very simple and others quite ingenious. Our discussion will examine specific types of tools, their requirements, design, application, and construction. The primary focus of this Section is on wafer and pin tumbler locks. Tools for lever locks, and specifically high-security mechanisms utilized on safes and vaults, are also detailed.

29_6.1 Basic Pick Set

Many companies market pick sets. Perhaps the most sophisticated

of these, for the working professional, is the Falle-Safe collection. This commercial item is sold to locksmiths as well as government agencies. There are 93 tools, picks, and torque wrenches included in the standard set. An excellent variety of stainless steel tension tools, including single and double-ended, variable wrenches, and tools with single and complex bends are provided.



Within the kit there are 22 separate picking tools, 3 stainless steel rakes, and a set of 5 lever lock picks. There are 6 double-ended deep-curved picks, 6 double-ended graduated-curved picks, 6 double-ended progressive curved picks, and 4 double-ended curved picks. Each of the picks is fabricated from carbon tool steel. This steel has been nickel-plated to prevent corrosion. There are no double bowl-ended, bowl-ended, diamond-ended, or double diamond-ended picks in these kits, as the manufacturer does not believe they have any utility.

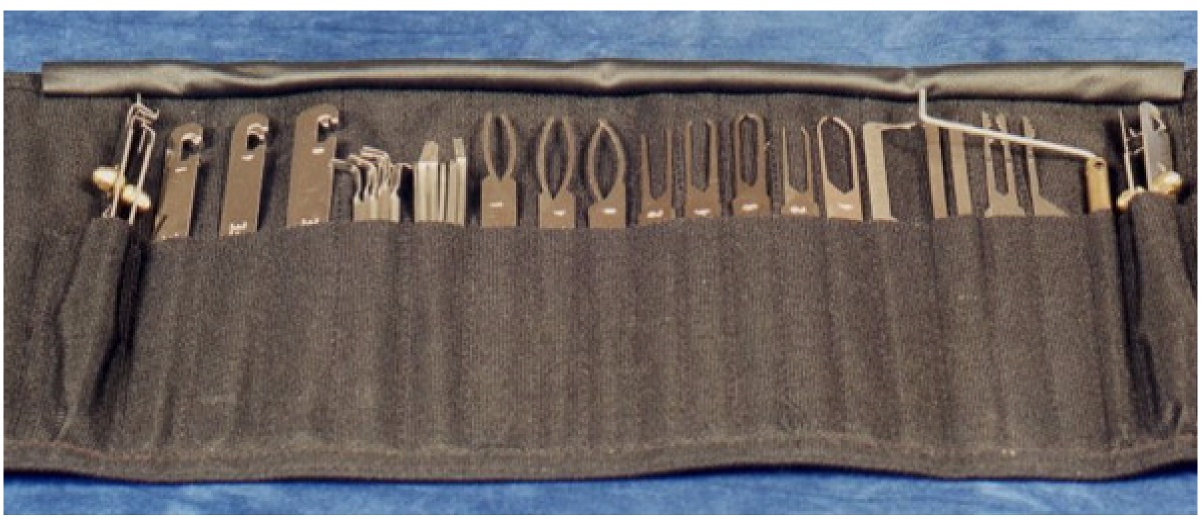
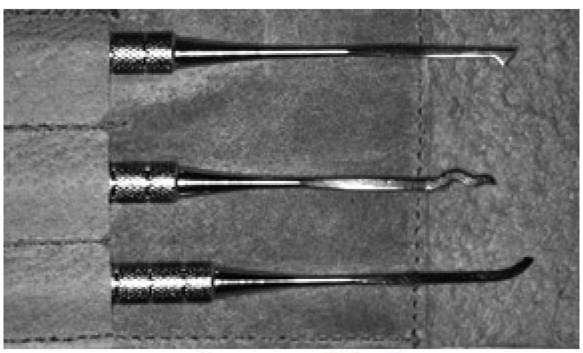


Figure LSS+2921 The John Falle pick set detail. Courtesy of John Falle.

This kit is an example of an all-inclusive lock pick set that will open virtually any mechanism. There are optional extras available for those countries where lever locks are prevalent. Falle-Safe does provide certain restricted items in the kits it offers to government intelligence agencies, such as decoders for high-security locks.

HPC and many other vendors also produce a variety of kits, shown below. Specialty picks produced by HPC, and recommended by the author include the NDPX set of three "dental" picks made of tool steel. These types of tools can be extremely useful and should be an adjunct to the professional arsenal. See patents (**4186577(273)**, **4006613(274)**), (**6082159(275)**).









29_6.1.1 Essential Characteristics of a Pick

The basic pick must have certain characteristics in order to function properly. These include:

- **Ability to imitate the actions of a key in**

order to raise individual tumblers to shear line;
- **Ability to make contact with each tumbler.**

29_6.1.1.1 Pick Shapes and Pick Tools

Picks are produced in many shapes and sizes, although certain designs must be used for certain locks or detainer configurations. For most pin tumblers, the author ordinarily uses only three different picks. The remaining two-dozen varieties contained in the standard pick kit are rarely employed. Picking is both a science and an art; personal preference and comfort play a large part in the selection of tools for a given lock.

There are four critical design criteria for any pick:

- **Shape of the end of the pick which comes into contact with the active components of the locks;**
- **Simple or complex angles associated with the contact surface;**
- **Gripping surface that allows the user to manipulate and move the tip and controls how the tip contacts tumblers or other moving parts;**
- **Tang, which is the connecting portion between tip and handle.**

Essentially, the handle and tang of most picks are the same. The handle must be comfortable and allow a firm and controlled grip; the tang must be thin enough to avoid moving the wrong pins. The design of the tang must be such that it is not too thin to create a spring, causing loss of feel of tip-pin interaction. Feedback is all-important in lock-picking; anything that diminishes that feeling is detrimental.

There are three considerations in the design of the tip of a pick: ease of insertion, ease of withdrawal, and transmission of feeling when the pick meets the tumblers.

29_6.1.1.2 Materials Used for Producing Picks

Many experts choose to cut their own picks. The author prefers to use handmade picks and tension tools in certain situations, especially where commercial picks are too large. Picks can be produced from many materials, although spring steel in .020” to

.032” thickness is desirable. Several custom pick manufacturers utilize etched stainless steel for precision forming. These picks, such as produced by HPC and Falle-Safe, are extremely strong yet thin. They offer very good freedom of movement. In an emergency, picks and tension tools can be fabricated from many commonly available materials, including steak knives, spring steel street cleaner bristles, bicycle spokes, unwound springs, and brick strapping material.

Tension tools can be made using metal of .040”-.050” thickness from steak knives, spatulas, pancake turners, or large bread knives. Picks can be produced using a 5” bench grinder with cutoff wheel, such as the B&D 790I, with a 1/2” arbor and 3600-RPM motor, or by hand filing. A needle nose vice grip and a burnishing wheel are also necessary.

With practice, precision picks can be made quickly. First, create the forward angle, using the front of the grinding wheel. Holding the material at a 45° angle, remove enough metal to create the proper slope. Do not overheat the metal or it will lose its temper and break during use. Next, create the back angle using the corner of the grinding wheel. The tip of the pick should be held stable to avoid breaking and to allow precision rounding. The cut should be made to about two-thirds of the thickness of the material.

Once the tip is shaped, the tang is formed, also using the corner of the wheel. The dimensions of the tang are largely dictated by the type of lock to be picked and personal preference, although a sufficient length will allow the tip to pass over the back pin of a seven-pin lock.

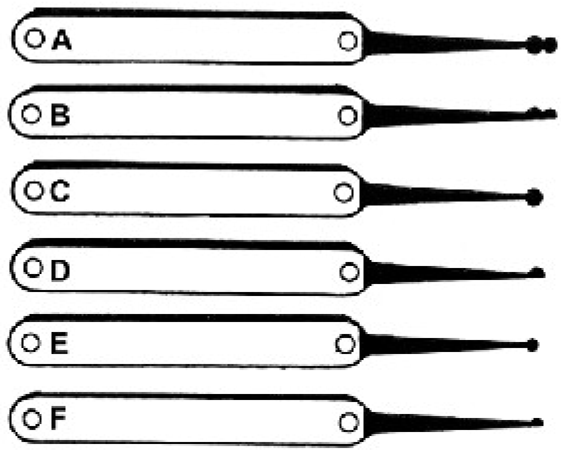
A hand file or burnishing wheel should be used to smooth all edges. If there are any jagged surfaces, difficulty in holding the pick will be experienced, as well as possible noise from tumbler interaction and loss of sensitivity of feel.

29_6.2 Specific Pick Shapes

Conventional picks as well as rake picks come in many shapes and sizes, although there are really only four distinctive shapes: **hook**, **rake**, **ball**, and **half-diamond.** The more common designs will be summarized here. In certain cases, picks may need to be modified for smaller keyways, especially in padlocks and some file cabinet locks.

29_6.2.1 Ball Pick

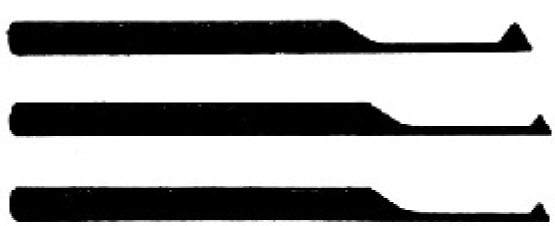
The ball pick is used for double-wafer cylinder locks, such as Chicago. The **double-ball** is primarily used as a rake pick.



29_6.2.2 Half-Diamond

Diamond picks are used for tumblers that are closely spaced, especially in the disc or wafer lock. The design allows for sliding of the pick to feel and move the tumblers. It also can bounce the pins like a pick gun. Diamond picks are especially useful for reverse picking, required with security tumblers.

The **half-diamond** tip, having **shallow** angles, is relatively easy to insert and remove. It allows significant pressure to be applied during forward or reverse movement. The same design with **steep** angles provides more information about the pins, although it may be harder to move within the lock.



A shallow half-diamond can more rapidly pick a lock, where the tumblers are about the same length. However, two deep pins separated by a shallow pin can pose a problem for this design.

The steep-angled diamond pick may also be used with difficult keyways such as the **Yale 8**, where vertical clearance is obstructed.

29_6.2.3 Half-Round Tips

The half-round tip works well in a disc tumbler lock, in dimple locks, and in locks where tumblers are closely spaced.

29_6.2.4 Full-Diamond and Full-Round Tips

The full-diamond and full-round tips are useful for double-bitted locks that have pins at the top and bottom of the keyway.

29_6.2.5 Rake Tips

Rake picks are designed to manipulate tumblers that all have minimal differences in their length or have ascending or descending lengths, much like a stair-step. Rake picks are quite popular throughout the world. The rake tip primarily works on **groups** of pins but may also be used to raise tumblers individually. The design of most rakes precludes forward pressure; contact occurs as the pick is withdrawn. With skill, a rake allows one to feel each pin and apply varying pressure as the tip interacts with the pins. There are many rake tip patterns; some very simple and some extremely sophisticated. Many have been designed with computer simulations.

Rakes incorporate many patterns. The primary shapes include diamond, ball, double-ball, half-ball, and half double-ball. Some rake tips are flat or dented on the top to make it easier to align the pick on the pin. Some are curved, with one, two, or three ridges. Some have equally high bumps; others vary both the center-to-center distance and height.

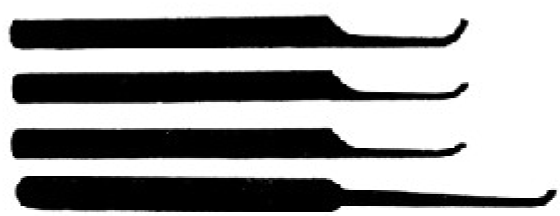
Complex rake tips are designed to simulate the signature of the key bitting and to achieve multiple and varied tumbler positions as the pick is moved in and out of the lock. Rapid insertion and removal of these picks, coupled with a vertical rocking or tilting motion, will cause the shear line to be crossed many times. With practice and a proper sense of when pins are binding or setting, a lock can be opened quickly.

Some rake picks have the capacity to set two or three pins simultaneously, depending upon design and the torque applied. The picks have the added advantage that they can be reversed

during the picking process, thus offering double the variations in bitting signature. As was noted in **Chapter 26**, raking a lock leaves definite indications of bypass in the form of scratches on the bottom of tumblers, and metal fragments or dust.

29_6.2.6 Curved or Hook Picks

The curved pick is available in many angles and radii for different applications, depending upon keyways and warding patterns. Generally, hook picks are designed to get behind or between two tumblers that have very different lengths. They are especially useful in lever locks.



Deep curved picks are for use on wafer locks and locks with very straight keyways. The basic idea is that the pick is levered from the bottom of the lock, allowing placement of each pin into its correct position in one smooth action. This saves time and simplifies the picking process.

Graduated and progressive curved picks are identical in every respect to deep curved picks, except they have a much stronger shaft. These are used in locks with more complex warding such as Yale, where levering up the base of the keyway would be impossible. They can also be used in circumstances where there is a very long pin next to a very short one. In this situation, a pick is required with a very large curve in its tip, in order to move the pin into the correct position without over-lifting the adjacent tumbler. Experience proves this an extremely awkward situation.

Thin curved picks are rarely used and are designed for locks with very complex keyways. Such is the case with the Evva, where the warding crosses the keyway at several different positions along its length. These tools are extremely thin, requiring very light tension to prevent them from bending.

29_6.3 Vibration and Other Mechanical Picking Devices

There are several methods of picking a lock, using a mechanical or electromechanical device that simulates the action of individually raising the tumblers, levers, or discs. All picking techniques that create vibration or shock waves are based upon essentially the same theory: creating a momentary gap between the lower tumblers and drivers. The underlying principle should be familiar to anyone who has played pool or taken high school physics. When the cue ball strikes another ball squarely, the cue ball stops and the other ball deflects with the same speed and direction as the cue ball.

These special tools provide a sharp, focused shock to all of the pins simultaneously. That energy is transferred to the driver pins which, for a few milliseconds, are driven above shear line. If torque is applied at precisely the right moment, then there is a window of time at which all bottom pins are in the plug, and all driver pins are in the shell. At that moment, there is nothing to impede the plug from rotation, and the lock can be opened.

29_6.4 999, Bump, Percussion or Code 12 Rapping Keys

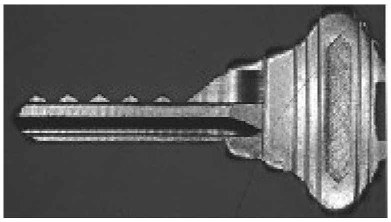
LSS202: The use of the "bump key" or "999" key, by Hans Mejlshede.

Use of a bump key, by Harry Sher

This is a procedure that is used to open conventional pin tumbler and dimple locks. It is also referred to as bumping, and appears to have its origins in Denmark. The term is derived from the description of a key that has all cuts to the deepest level (9 cut). The key has also been referred to in Europe as a Code 12 or bump key. In England, the process is referred to as percussion opening.

The theory behind the use of the 999 key, Courtesy of Hans Mejlshede.

The procedure requires that a specially cut blank be inserted and “rapped” in order that shock waves be created so that tumblers can be bounced above shear line. The technique is essentially identical in theory with the use of a pick gun.




Rapping is based upon Newton's Third law of motion: for each action there is an equal and opposite reaction. Thus, the application of energy that causes the pins to momentarily bounce can be used to open a lock.

In practice, a rubber or wooden mallet, plastic screwdriver handle, hardwood handle, or rubber workbench top can be used to initiate shock to the pins. A special key, with all cuts to the deepest point (hence the name 999), must be inserted so that the **ramps** (not valleys or flats) are pressed against each of the lower pins. After the key has been inserted to the proper position, several sharp raps are applied to the top of the key. If a tabletop is used, then downward contact is utilized. At the same time, forward pressure and a slight rotation is exerted on the key. When the proper force is applied to the key, combined with the correct shock, each tumbler will be caused to bounce above shear line; the plug will then be free to move.

The proper technique for the use of the 999 or bump key, Courtesy of Hans Mejlshede.

An alternate method, once the retaining screws have been removed, requires that controlled pressure be applied to the rear of the plug, while the lock is lightly rapped against a tabletop. The proper creation of shock will bounce the tumblers above shear line, allowing the plug to be moved forward in order to trap the drivers.

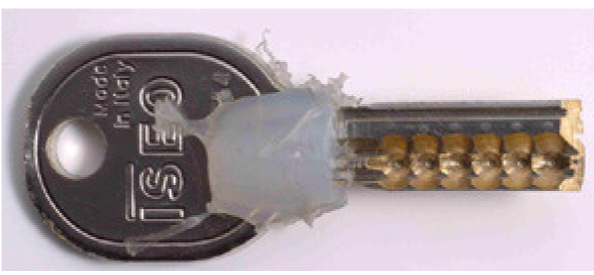
The requirements to rap a lock are as follows:

- **The lock must be clean;**
- **The pins must move easily in their chambers;**
- **The plug-retaining screws must be removed prior to**

rapping;

- **The lock should be held between the thumb and index finger;**
- **Slight pressure should be applied to the key;**
- **The lock should be struck from above;**
- **Once all pins are set, care must be taken not to slide the plug forward so that pins relock at the next tumbler position;**
- **Turn the plug slightly after all pins are set, prior to opening.**

A similar technique has been applied to dimple locks. The key requires that all pin positions be bored to the maximum depth, and a stop be applied at the shoulder. Here, a bump key for the Iseo six pin lock has been constructed with a stop made from a glue gun. The inventor was Oliver **Diederichson** in Hamburg, who also developed the Sputnik picking tool. The key is fully inserted into the lock, then withdrawn one pin position. Rapping is accomplished in the same fashion as with a conventional cylinder.



29_6.5 Comb Picks



Figure LSS+2927 The John Falle comb pick set. These picks have been designed for different cylinder chamber sizes and spacing.

Buday described this technique in 1936 (**2064818(276)**). Comb picks appear as their name implies: they are formed with teeth, spaced with the same center-to-center dimensions as the tumblers in each chamber. There is one tooth for each pin. A comb pick creates a new shear line by forcing all tumblers into the shell.

The function of the comb is to raise all tumblers above shear line and to crush or compress the springs, making room for the pin-stack. Generally, a comb pick is used with a wedge underneath it in order to aid in lifting the tumblers. In many instances, the brass retaining strip above the top chambers is actually broken loose, allowing unlimited room for the pin stacks to rest.

Comb picks are difficult to utilize in paracentric keyways, because the wedge cannot be raised. So also, certain high-security locks use setscrews to seal the top chambers and often cannot be combed.

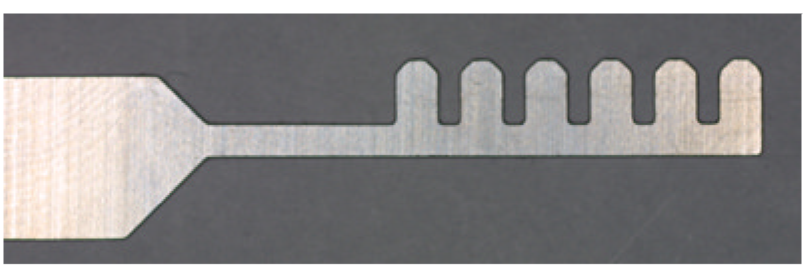
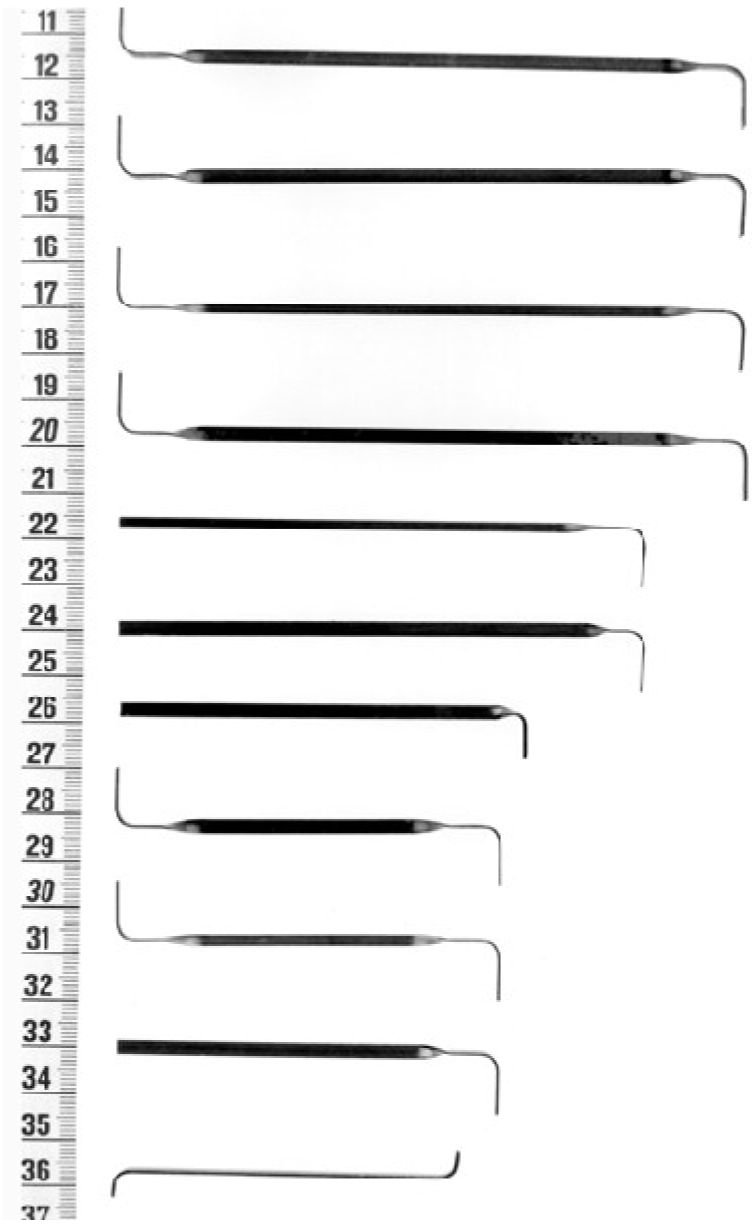


Figure LSS+2904 A John Falle comb pick.

29_6.6 Tension Wrench

There are two required tools to bypass most locks: the pick and the tension wrench. Each is equally important. The tension tool, or more precisely named, the torque wrench, provides the means to apply the rotational force necessary to bind the pins and turn the plug after all wafers, pins, discs, or levers have been raised to shear line. The tool is indispensable to all forms of lock-picking and comes in a variety of shapes, sizes, and tensions.



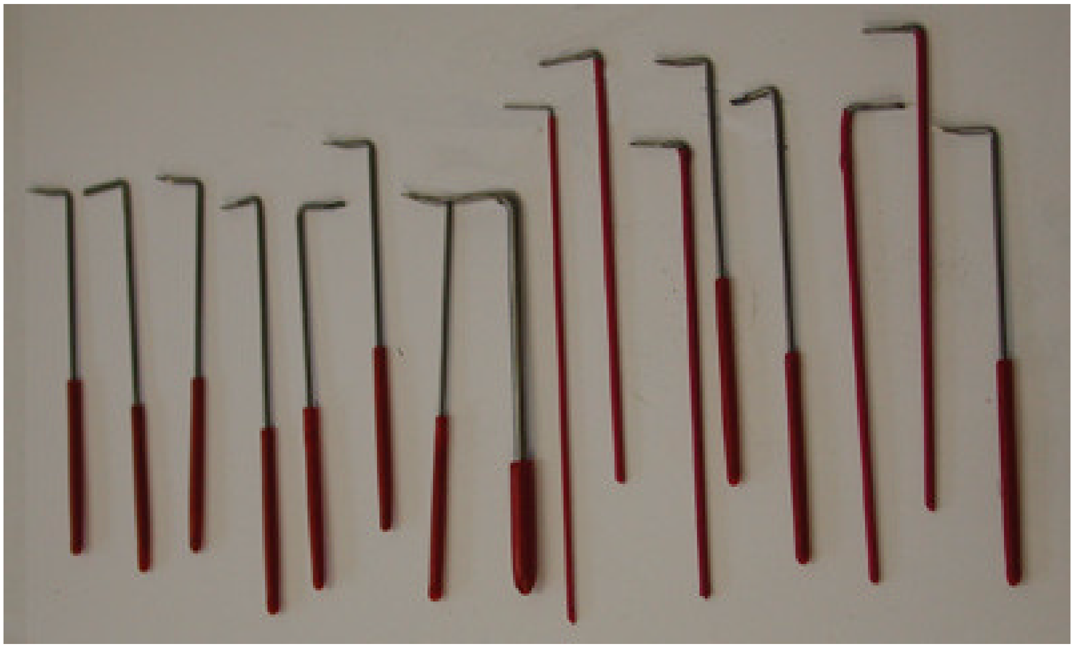




Figure LSS+2905 Special torque wrenches produced by MSC in Germany are plastic coated and are available in many lengths and tang sizes and thicknesses.

LSS201: MSC Assortment of tension wrenches, courtesy of Mahmod Abu

Shanab

Just as there are many variations in pick designs, every skilled lock picker has a preference for a tension wrench. Torque wrenches can be grouped into six general classifications: **light, medium, and heavy tension; narrow, medium, and wide tangs**. Torque wrenches are available in many shapes, lengths, sizes, widths, and thicknesses, for both the tang and main body. Some wrenches will have different angle bends in the handle. It is suggested that wrenches be provided with the following tang widths: .025″, .030″, .042″, .075″, .093″, and .125.″ There are few universal wrenches, perhaps with the exception of the Falle-Safe tool, because of the differences in locks and keyways. Wrenches must be capable of working with any lock, in any position, and allow the application of torque without obstruction. One unique design was invented by Cooke (**4606204(277)**) that involved an automated method of placing tension on a plug.

29_6.6.1 Criteria of the Basic Tension Wrench

The essential requirements of a tension wrench include:

- ***Ability to hold all pins in place;***
- ***Ability to apply torque while manipulating a pick;***
- ***Ability to hold pins after they are set.***

Additional design criteria include the material thickness, length, and width of the tang and handle. The orientation of the wrench with respect to the head and handle will change based upon a number of factors. Often, a 45°-90° twist is incorporated into the head-handle junction, for ease in manipulation. Torque wrenches may also be constructed as sliding plates, secured in the keyway with locking pins. The author prefers the Falle-Safe turning wrench that employs this design because of the precision control it affords during the picking process.

Regardless of materials and design, all torque wrenches have a head and handle. The head is generally ½″ to 3/4″ long; handles can be up to four inches in length. There is generally a bend at the point of head-handle junction. This bend must be designed to allow the wrench to overcome any protrusions, allowing the plug to be securely gripped.

Long handles provide precise control of tension and rotation,

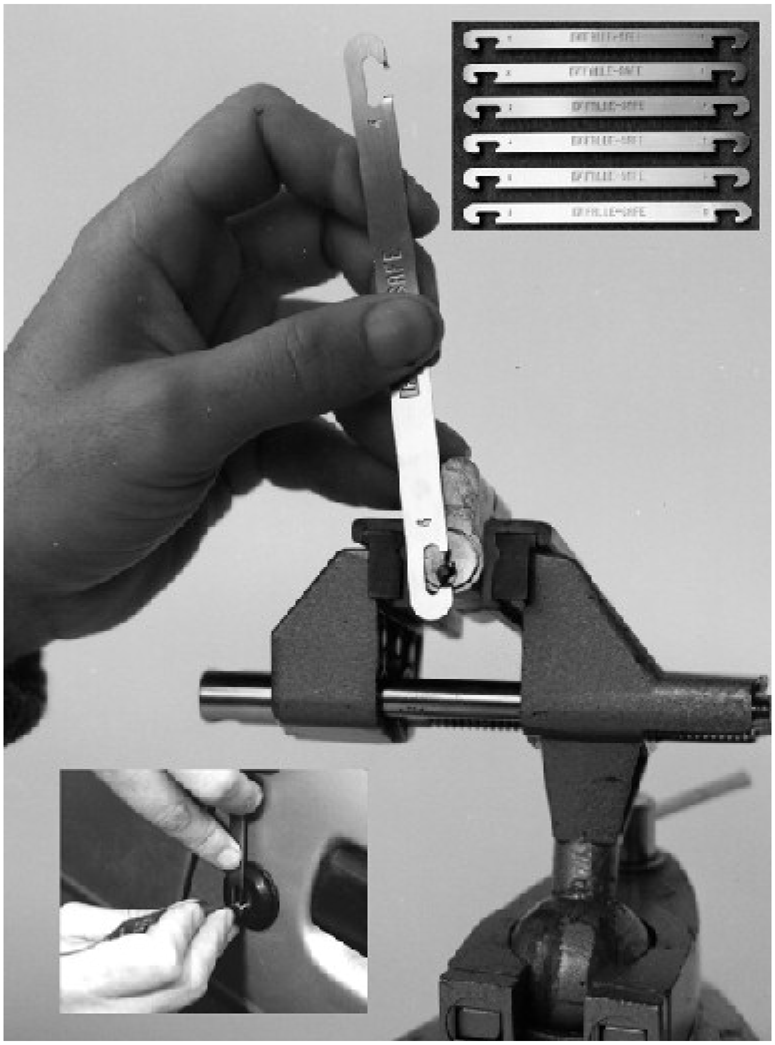
although if too long they can meet doorjambs. The purpose of the handle is to act like a spring, setting the amount of torque that is applied. The width and thickness of the wrench head determines how well it will fit into the keyway. A number of tension wrenches are normally offered in a professional pick set because of the differences in keyways.

Tension wrenches are generally made of spring steel stock, and are from .020”-.040” thick, and 1/8”-3/16” wide. Wrenches can be made from many materials other than spring steel in an emergency, including eight-penny nails, bicycle spokes, and screwdrivers. For high-tolerance locks, an Allen wrench can be modified by filing (not grinding) to create half a tang. This tool can then be inserted into the top or bottom of most keyways for more precise control.

29_6.6.2 Bent Tension Tools

Normal tension wrenches having a single tang can obstruct entry and manipulation of picks in keyways with complex ward patterns. Specially designed bent tools, produced by Falle- Safe, bind as they are inserted into the keyway and turned. These tools are produced in four different widths: 2.25 mm, 2.5 mm, 2.75 mm and 3.0 mm. Generally, one of these tools will fit at the very bottom of the keyway, and minimize its obstruction. They should only be used on locks that do not have mushroom tumblers.

The unique Falle-Safe fixed tension tools have two prongs that enter into the bottom and the top of the keyway, causing a minimum obstruction. The widths of the two prongs vary. Each end of the tool is double-sided for reversal, allowing torque to be applied in an upward or downward direction.

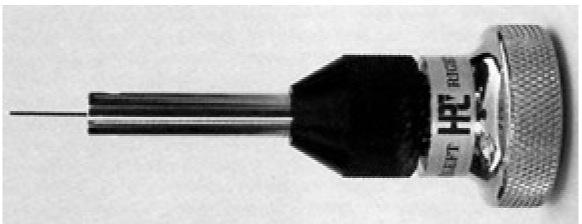


The benefit of these tension tools is most apparent on locks that contain mushroom tumblers. When picking a mushroom pin, the core has to be rotated in the opposite direction from opening in order to push the heads of the mushrooms above the shear line. This is very difficult to accomplish with standard tension wrenches; control of the core is lost the moment reverse torque is applied. The fixed tension tool, however, becomes an integral part of the core: both move in concert, providing precise control.

29_6.6.3 Plug Spinner

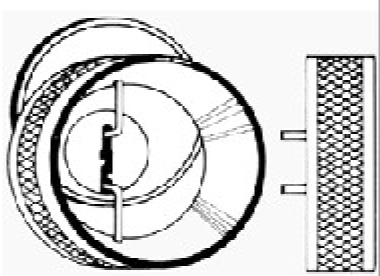
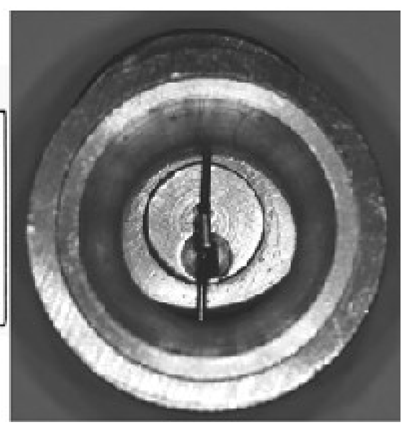
A plug spinner can be very helpful if a cylinder is picked in the wrong direction. Often, due to wear of the plug or tumblers (because it is a right or left-handed lock) or the location of the lock, it may be easier to pick in one direction. The plug

spinner provides a means to apply high rotational torque to the plug when picked and move the lower pins across shear line without having any drivers drop into lower chambers.



29_6.6.4 Special Torque Wrench Designs

Specially designed torque wrenches, such as the **round** torque wrench manufactured by HPC and MSC (Germany), can make picking easier and allow more rotational control of the plug. This device looks like a spring-loaded donut, with protruding pins at the 6 and 12 O'clock positions. The pins insert into the keyway and provide complete access for picks. The pin at the 12 o'clock position is adjustable to fit any keyway.

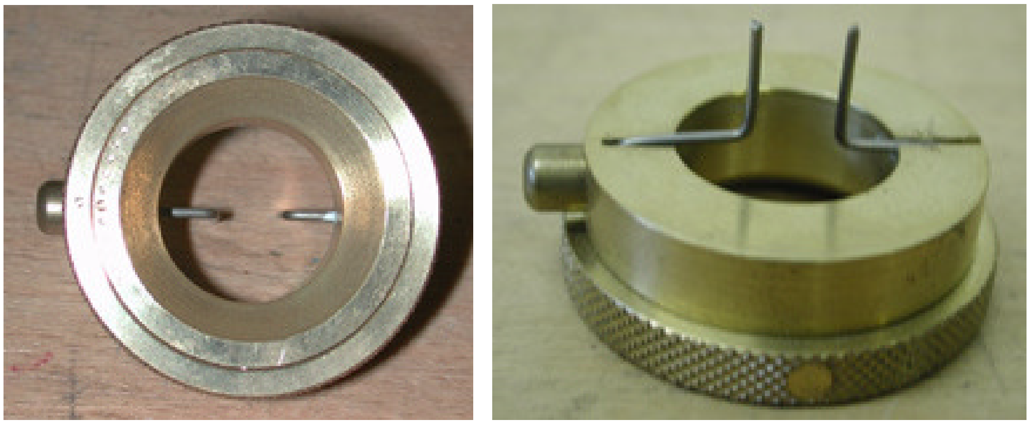


Figure LSS+2906 MSC in Hamburg, Germany produces a similar round torque wrench to that of HPC. It may offer somewhat better control and feel of core rotation and has calibration markings.

Tweezers, also offered by HPC, provide for control of the plug, much as the round torque wrench described above. The arms of the tool enter the keyway at the top and bottom of the plug. Tweezers have a tendency to release during picking; the author does not recommend their use.







The **Falle-Safe** tension wrench is the best designed device that the author has utilized to pick pin tumbler locks. It is adjustable and allows for precise control over the plug.

SECTION 7: Opening Locks

Picking Specific Locking Mechanisms

29_7.1 Picking Warded Locks

Originally developed by the Romans, these locks can have very intricate and complex designs, with many angles and zigzags, likened to a puzzle or maze. Nonetheless, a warded lock still is based upon blockage in some form of the keyway. Thus, all are subject to bypass by a key with any material removed that could encounter a ward. The portion of the key that remains will spread locking bands, or otherwise actuate a bolt.

Rim and mortise locks can still be found in old hotels and homes. Warded mechanisms are also very popular in inexpensive laminated padlocks, and they are used for cabinet and furniture locks. Warded locks are the easiest of any mechanism to pick and impression. It will be recalled that their security resides in the placement of obstacles (wards) in the keyhole that blocks entry or turning of the key or access to the release for the bolt or shackle. Wards may be of the rotating type that require barrel and bit keys to pass them. This is the traditional hotel key. Wards in padlocks take a different form and are blocks of metal located around the keyway. They prevent any key that does not have matching cuts from turning.

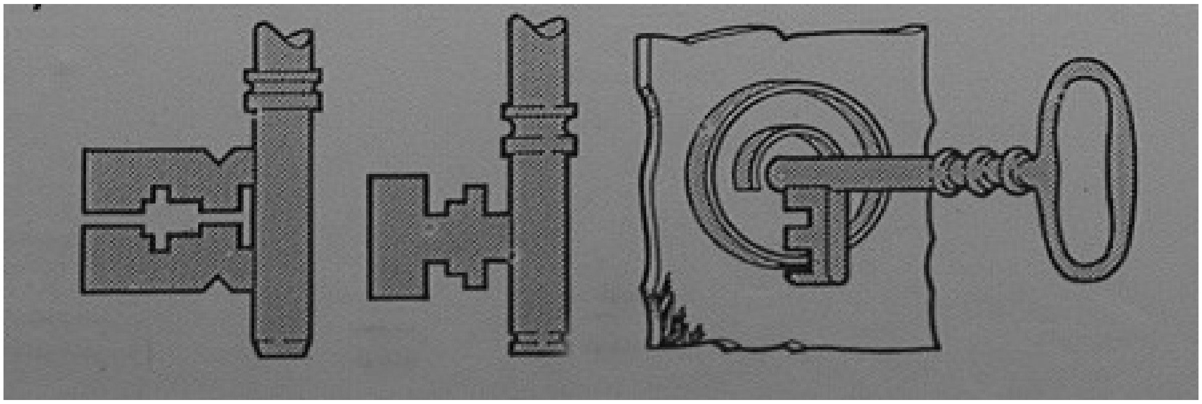


Figure LSS+2907 Examples of traditional warded keys. The mechanism (right) shows the interaction of the circular wards and the fundamental design of all warded keys. Note the removal of material on the key to pass the wards. This also is the principle that underlies all skeleton keys.

29_7.1.1 Skeleton Keys and Picks

Skeleton or passkeys can be fashioned for any type of warded mechanism. A set of five skeleton keys is available from HPC that will open most of the warded padlocks. This set has different tip configurations that are designed to spread single, double, or triple locking bands. A homemade “T” shaped pick can also be made to accomplish the same result.

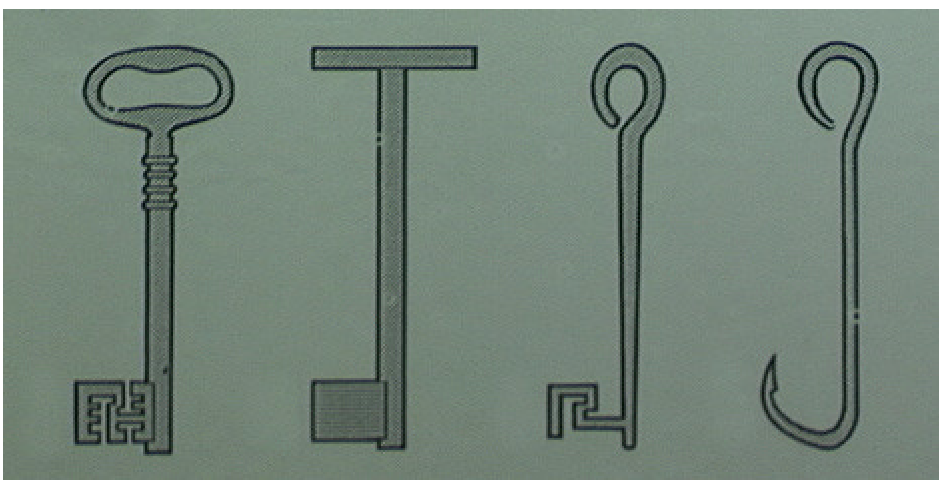


Figure LSS+2908. The above illustrations (from left to right) show a standard warded key, a blank for a warded lock, a key that has been produced by impressioning, and a burglar's skewer for manipulating the bolt.

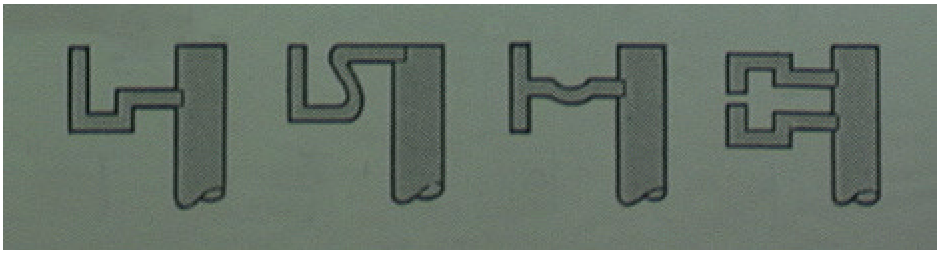
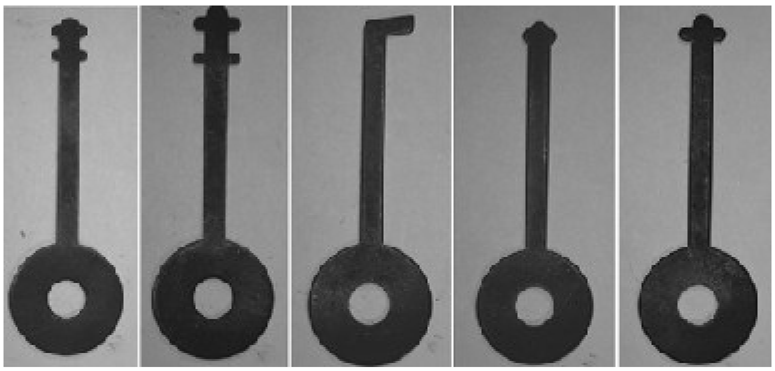


Figure LSS+2909 Examples of different skeleton keys for warded locks.



29_7.1.2 Picking Warded Mortise Locks

It is a simple matter to bypass wards and thereby reach the lever that actuates the bolt. A buttonhook pick can be made of .03"-.050" heavy piano wire and can be used to raise the lever, so as to pass the bolt without restriction. Perhaps the most difficult task when opening one of these old locks is to know the internal mechanical configuration and where to place the pick.

29_7.1.3 Picking Warded Padlocks

The warded Master padlock is probably the most popular inexpensive device of its kind in the world. It is typical of all padlocks and will be used for illustrative purposes in this text. It has four primary components: the **pass plate** allows turning of the key; the **ward plate** prevents turning of the key; the **rotating ward plate** is at the bottom of the keyhole and defines the keyway; and the **top plate** forms the center and stops the key. See **Chapter 13** for a complete description. Keys for the Master padlock have symmetrical rectangular cuts that correspond exactly with the placement of the wards. They allow the key to turn after it has been fully inserted. The protruding portions of the key will separate blades of the locking bands that are utilized to retain the shackle.

It can be seen that releasing the shackle simply requires the simultaneous expansion of the locking bands. The insertion of a skeleton key, an "L" key, or a hooked pick can be used to accomplish this task. If there are two or three locking springs, then two picks can be utilized, or a passkey with two "T" configurations can be employed. Slight pressure applied to the shackle, by either pulling or pushing, coupled with a twisting of the bands to about a quarter turn, will open the lock. Spreading of the locking springs may require some manipulation, but the bands are easy to locate.

29_7.1.4 Impressioning Warded Locks

Warded locks can be impressioned easily. See **Chapter 30** for a description of the procedure.

29_7.2 Picking Wafer Locks

29_7.2.1 Introduction

Wafer locks are extremely popular and can be found in almost every installation requiring low to medium security. They are used on filing cabinets, desks, mailboxes, padlocks, doors, lockers, cars, garage doors, and many other applications. This mechanism found universal acceptance in the vending industry as the result of Chicago Lock introducing the first wafer design in the United States. There are also sidebar wafer locks that were first introduced by Briggs and Stratton in 1935 for use in automobiles. The same design is prevalent today in General Motors products.

Wafer locks can be identified visually by looking into the keyway: the discs will always appear flat, rather than rounded. The plug comprises about eighty percent of the overall diameter of the lock. Wafer locks, by their design, are easy to pick either conventionally or by raking. It will be recalled from **Chapter 15** that their mechanical locking principle relies upon a single wafer moving vertically in the plug, either above or below shear line. A plug, containing all springs and discs, rotates within a shell. The key simply centers each wafer so that neither the top nor the bottom protrudes from the plug's surface. Tolerance errors in the disc and plug allow these locks to be picked. The size of each disc will vary slightly because they are stamped. Parts are generally cast and so the walls of the shell may not be uniform.

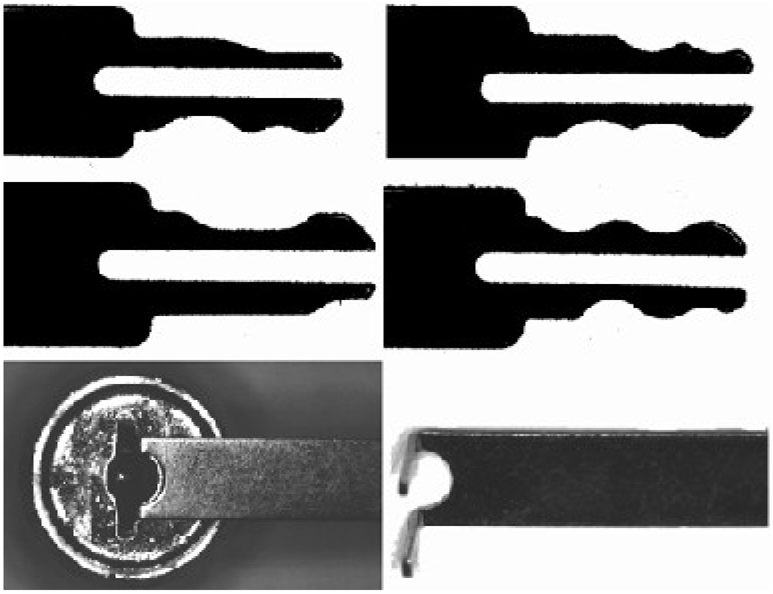
Depending upon design, locks may have wafers that extend only into the top **or** bottom portion of the shell, or, in the case of double-bitted locks, will protrude in **both** directions when locked. The key having the correct bitting will always force all wafers to the **center** position. Any bitting position on the key that are either too low or too high will allow or cause a wafer to protrude from the surface of the plug, thereby preventing rotation. All wafers are always of the same overall length. Depths are determined by the correlation of the internal slot length and position to the vertical position of that slot within the wafer. Thus, filing the tops of discs cannot change combinations.

The plug is generally retained by an arc ring, an extra disc that protrudes into the shell, or by screw and cam. Regardless of design, the lock is picked by moving all wafers or discs into alignment with the top and bottom of the plug. There are generally four, five, or six depth cuts, although this is by no means a hard and fast rule. They differ from the pin tumbler lock in that the wafer or disc is a great deal easier to trap between the plug and shell. Thus, there are two points of engagement for the wafer (top and bottom of the plug), rather than just one, in the case of the pin tumbler. This fact allows raking with a much higher degree of success. The order of picking is not particularly critical, nor is tension. In fact, the author generally utilizes a stiff tension wrench to pick these locks.

Wafers are much thinner than pins, so more care must be exercised if picking individual discs, in contrast to raking. There is less distance inter-disc, so movement of the pick must be more controlled. Additionally, the plug may be heavily spring loaded for the actuation of certain bolt mechanisms, so more tension than normal may be required to actually turn the plug. There is a very different feel when picking wafer locks as compared to pin tumbler.

29_7.2.2 Picking Tools

Almost any pick tool can be used to open wafer locks, although certain tools work particularly well or have been specially designed for the task. Generally, a hook, ball, half double-ball pick or rake is preferred by most experts. There are, however, rocker picks, keys, and double-sided picks such as the HPC DSP-1 and COMP-1. Depending upon the design of the pick, a tension wrench may or may not be required.



In deciding upon which pick to use, the size of the keyway and design of the tumbler pack must be considered. As with the pin tumbler, free access to wafers or discs must be obtained with both the pick and torque wrench inserted. Often, two picks and a tension wrench may be used; thus, clearance is critical.

29_7.2.3 General Picking Procedure

Picking wafer locks is similar to pin tumbler in terms of overall procedure. The following discussion applies to all wafer and disc locks that do not employ sidebar designs. Specific information pertaining to single and double-bitted mechanisms is presented later. Training exercises, with respect to acquiring picking skills, follow the same guidelines as pin tumbler locks. The following general considerations apply when picking wafer locks:

- ***Wafer locks are easier to pick than pin tumbler, however, and the same principles and procedures apply;***
- ***Picking wafer locks may feel quite different than pin tumblers in some cases;***
- ***Wafers are thinner than pins, therefore, more care must be exercised when manipulating individual wafers;***
- ***There is less distance between wafers as compared to pins, thus it is easier to lift more than one wafer***

at a time;

- **Wafer locks may require slight to heavy tension; it depends upon the particular mechanism;**
- **The plug may be heavily spring loaded and require a great deal of torque;**
- **Raking is generally the fastest and easiest way to open wafer locks;**
- **Many locks are opened using a combination of raking and conventional picking;**
- **The discs will pick in a sequence, just as with pin tumbler, but such sequence is not usually relevant;**
- **Most wafer locks can be successfully raked;**
- **In order to successfully bypass a wafer mechanism, all discs must be aligned at shear line;**
- **A wafer lock may have one or two shear lines: at the top, bottom, or top and bottom of the plug;**
- **The Chicago double-bitted disc pack uses a hairspring to retain all discs in a sandwich configuration. There may also be a spring-loaded locking bar at the back of the tumbler pack that must be released to turn the plug;**
- **Double-bitted locks will pick in sequence. Each wafer will have its own spring;**
- **If rocker picks are utilized, slight rotation off-center may be required;**
- **If the keyway is very worn, the lock may be opened by inserting a key and jiggling, much like the use of rocker picks;**
- **Wafer locks can be bypassed by inserting a blank key fully into the plug, then slowly withdrawing while applying slight tension;**
- **Wafer locks, regardless of design, are quite susceptible to raking. Far less skill is required for successful bypass. Wafer locks can generally be opened in seconds using either technique;**
- **Using double-sided rocker picks is easier on a worn keyway.**

29_7.2.3.1 Applying Torque

Generally, a much smaller tension wrench is utilized because of reduced keyway size. The author prefers specially designed

torque wrenches described earlier that rely upon the anchoring of two pins at the top and bottom of the keyway for the application of tension. HPC and other manufacturers make tools for double-bitted wafer locks, such as the HPC DSP-1.

Torque wrenches for double-sided locks are available in different widths. Their design makes them well suited for pushing aside shutters on vehicle locks. A small screwdriver can also be quite handy for picking double-bitted locks if nothing else is available.

29_7.2.3.2 Picking Single-Bitted Wafer Locks

It is simple to determine which way to pick discs in a single-bitted lock. They will always move towards what can be considered as the top of the keyway. The first tumbler closest to the front of the plug will be partially visible, and indicate the direction to apply pressure.

Once rotational force is applied, the pick is inserted. Each wafer can be manipulated individually, or all wafers can be raked. Less precision is required to open one of these locks in terms of pick control and movement. Remember, wafers may need to be moved up, down, or in both directions alternatively to align them at shear line. The basic principle of picking any wafer lock, regardless of the number of bitting surfaces, is the same.

29_7.2.3.3 Picking Double-Bitted Wafer Locks

In the double-bitted lock, the procedure for manipulation of the pick and tension tool is different and slightly more complicated, depending upon the type of pick and torque wrench that is used. In locks where wafers extend to the top and bottom of the plug, conventional picks must be inserted and removed from the keyway using two different vertical orientations. This is especially difficult if a standard tension wrench is used, because it often must be switched from one side of the keyway to the other with some wafers already set. In this case, the thumb can be pushed against the plug to hold it in position while the torque wrench is moved.

All tumblers oriented in one direction must be manipulated. Then, while maintaining tension, the pick is removed and reinserted with the tip pointing in the other direction. The process is then repeated until all wafers, both top and bottom are aligned. Generally, not all of the wafers will set on the first pass in

either orientation, so the procedure must often be repeated several times. This must be accomplished while maintaining tension; otherwise, those discs already set will return to their original position. Wafers should be picked on top, then the bottom.

If the proper tension wrench is not utilized, picking double-bitted locks can be quite frustrating. This is because there is no easy way to maintain torque while switching picks or pick surfaces. If a special double-sided pick tool is utilized, such as the HPC DSP-1, then bypass can be a great deal simpler to accomplish. With this or a similar tool, moderate up-and-down motion is applied with some tension. The pick itself may provide the needed torque or a separate wrench may be inserted (**2279592(278)**).

Once a double-bitted lock is picked, the plug should be rotated to about 45°. The keyway can then be packed with string or other material that will then allow free rotation, retaining the wafer configuration. Remember that some locks will only rotate a maximum of 90°.

29_7.2.4 Picking Abloy Disc Locks

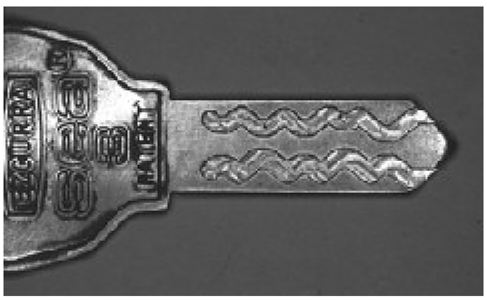
The Abloy disc lock is a highly secure disc wafer mechanism produced in Finland. It is relatively inexpensive and can be field programmed. There are several versions of the design, based upon the number of discs, keyway shape, and gate shape and position. As described in **Chapter 17**, the primary concept was derived from a traditional combination lock and wheel pack containing rotating discs, each having one gate. The manufacturer claims 60,456,176 possible permutations. The lock contains ten concentric discs, each with one active gate and several false gates. The action of the key will turn all discs so that the gates are aligned, allowing a sidebar to retract to clear the obstruction for full rotation of the plug. Removal of the key automatically scrambles the position of each disc.

Although these locks cannot be effectively picked in a conventional manner, most can be decoded and opened using a special tool that was designed for each version. The precision decoder allows the manipulation of each disc and provides information from which the true gate can be sensed. The result of decoding also places the gate of each disc in an aligned position so that the lock can be opened. From the information derived, a key can also be produced. See **Chapter 31**, for

information regarding the Falle-Safe decoding tools.

29_7.2.5 SEA and Evva 3KS Sidewinder Locsk

The SEA and Evva 3KS sidewinder locks are a wafer mechanism. In actuality, they are a modified pin tumbler design but operates on essentially the same principle as most wafers. The lock utilizes gravity rather than springs to locate the tumblers when a key is **not** inserted.





In the case of the SEA design, the tumblers have side-protruding pins that engage with the tracks on the surface of the key upon insertion. Chambers at the top and bottom of the shell correspond with those in the plug. In order for the plug to rotate, all pins must be centered so that they do not extend into the shell (much like the wafer lock). The picking procedure is similar to traditional wafer mechanisms. The Evva 3KS is much more complicated and utilizes two sidebars that align on either side of the plug with six sliders. A special tool has been developed by John Falle, discussed in **chapter 31**.

29_7.2.6 Tibbe Lock

The Tibbe lock is utilized in Ford automobiles in Europe, and on Ford Mercur and Jaguar in the U.S. It is a wafer mechanism and similar in principle to the Abloy. A defect in the design allows a set of tryout keys or a special decoder to open a high percentage of these devices. John Falle has devised a unique decoding process that is described in **Chapter 31**, and in **LSS+/^{x} CD/ROM**.

29_7.3 Picking Lever Locks

29_7.3.1 Standard Lever Locks

Lever locks offer all levels of security. Some may have up to ten levers and can be extremely difficult to bypass.

29_7.3.1.1 Tolerance Errors

Two forms of tolerance errors allow lever locks to be picked:

- **The failure of the edge of the gates of all levers to be vertically aligned with each other, not in a parallel plane;**
- **A failure of the fence to enter the gate of each lever at the same precise point.**

These errors are caused by the following manufacturing imperfections:

- **Difference in width of levers or gating;**
- **Difference in the length of the levers;**
- **Tendency of the top of the fence (portion not secured to the bolt) to flex when tension is applied;**
- **Tolerance differences from the pivot point to the edge of the tumbler.**

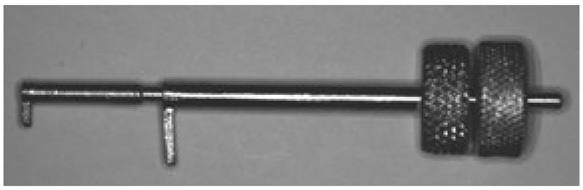
Each lever presents different imperfections to allow picking. Some will have parallel errors, some may have gate misalignment, and others may exhibit both errors.

29_7.3.1.2 Specific Picking Tools



Figure LSS+2922 The John Falle two-in-one wheel pick set and two locks that it will open. Courtesy of John Falle.

In order to pick a lever lock, a special tool known as a two-in-one pick may be employed. This tool was originally developed by Hobbs and was used in conjunction with a weighted line to maintain constant tension on the bolt action. Such a technique is still in use today by safe technicians, especially where there are two separate lever mechanisms to be picked.



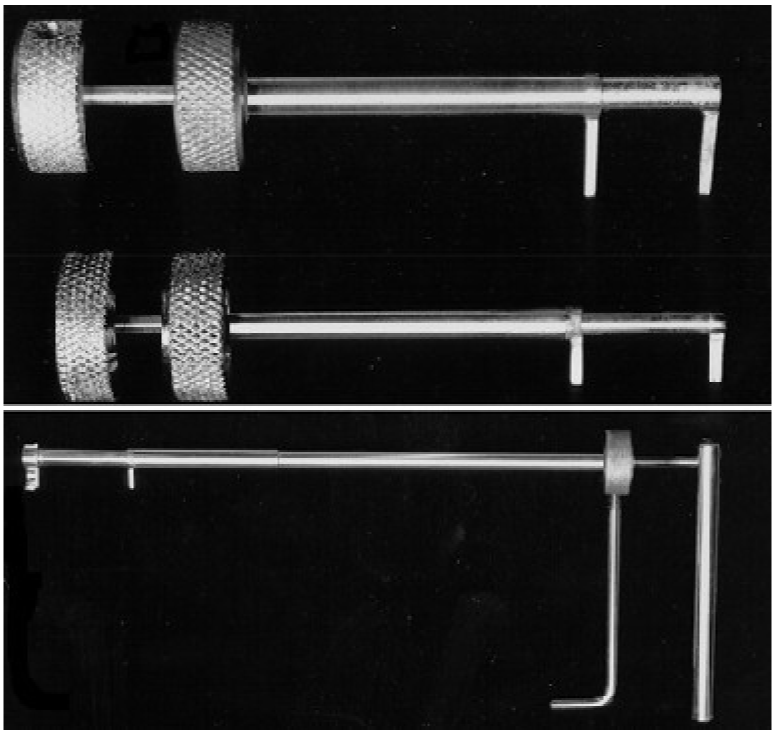
The wheel pick accomplishes two primary tasks: it provides a constant tension to the stump or fence while allowing the simultaneous manipulation of each individual lever. The center of the pick is hollow and fits over the post, the same as the proper key. The lower protruding section of the pick is used to enter that portion of the lever that transmits energy to the bolt, and causes it to slide when all levers are aligned.

Another shaft, with a slightly larger diameter, rotates around the smaller, lower shaft. The protrusion from this piece is used to manipulate each lever and can be moved vertically to accomplish the task. It has the thickness of one lever. When operated together, this pick can be used to open most mechanisms. When rotary tension is provided to the lower portion of the pick, the stump or fence is forced against the edge of all levers. Assuming a tolerance error, the gate on the lever that is most out of alignment will first encounter the stump. When the lever is moved to the position where the gate is aligned with the stump, the stump will move slightly, trying to enter.

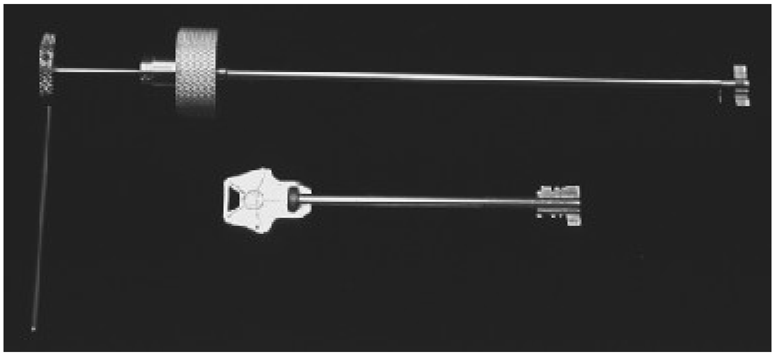
Picking lever locks with a two-in-one pick in certain respects resembles impressioning. There is a difference in feeling when manipulating false and true gates against a racking stump. The levers that are bound against the racking stump will be felt to move slightly, although there is a trade-off between tension and lifting pressure. Loose levers are not bound by the stump in their “true” gate, although they will feel tight when in a false gate. If the false gate has been designed with the exact same dimensions as a true gate, then the lock may be very difficult to pick.

A modified tension wrench and hook pick may also be used to bypass lever locks. However, some lever mechanisms can only be

opened with a two-in-one wheel pick, or a modified device. A more traditional tension wrench can be made from .100” piano wire and must be shaped according to the internal dimensions of the lock and the trunnion. A standard turning wrench or a special “L” shape will work. Whichever is selected, it must be capable of reaching and throwing the bolt.



A pick can be fashioned from .035” spring steel stock and should be formed in the shape of a high hook. Although thinner picks will not have the strength to lift tumblers, the pick cannot be thicker than one lever. The tip angle should be designed to point straight at the lever. In the Falle set, special picks are made for use on locks that have warding around the keyway. In such cases, an angle at its tip is required in order to avoid the warding.



John Falle produces a set of "jiggers" for manipulating levers. This process is similar to utilizing tryout keys in wafer locks. The kit shown (right) is a set of JIGGLERS or tryout keys for locks containing two Levers such as UNION and LEGGE. Most of these locks are very easy to open because of the limitations caused by having only two detainers. Security of these locks could be enhanced by introducing different profiles but these tools can bypass any profile.

The tools will open most locks but vigorous movement may be required. Derivation of an accurate code is difficult, because they are not stable within the lock. Most of these locks will open after trying just a few different tools.

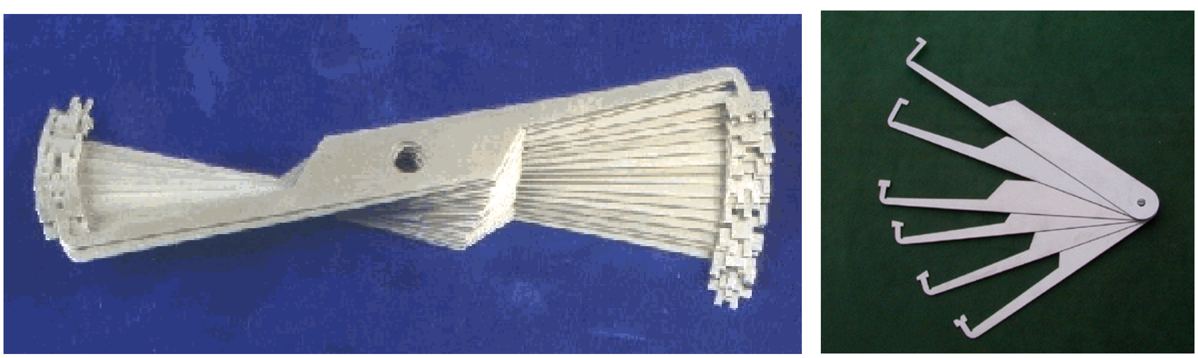


Figure LSS+2923 Two sets of "jiggers" to bypass lever locks. Courtesy of John Falle.

John Falle produces **wheel picks** as well as pick and decode systems for most **lever locks**, including high-security locks on safes and vaults.



Figure LSS+2924 A variety of tools are produced by John Falle for opening high-security lever locks. Courtesy of John Falle.

29_7.3.1.3 Theory of Picking Lever Locks

Successful bypass of a lever lock requires that all gates be lifted to align with the stump. As with the pin tumbler mechanism, the location of each gate can be sensed with the application of pressure exerted by the stump against the edge of the lever. Obstacles to deriving this information are incorporated in most mechanisms. These include false gates and barrel and curtain assemblies to block access to the keyhole during rotation. In theory, then, the steps to successful bypass are:

- **Know the type of lock and its theory of operation;**
- **Apply tension to the bolt so as to bind the levers by rotating 45°;**
- **Locate and lift each lever to align its gate with the stump;**
- **Trap each lever when aligned;**
- **Turn the wrench toward the levers to unlock.**

29_7.3.1.3.1 From the Perspective of the Lock Picker

An excellent description of the fundamentals of lever lock-picking appeared in a Bell Laboratories patent (**3402581**). In

1968, a pick resistant lever lock was developed for coin telephones. An excerpt from the patent application succinctly described the process:

"The basic problem of a lock-picker is to rotate each lever, without the benefit of a key, to a point at which each lever gate is in alignment with the fence portion of the bolt. This problem is readily solved by skilled lock pickers by any one of a number of methods, most of which employ some combination of the following steps.

First, pressure or tension is exerted on the moveable locking members in a direction to open the lock. This step is typically accomplished by rotating the plug and its associated cam with some suitable tool. The tension thus applied takes up the clearances between the lever pivot pin and the pivot hole in the levers and between the fence and the top radius of the levers.

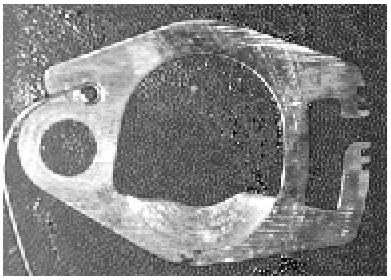
Next, each individual lever is rotated with a picking tool. As the gate is aligned, the lever is moved further toward the fence by the amount of clearance between the pivot hole and the pivot pin under the urging force of an individual lever return spring. The spring conventionally biases each lever toward its home or locked position.

Each lever gate is aligned with the fence in this manner, and each is held in that position by the combined force of the tensioned bolt and the lever return spring associated with each of the levers."

29_7.3.1.3.2 Conventional Picking Technique

To **conventionally** pick a lever lock, the appropriate tension tool is inserted into the keyway; the exact area must be located on the bolt to apply rotary force to the mechanism. After torque is exerted, the hook-pick is inserted. Each lever is lifted in turn until trapped; then the torque wrench is turned to throw the bolt. While maintaining tension, each lever in succession is raised until trapped as the stump partially enters its gate. False gates and serrations may be encountered that are used to frustrate picking. In such case, tension must be adjusted during the picking process to lift an individual lever in order that the true gate may be found.

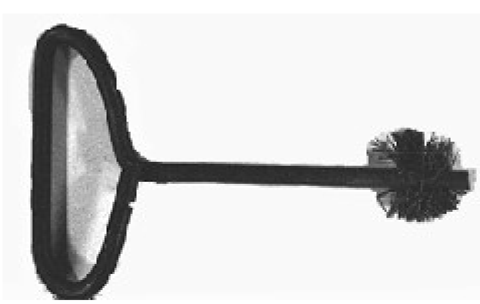
In at least one high-security lever lock, the manufacturer placed a precise number of false gates to either side of the true gate, not realizing that such pattern could be used to advantage. In order to pick this lock, one simply counted two gates; the third would be the one that required alignment of the gate.



Often, one or more false gates are placed on the levers where the stump contacts the edge of the gate. These may take the form of matching sawtooth serrations on the stump and lever edge, actual indentations near where the real gate is found, or H configuration gating. Certain high-security lever locks, such as S&G and Western Electric, have been specifically designed and patented to frustrate picking.

If a lever is picked to a serration or false gate, then all other tumblers may be extremely difficult or impossible to raise. In the alternative, once a lever has been trapped by a false gate, all other levers may be raised easily but none will set at the point where the stump is aligned with the gate. Generally, more torque is required to pick a lever lock than a pin tumbler or wafer mechanism. There must be an individual assessment and adjustment of tension as each lever is picked. However, it will also be noted that levers that are not set will raise quite easily. Weber invented a special pick set for lever locks in 1984 (**4457191(279)**).

The degree of binding of each lever may change due to the relative position of the bolt and pivot point. Thus, it is important to maintain a constant pressure to keep those levers that have been set in such a position. If a lever is trapped at a false gate, often the tension wrench can be vibrated and the lever raised and lowered rapidly until it is released.



Lever locks can also be picked using a borescope to determine the

wear on each belly, based upon the length of travel from the pivot-point. This is dependent upon the depth of cut of the key. See **Chapter 31** for a detailed discussion of the procedure.

29_7.3.2 Picking Safe-Deposit Lever Locks

Locks utilized in safe-deposit vaults generally provide higher security than the traditional lever mechanism. They often have dual control, requiring that both renter and the bank must insert keys at the same time. These locks can be picked, but often require a special tension wrench and hooked pick with a greater tip angle. The following special considerations will apply when bypassing these locks:

- **Those levers closest to the racking stump (fence) will generally be picked first;**
- **The pick can be no thicker than one lever;**
- **When a lever is picked, the top edge will generally rest on the fence;**
- **Any significant lessening of torque will release any picked tumblers;**
- **As with conventional lever locks, the tumbler lengths may vary slightly; thus, the first lever which sets will often be the most difficult;**
- **Application of tension must be in conjunction with movement of each lever; working the fence into each gate is required;**
- **After setting more than two tumblers, picking may become quite difficult; tension may have to be slightly released in order to manipulate added levers;**
- **When all levers are precisely the same length in high-security locks, it may be necessary to set the one closest to the bolt first, because there is more pressure applied to this lever from the bolt mechanism;**
- **The use of heavy torque can wear down the edge of the tumblers slightly; this can be of assistance where serrated levers are encountered.**

The "drill and pick" procedure may also be utilized to bypass lever locks. This technique requires that a hole be drilled directly above the gates to allow a wire or probe to be inserted

into the lock. Each lever is picked and retained in position by the wire. It is much like shimming a pin tumbler lock and accomplishes the same result.

Procedure to open a lever lock with the "drill and pick" technique. Courtesy of Harry Sher.

29_7.3.3 Safe Opening Tools

Specialized tools have been developed to pick and decode **high-security lever locks,** found in safes. It will be remembered that there is a preference for lever mechanisms for use on security containers outside the United States. John Falle, Martin Newton, and others have developed **unique wheel picks, pin and cam systems,** tools and techniques to covertly compromise the highest security locks.



Figure LSS+2928 Safe opening tools for many different locks are available from John Falle and others. Two popular European locks are shown: (middle) Fichet Monopole, and (right) Fichet mounted lock. The Fichet Monopole decoder kit is

available and described elsewhere in this text.

29_7.3.3.1 Opening High Security Lever Locks

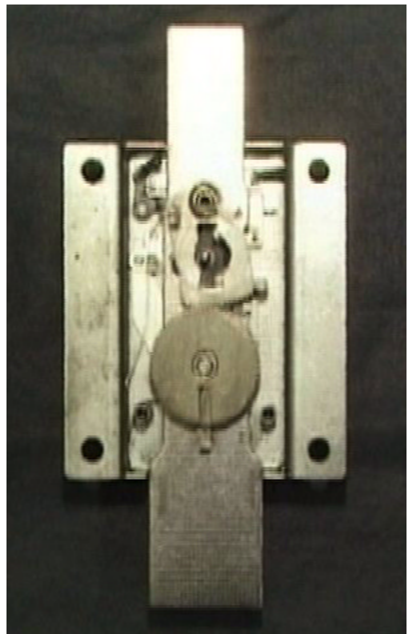
Specialized techniques are required to open many of the high security lever locks that are utilized in safes. Picking procedure are shown to open the Kromer Convar, Kromer Novum, Rosengrens ABN, and the Stuv mechanisms. Detailed information is also presented regarding the Rosengrens RKL10 lock. Markings on the levers can also be utilized to analyze the lock prior to picking, and to provide forensic indication of such action.

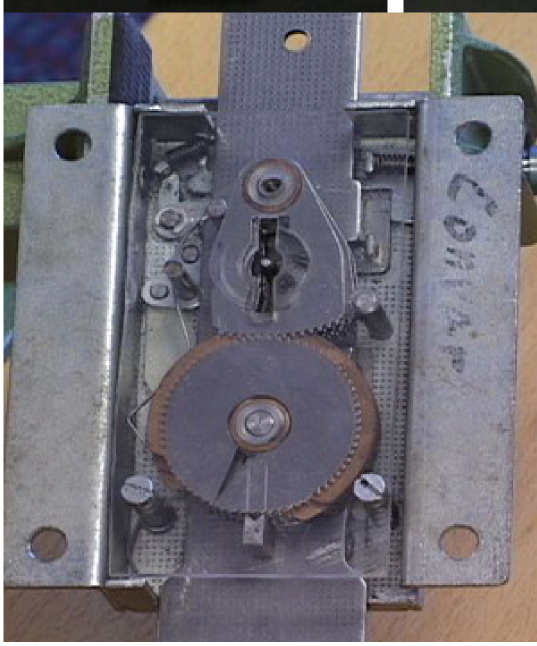


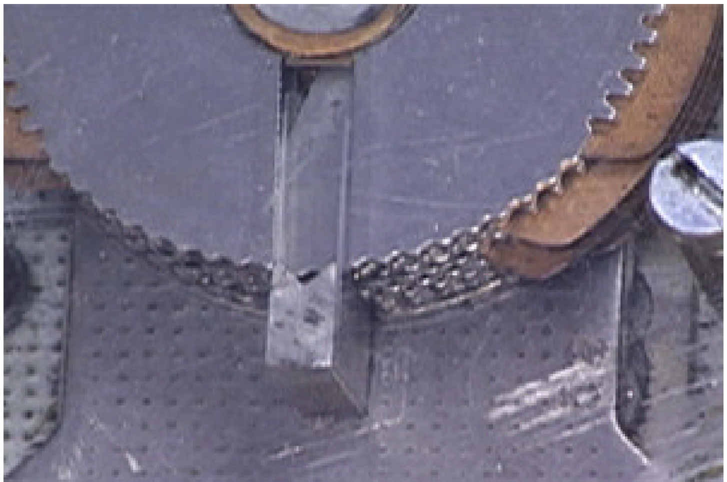
Figure LSS+2939 Markings on levers can be utilized as an aid to picking.

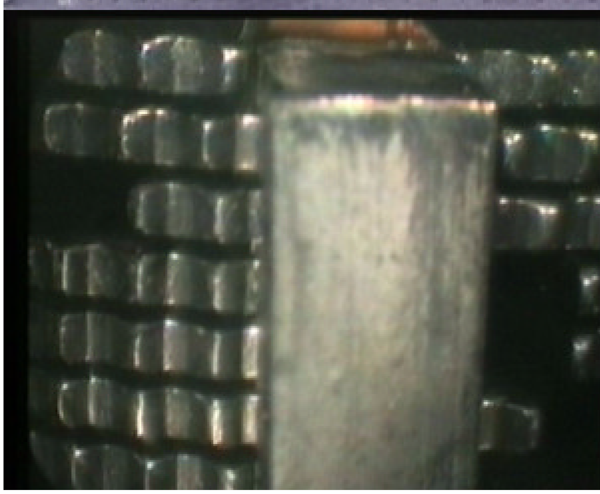
LSS204: Owe Bengtsson on picking lever locks and utilizing markings on the levers.



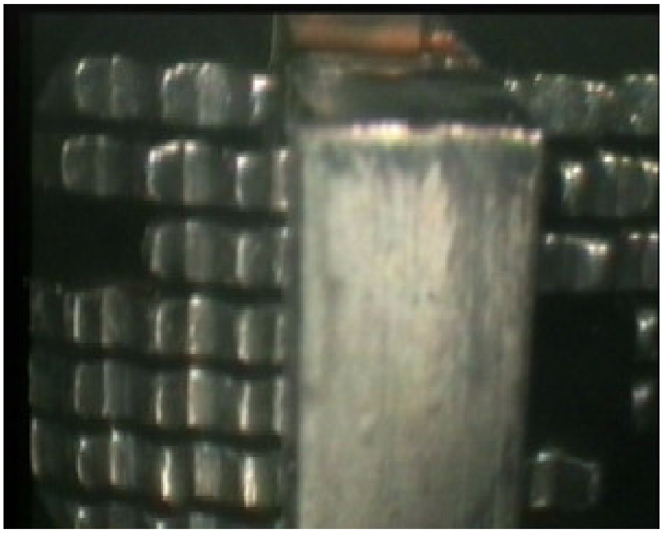


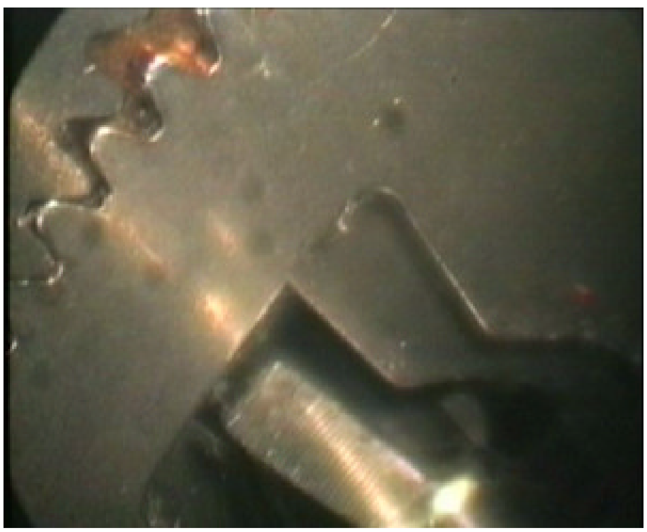












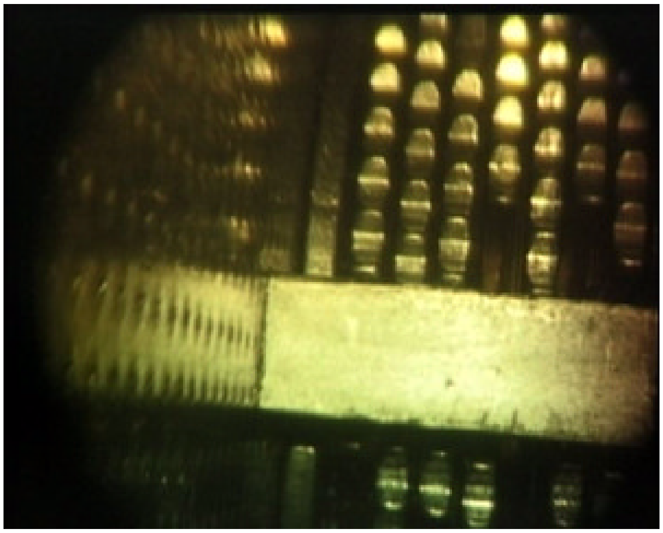
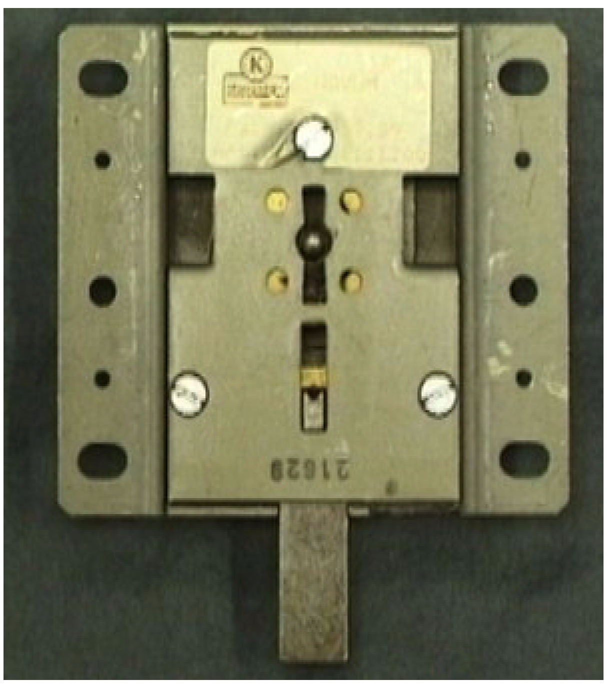


Figure LSS+2934 The Kromer Convar lever lock.

LSS204: Owe Bengtsson on picking the Kromer Convar lock



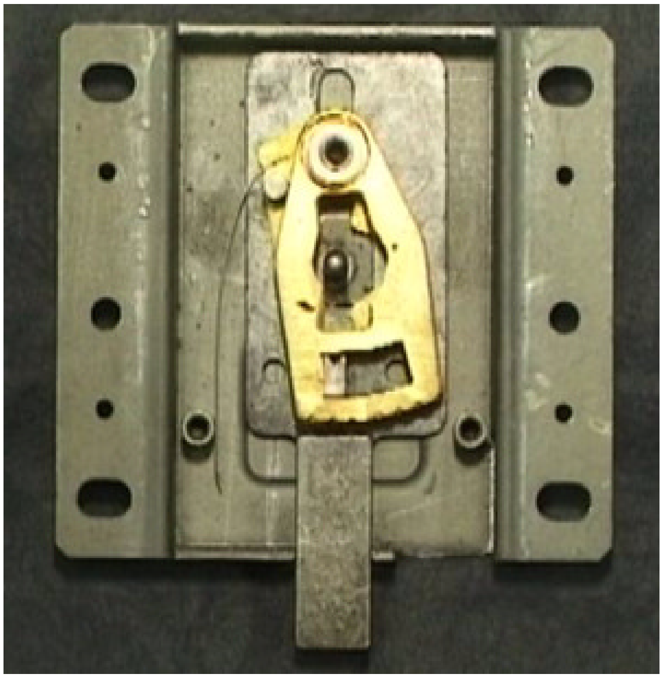
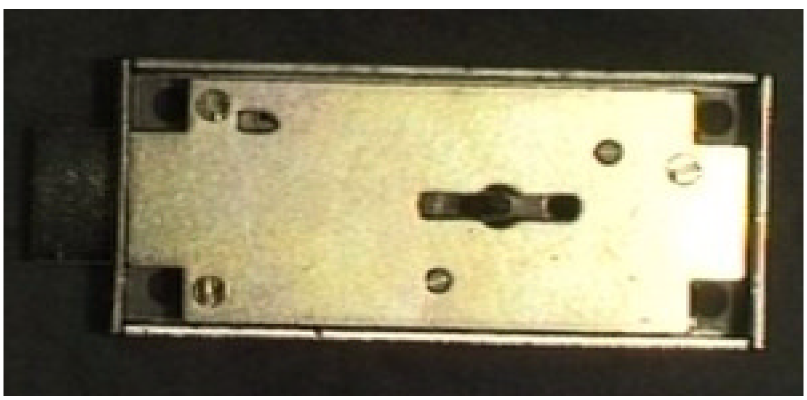
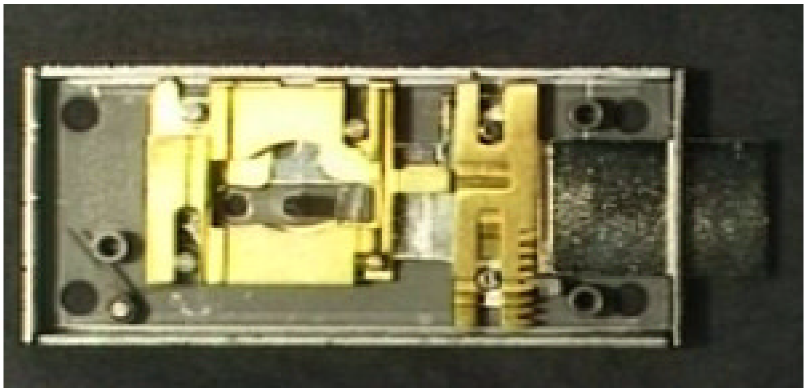
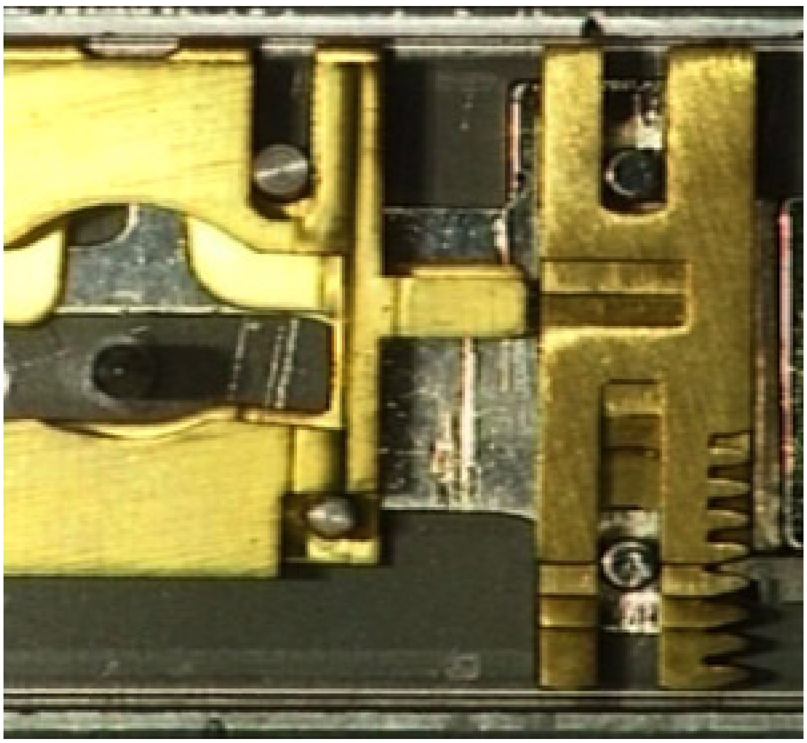


Figure LSS+2935 The Kromer Novum high security lever lock.

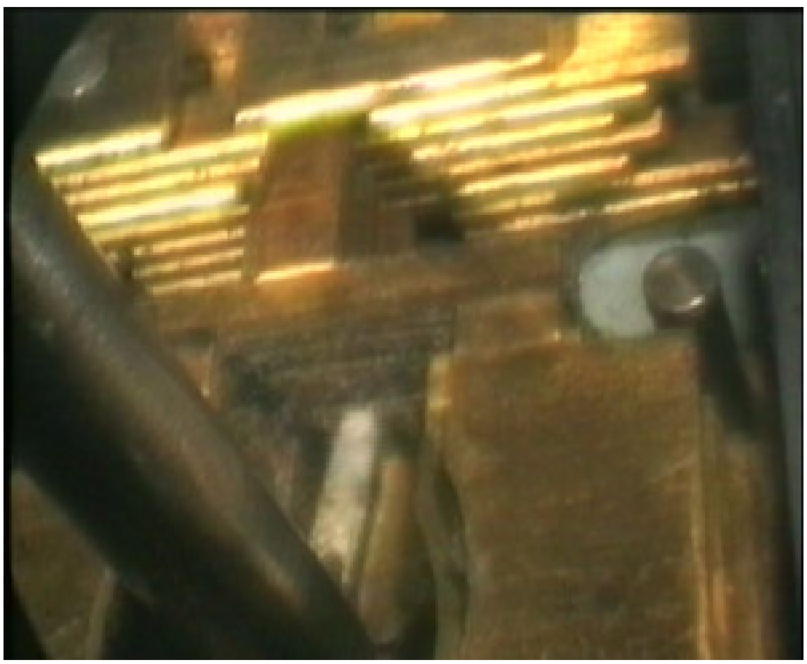
LSS204: Owe Bengtsson on picking the Kromer Novum lever lock











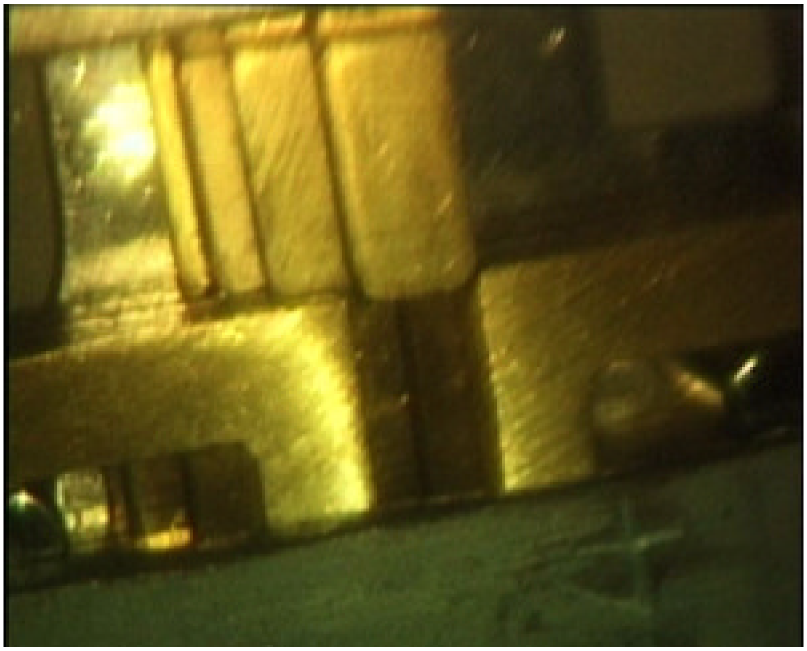
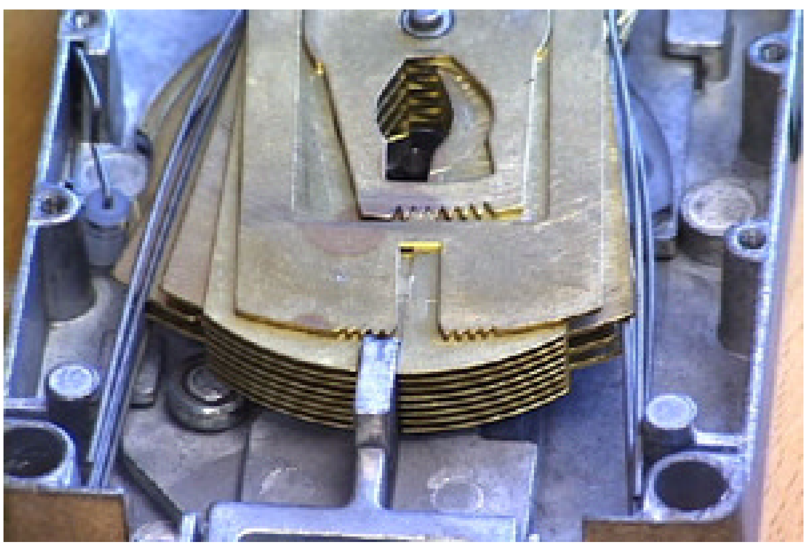


Figure LSS+2936 The Stuv lever lock.

LSS204: Owe Bengtsson on picking the Stuv lever lock.



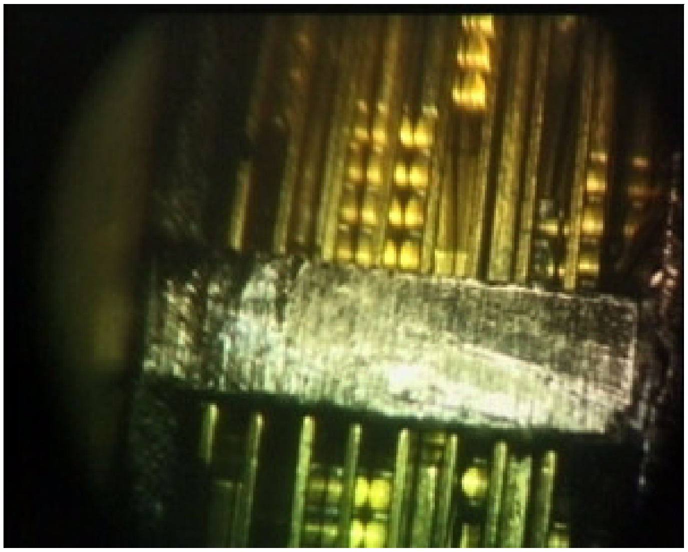


Figure LSS+2937 Rosengrens ABN 1 lever lock.

LSS204: Owe Bengtsson on opening the Rosengrens ABN1 lever lock.

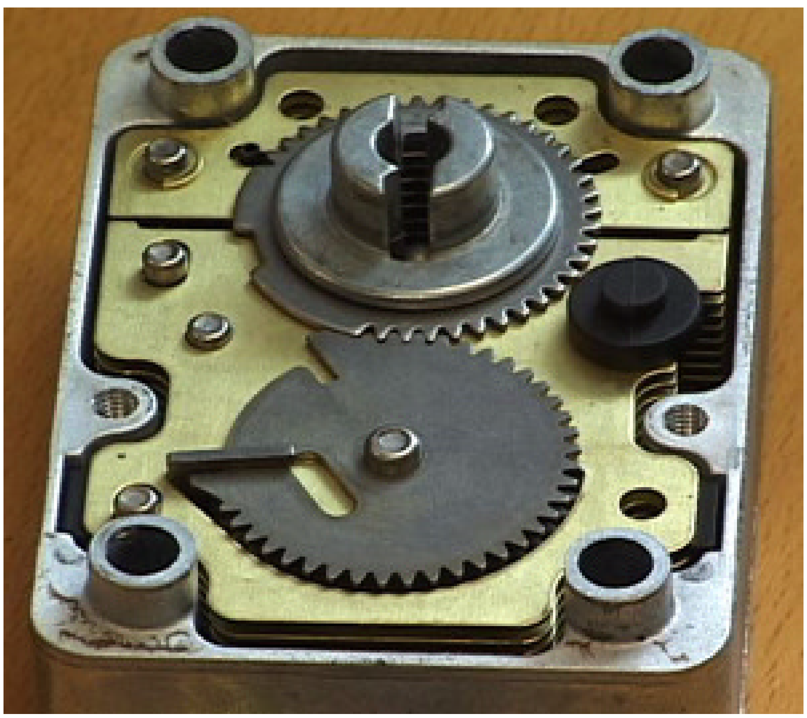


Figure LSS+2938 Rosengrens RKL10 high security lever lock.

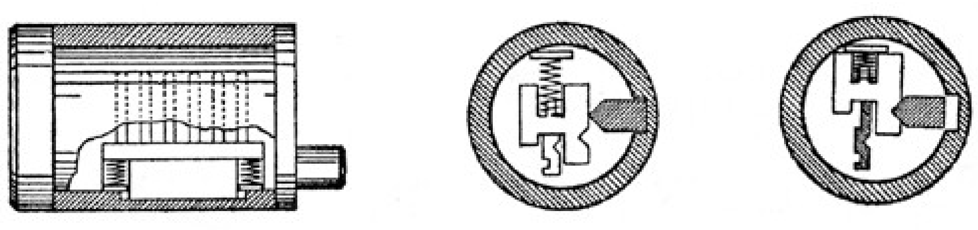
LSS204: Owe Bengtsson on opening the Rosengrens RKL10 high security lever lock

29_7.4 Sidebar Lock

A **sidebar lock** is a mechanism that incorporates a secondary locking bar that retracts into the plug to allow rotation after all tumblers are aligned. The sidebar principle appears in both disc and pin tumbler locks, and was originally developed in the United States by Briggs and Stratton for the automobile. There is evidence that the technique was actually patented in England in 1919. Sidebar designs actually evolved from a combination of the wafer and lever locks, and can offer high-security in both wafer and pin tumbler mechanisms. They are extremely resistant to picking because direct binding of pins is impossible.

Interestingly, there are many parallels in the design of the sidebar in comparison to modern combination locks. Each has gates into which a fence must drop in order to actuate the bolt. Each has a moving tumbler for each bitting position or, in the case of a combination lock, dialed number. The only real difference is in the number of depths or permutations available to each and the movement required for alignment. In the combination lock, it is rotational for each of the wheels in the wheel pack; in the sidebar wafer lock, it is the vertical movement of each wafer, determined by the bitting of the key. Pin tumbler sidebars add rotation as a security component.

29_7.4.1 Briggs and Stratton Sidebar Wafer Locks



The original Briggs and Stratton sidebar design is still in use today in millions of automobiles. Since 1984, Ford has also utilized a similar design. The GM lock consists of six wafers, each having a concave-shaped V gate that is cut into the side of the wafers at one of five locations, depending upon the desired

bitting depth. Each of the wafers rides in a channel within the plug (which also contains the springs, wafers, and sidebar). In this regard, a sidebar plug is similar to a traditional wafer lock. However, this is where the similarity stops.

A rectangular channel is cut along one side of and perpendicular to the plug in order to contain the spring-loaded sidebar. This metal bar floats within the slot, applying a constant pressure by its convex V surface against the sides of all of the wafers. The sidebar can only retract fully into the plug when all of the wafers are individually raised, so that each of their gates mates with the protrusion of the sidebar. The proper key will lift each individual wafer to align its gate to the sidebar. Depth coding is determined by the placement of the gate along the vertical surface of the wafer in one of five positions. Field disassembly and recombinating of these locks is quite simple, and can be accomplished rapidly.

The entire plug assembly is inserted into the shell of the lock. In the case of the ignition, the shell is actually part of the steering column. The application of torque to the plug will only cause the sidebar to catch on the corresponding channel in the shell. Thus, manipulation of tumblers accomplishes nothing. See **Chapter 23** for a complete description of the lock.

29_7.4.2 Sidebar Disc Locks

Abloy, Chubb, and other manufacturers of cam and cylinder locks developed a modification of the sidebar wafer principle. Rather than wafers, these locks employed rotating discs, much the same as within a combination lock. Disc sidebar locks function on the same principle, however, as the original Briggs and Stratton; only the design of the gate structure is different.

29_7.4.3 Sidebar Magnetic Disc Locks

A further design departure from the original sidebar lock is a unique mechanism developed by Evva (Austria) and Ikon (Germany) that utilizes eight very special magnets embedded in the key. They in turn drive eight magnetically rotating discs to control two sidebars. Each of the discs has a gate, much like the Abloy. All gates for each set of four discs must be aligned for the sidebars to retract. They cannot be picked or otherwise compromised in any traditional manner and are ideal for high-security complex keying applications. See **Chapter 19** for a complete description of these locks.

29_7.4.4 Sidebar Pin Tumbler Locks

Medeco, in 1967, created the sidebar revolution in pin tumbler locks with their radical design of rotating tumblers. See **Chapter 17** for a full description of the Medeco lock. This mechanism is another permutation of the original Briggs and Stratton. Substituting pins for wafers, the inventors developed two different kinds of locks, both employing the sidebar principle for maximum security.

A cam lock was introduced that has several single spring-loaded pins, almost resembling a mixture of a traditional wafer and pin tumbler lock. However, each of the tumblers has a small hole placed along a vertical surface, to correspond with pins protruding from a sidebar. The vertical and **horizontal** location of the holes determines the depth code for the key bitting and rotation angle.

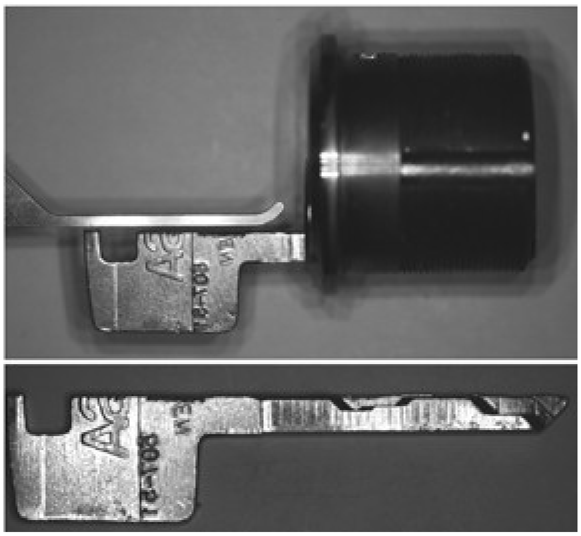
The correct key not only lifts each pin to the proper height but also rotates it in one of three orientations to align all of the holes so that the sidebar may enter and retract into the plug. The high-security pin tumbler version of the Medeco sidebar added one more security layer to the cam lock, described above. A full set of lower and upper pin tumblers was incorporated into the design. Thus, the original Medeco, and the new Biaxial are each a standard pin tumbler lock with all of the attributes of a high tolerance, certified device. In addition, a sidebar is added that can only be retracted when all of the pins are lifted and rotated to the correct position.

29_7.4.5 Picking Sidebar Wafer Locks

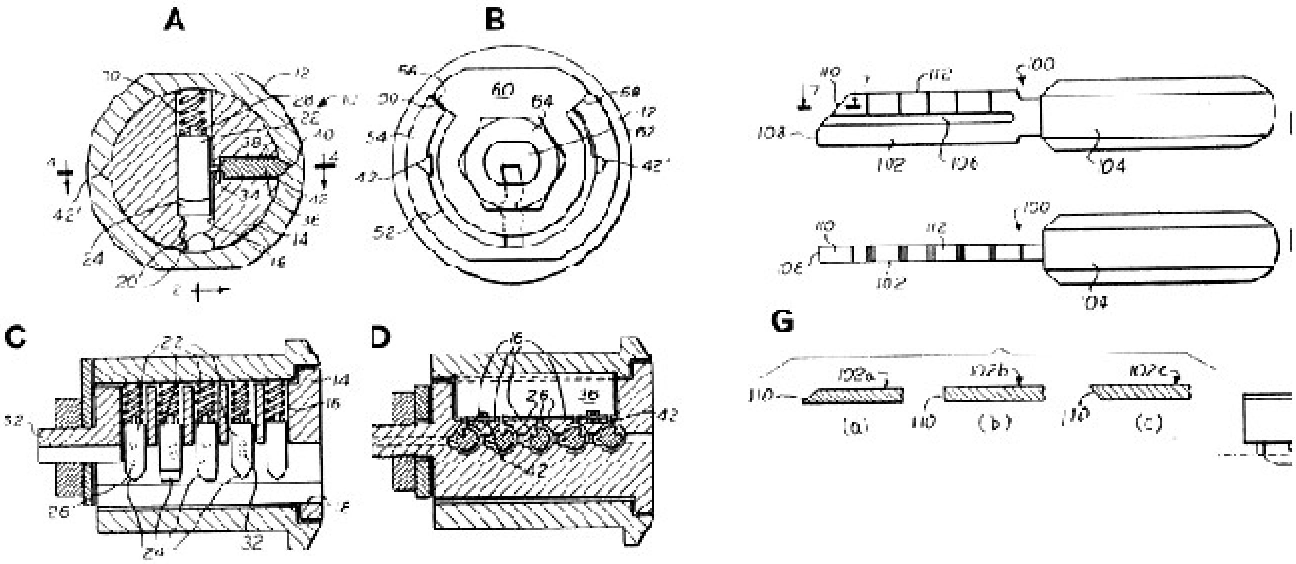
Although there are claims to the contrary, the Briggs and Stratton lock cannot actually be picked effectively. It can, however, be impressioned and decoded as described in **Chapters 30** and **31**. A unique GM and Ford decoder system has been developed and was patented by Joosten in 1987, that allows the rapid decoding and opening of these locks. This system is fully described in **Chapter 31**.

The lock can also be opened by drilling a small hole to the right of and centered over the sidebar at a 30° angle. A wire or straight pick is then inserted to place pressure directly upon the sidebar. Because the keyway is off-center, there is room to physically depress the sidebar against each of the wafers. Each

wafer is then picked, causing the bar to become rigid. There is no rotating tension to be applied; just pressure on the sidebar until retracted.



Medeco cam locks can be decoded based upon the use of a set of depth-rotation tryout keys. This procedure is more fully described in **Chapter 31**. It was also the subject of a Japanese patent. Medeco pin tumbler locks can be picked, impressioned, and decoded. However, special tools are required and a great deal of expertise. A patent was granted for the first Medeco pick and decoding tool in 1976. Since that time, several techniques have been developed to accomplish bypass. Four patents have been granted to Hughes in 1999, 2000, and 2001, for tools to pick the Medeco and other locks (**5956984(280)) (6041629(281)) (6138486(282)) (6173595(283)**). Falle-Safe produces a special decoding tool and procedure that is more fully described in **Chapter 31**. The technique involves the use of a fine shim wire and decoder to ascertain the required rotation and depth of each pin.



The original Medeco series were much more susceptible to picking and decoding because the channel on the side of each pin extended to the chisel point. Some of the newer pins have eliminated this characteristic by running the groove only partially down the pin. In addition, special security pins described elsewhere in this text are now employed in the Medeco Certified locks. Various pick tools have been developed over the years for Medeco products. One utilizes a “twisting wedge” point, made from a standard diamond pick. The last 1/32” is heated until blue, then twisted 15°. It is then filed to a wedge shape. To pick some series, a featherlight tension is applied. Raking is done to shear line, then regular tension is applied and the tumblers are rotated until the sidebar is aligned. Small mirrors have also been used to view the relationship between the channels and chisel points on the bottom of the pins.

There are other sidebar locks that, in the opinion of the author, are not as secure as the Medeco. Assa and Primus utilize a secondary locking sidebar, but unlike Medeco, the mechanical sidebar function has been split from the process of raising tumblers to shear line. The result offers the ability to obtain the unique sidebar code, and circumvent that portion of the lock’s security. Then, it is easier to bypass the lock in traditional fashion.

Picking Medeco locks. A discussion by Harry Sher.

29_7.4.5.1   Opening Sidebar Locks with Tryout

Keys

Tryout keys have been available for many automobile locks for almost fifty years. They can be used to open wafer and lever locks primarily, although keys may be devised for any mechanism with poor tolerances. These specially cut keys take advantage of the gap between the plug and shell, and theoretical versus actual differs. In fact, the correct key for a given lock only approximates the required depth-cut. It is rarely absolute. For example, a tumbler may theoretically be cut for a depth of .065" of bitting on the key, for a #1 cut. However, in reality, the tumbler will not block rotation of the plug with a bitting measurement of .063"-.067". Thus, a key having a cut of .063", .064", .065", .066", and .067" will work.

Now, let us say that the next cut, a #2 in our example, has a theoretical depth of .070", but will actually operate from .068"-.072." A tryout key can be made with a depth-cut of .0675", that will raise either a #1 or #2 tumbler to shear line with slight rocking. What this means is that a few keys can be made to approximate the depth cuts of all tumblers. The original Briggs and Stratton sidebar lock for automobiles, manufactured in 1935-1968 and used in all General Motors products, utilized six wafer positions with four possible depths. There were **4,096 (4^6) theoretical** differs. However, the tolerance of the lock allowed a 1.5 cut to open a 1 or 2, and a 3.5 cut to open a 3 or 4. Thus, in fact, there were only two depths for each tumbler position: a 1.5 and a 3.5 cut. The actual number of differs then became **2^6**, or **64.** Sixty-four tryout keys would open any General Motors vehicle in the United States prior to 1968, when the number of depths was changed.

In the later version of the lock, five depths were established as shown below. Three different bittings are required to open this series. There is a one-half depth tolerance, thus, a 1.5 will work for a 1 and 2 cut; a 3.5 will operate a 3 and 4 cut; and a 4.5 will operate a 4 and 5 cut.

DEPTH CODE	***ACTUAL DEPTH***	***TRYOUT DEPTH***	***TRYOUT DEPTH CODE***
1	***.248***	***.235***	***1.5***
2	***.223***		
3	***.198***	***.185***	***3.5***
4	***.173***		
5	***.148***	***.160***	***4.5***

For the same reason, combination locks used in safes can be manipulated and opened with automatic dialers. Although there are theoretically 1,000,000 combinations in a three-wheel, 100-segment lock, in fact, there may be as few as 290,000 actual combinations based upon 1.5 increment steps (1.5 increment steps, 100 divisions, 3 wheels: $\mathbf{66^3}$). The number will be reduced to 64,000 with 2.5 increment steps.

Tryout keys are generally produced on soft blanks and are milled to provide the maximum lateral movement by widening the wards and making the blank thinner. A unique variable key generation system, produced by Falle-Safe, is based upon this same theory. See **Chapter 31** on decoding. Tryout keys may also be designed for pin tumbler locks. In such cases, the ramp angles for each cut may be taken advantage of to provide added depths that may be simulated during oscillation of the key. Rocker picks are based upon the same general premise as tryout keys, but they are not usually designed for specific depth cuts. Their movement is less restricted, and thus they can simulate a wider latitude of depths.

29_7.5 Vehicle Anti-Theft System (VATS)

VATS was introduced by General Motors in 1986 on Corvettes in order to deter theft. Since this car was the most often stolen vehicle in the United States beginning in 1954, this was the first beta test of the system. Since that time, it has been incorporated in many other vehicles. The system, as described in **Chapter 23**, is based upon the integration of a simple resistor “pellet” in the head of the ignition key, together with a traditional sidebar mechanical lock. When inserted, a set of contacts reads the value of the resistor and transmits that information to a microprocessor in the vehicle. Electrically, the system is quite simple yet effective and easy to implement.

If the resistor value matches that stored in memory, the car can be started in the usual fashion when the key is turned. If the value does not match, the electrical and fuel systems are disabled and a fifteen-minute delay is triggered, during which **no key** may be used to start the vehicle. At the end of this period, the cycle begins again. The security of the system rests in the inability to derive the resistor value from the internal processor and the time delay that occurs whenever an improper value is input.

The system can be bypassed through the diagnostics port on the microprocessor with the proper test equipment. The only other way to compromise the system appears to be by obtaining the correct key, reading the value of the pellet with an ohm meter, then duplicating the key on the correct blank. To legally duplicate a key, a locksmith simply follows the same procedure.

29_7.6 Picking Axial (Tubular) Pin Tumbler Locks

The first patent for a tubular configuration was granted in 1934; the lock was manufactured by Chicago Lock Company. Axial pin tumbler locks are extremely popular in a variety of applications worldwide. They have proliferated into vending, telephone, banking, alarm, access control, and many other uses. These mechanisms can be found in mortise cylinders, cam, and padlock configurations. One reason they are so popular is that they are essentially impervious to climate and environment: temperatures, frost, dust, salt and other factors will generally not affect operation. Their popularity makes them a target for thieves, and thus, detailed information will be provided here.

Axial locks are based upon the same operating theory as traditional pin tumbler mechanisms: equivalent bottom and driver pins are placed to create a rotating shear line. The principle difference between the two designs rests in the location of the pin stacks. In conventional locks, all pins are contained within a rotating plug, wherein each chamber is oriented in a straight line, traversing the full length of the plug. Only the first pin is exposed in the keyway. In the tubular lock, pins are generally oriented in a circle around the axis of the plug rather than in a straight line, although this is not always the case. All pins are usually visible.

Axial keyways are defined by their diameter, number of active pins, diameter of the pins, spacing, number of dead (non-moving) pins, and whether the active pins are flush or protruding from the shell. The “standard” keyway uses a Taylor 137, Ilco 1137s, or HPC 1SP blank, .375” diameter. Most axial locks have standard keyway diameters. There are, however, undersized locks that have smaller keyways, making it impossible to insert the standard tubular pick.

Master keying schemes have been developed for axial locks, including the use of traditional master pins and additional master rings. Special keying systems and options are also available. Chicago and Fort, for example, offer instant rekey

systems, and which are discussed elsewhere in the text. Due to the acceptance of these locks, many special bypass tools and techniques have been developed for the locksmith trade. Several of these devices, primarily manufactured by HPC, are detailed in this section.

29_7.6.1 Definitions

There are a number of terms describing the parts of an axial lock and their bypass tools.

Bottoming Out

The springs and pins are compressed within their chambers to the maximum.

Dead Pins

These are solid pins placed between regular pins to act as wards. Generally, there is no more than one in a cylinder. Their function is to inhibit the entry of picks and keys. They can be bypassed by extending feelers in the bypass tool past the outer edge of the pick.

Feelers or Tynes

Sliding pins, shims, or other similar devices are used in pick tools to manipulate each corresponding tumbler within the lock. The tynes are generally very fine, flat spring steel shims that are placed axially around the circumference of the bypass tool. They mate with the pin tumblers and depress them, based upon the application of pressure exerted upon the tool.

Key

A key for an axial lock is, in effect, a round hollow shaft with indentations of varying depths placed around its circumference. They correspond with the depth of each pin tumbler. The key generally has a guide that fits into the slot on the shaft and facilitates rotation.

Keyway

The keyway is the round opening that allows a tubular key with a specified diameter to enter and depress the tumblers to shear line. It is formed so that the key fits over a slotted shaft.

Pin-Stack

The pin-stack consists of a spring, driver, top pin, and any master pin.

Shaft

The shaft provides the medium for transmission of rotational energy by the key and is the method by which the shear line is created and aligned. One thick round disc or rotor is generally affixed to the shaft. In combination with a mating parallel rotor, it creates a shell, plug, pin chamber and shear line. The shaft generally terminates in a cam that is used to actuate the bolt mechanism.

Shear Line

A shear line is created in the axial lock by the placement of two parallel stacked concentric rotors or discs, having holes drilled around their circumference. As in the conventional pin tumbler lock, a pin-stack is contained within each of these holes.

Shell

The shell is actually formed by one of the two concentric rotors that are affixed to the body of the lock. The other rotor, attached to the shaft, is the equivalent of the plug in a conventional pin tumbler lock.

Zero Cut

There are generally eight depths in most tubular locks: the zero cut is a no cut; the number eight is the deepest cut.

29_7.6.2 Producing Keys for Axial Pin Tumbler Locks

There are a number of manual and automatic cutters available to produce tubular keys. These can be small, handheld units or sophisticated and expensive computer controlled milling machines that are capable of reproducing virtually any key. The author recommends the HPC handheld cutters for use in the field. These devices allow generation of the “standard” keys rapidly in any environment.

29_7.6.3 Pick and Decoding Tools for Axial Locks

29_7.6.3.1 Introduction

Many picking and decoding tools have been developed to open these locks and generate keys. Actually, these tools manipulate tumblers, impression each pin, and decode pin length. Their operation will be discussed in this chapter, although they could just as logically be presented in **Chapter 30**, Impressioning, or **Chapter 31**, decoding locks.

The first decoding devices were patented by Harvey Wilson in 1953 and Robert Gruber in 1966 (**3149487(284), 2059376(285), 3251206(286), 2070342(287)**). Shortly thereafter, HPC began manufacturing and developing a wide array of tools for virtually every axial lock. A newer device was invented by Persson in 2001 (**6230529(288)**).

29_7.6.3.2 Basic Pick and Decoding Tool Design

Both pick and decoding tools for conventional axial locks generally operate upon the same theory: a modified form of impressioning. Virtually all picks employ a sliding shim or pin that is used to depress corresponding pin tumblers within the lock. Each shim is caused to drive the lower pin to shear line and stop. The position of each shim can thus be used to reproduce the correct key once the lock has been opened.

HPC has introduced many modifications since the first axial picks were introduced. Today, there is a selection of sophisticated bypass tools to open virtually any tubular lock. There are a number of different tools available, each designed for a specific lock design. They are produced in plastic and tool steel, and vary in sophistication. They all, however, perform the same function.

Some tools allow the manipulation of individual tumblers; others work on all pins at once. A particularly clever tool is called the "peanut." It is available for several different keyway diameters and is made of delrin plastic, with embedded shims. These devices are very small and convenient.

29_7.6.3.3 Tension Tools for Axial Locks

Tension tools may be constructed to allow conventional picking of

tubular locks. Generally, these take the form of square shapes, often using a specially cut Allen wrench. Square shapes, having measurements of about .62” on a side, are popular but are difficult to use. Remember, axial locks must be picked as many separate times as there are pins for just one revolution. Conventional picks may be utilized to manipulate each pin.

The main problem in conventionally picking these locks is that of leaving the plug partially rotated. The criminalist should be alert to this condition. As noted elsewhere in the text, a partially rotated shaft may also have been caused by a key being withdrawn that did not have a guide pin. It could also result from the use of a special master key or instant rekey system that allows removal of the key in any position.

Special forcible-entry tools are available, including hole saws and lock pullers. Hole saws, without the pilot bit, are quite effective; a needle nose pliers is used to turn the shaft. See **Chapter 32** for these techniques.

29_7.6.4 Security Features Incorporated within Axial Locks

In order to frustrate the use of traditional bypass tools and techniques, a number of manufacturers have developed high-security axial locks. Generally, telescoping or tube pins are utilized as the primary mechanical design alteration to increase security. In addition, springs of different tension, as well as mushroom, spool, and serrated tumblers may also be employed. Counterboring of chambers, and rotating plugs are other techniques. Some axial locks are UL listed.

29_7.6.4.1 Rotating Plugs

When this security feature is incorporated, the application of pressure to the face of the lock will cause the plug to rotate. These locks can be picked once a **single** pin is set. The procedure to bypass locks with rotating plugs is:

- **Insert the pick without any torque;**
- **Apply a slight turning tension as the tool is inserted;**
- **Once the initial pins are picked, release, and maintain a marginal turning pressure;**
- **Determine the sequence of picking.**

29_7.6.4.2 Counterboring of Chambers

Chambers close to the shear line are often counterbored or enlarged and widened to allow lateral movement of the pin. Once the tumbler is partially picked and the plug slightly rotated, the pins in such chambers cannot reach shear line. When they are picked, they will feel as if set at shear line, when in fact they are not.

29_7.6.4.3 Tamper-Resistant Locks

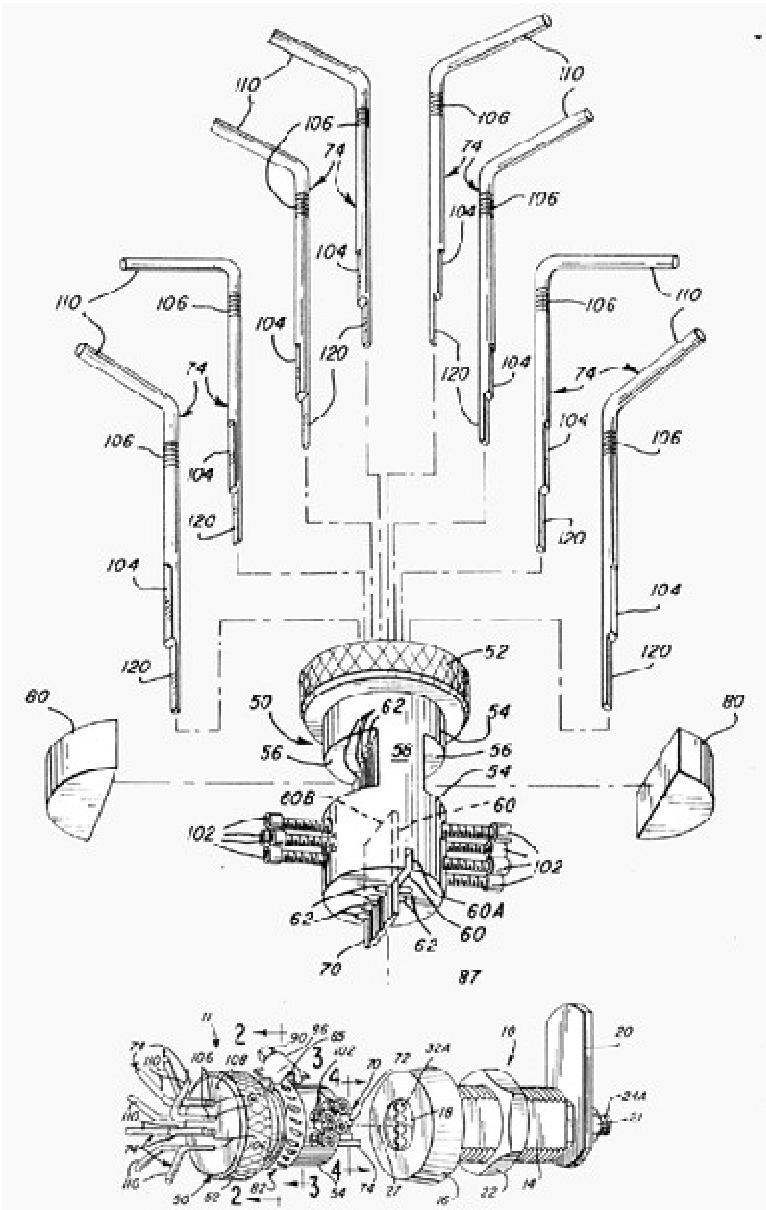
Combination pins that resemble master pins are used to create another shear line, making picking more difficult.
The second shear line is located at the "0" cut position. The lock is actually picked and can be turned slightly, but there is a steel roll-pin to prevent complete rotation.

29_7.6.4.4 Square Pins

Locks made in the Orient may contain square pins that reduce the cost of manufacture. These can be bypassed with standard picks.

29_7.6.4.5 Rectangular Keyway

Chicago Lock introduced an axial device having a rectangular keyway in about 1985, called the Tubar. These locks had a series of eight pins in two rows and featured a dual sidebar. Initially, no pick tools were available and bypass was quite difficult. The lock originally had a number of design problems and could be forcibly entered with little difficulty. See **Chapter 17** for a detailed description.



Exploded views 1, 2, 3.

29_7.6.4.6 Shrouded Entry

Locks in high-security applications can be protected with shrouds and pick guards to restrict the entry of bypass tools. These elongated metal throats cover the keyway, making manipulation of tumblers difficult. They are popular in coin-operated laundry machines; they can be bypassed using the HPC ALCP-10 automobile lock face cap puller. Pick guards may cause problems when a total lockout occurs. They are used on alarm switches and vending

machines and are very popular, assuming there is ample space for mounting. The HPC TLG-10 is an example of a shroud.

29_7.6.5 Basic Picking Theory for Axial Locks

Bypassing axial pin tumbler locks differ in several respects from conventional lock-picking. In many ways, opening is easier than when using traditional techniques and tools. Because all pins are accessible and may be observed, they can be individually picked with greater precision and less difficulty. There is more room to physically manipulate tools without affecting adjacent tumblers.

Although picking pins individually can be accomplished, it rarely is, because of the difficulty in applying torque to the shaft. Picking these locks with the class of bypass tools that utilize moveable feelers actually relies upon a modified form of impressioning and picking. Each pin, simultaneously, is biased with a corresponding spring loaded feeler or tyne. These shims are used to depress the pins in concert.

The underlying principle relies upon the fact that the resistance of the tyne will approximate the bias placed upon each pin by its spring. When the feeler is pressed against a pin, it will continue to move the pin until stopped by shear line. As the pin moves in the lock, so moves the feeler. Thus, whatever the distance the pin moves to reach shear line, so will the feelers move from the tip of the pick tool. In this way, the lock can be decoded after being opened.

In order to move the feelers, the tool is “pumped” back and forth, with new torque being applied for each cycle. This is precisely how a lock is impressioned. Pins will only bind when “set” at shear line. At all other times, they will be free to move, just as in the conventional pin tumbler lock.

The major problem in bypassing axial locks is that once picked, the plug will only rotate 1/7 or 1/8 of a revolution. This is why it is important to be able to decode the combination after impressioning/decoding one time. In case of difficulty, the tool can be removed and inspected for all feelers that have been moved to the #6 or #7 positions (far in), then reset to “0.” The tool is then reinserted, and the process repeated.

29_7.6.5.1 Preliminary Considerations for Picking Tubular Locks

Prior to picking any axial pin tumbler lock, the following items must be accomplished:

- **Identification of the type of lock and the corresponding tool to use for bypass. There are four different types of axial locks:**
  - **7-pin center (first pin is at 1 O'clock);**
  - **7-pin center; use HPC TLP-PEANUT or MIDGET;**
  - **7-pin offset;**
  - **7-pin left or right offset:**
    - **RIGHT = just right of keyway;**
  - **LEFT = just left of keyway;**
  - **8-pin center;**

- **Assessment of the best method to bypass;**
- **Selection of the proper pick tool;**
- **Be certain the plug is free to rotate. It can be tested with the insertion and turning of a blank key;**
- **Determine if there is external pressure on the shackle (in a padlock) that may cause the shear line to be inoperable. In this case, reverse shackle pressure may be applied;**
- **Inspect the keyway for dead pins;**
- **Be certain that the plug has some play: at least 1-2º is required;**
- **All pins must be able to move freely and easily. A key can be inserted and removed to move each pin or a regular pick is used to depress each pin;**
- **The O-ring on most tools is used to maintain constant tension of the shims or feelers. Be certain it is intact;**
- **Determine that each tumbler is working by testing with a conventional pick.**

All springs must be operational and not compressed, especially if the lock is exposed to elements (such as corrosion from temperature extremes, humidity, salt air, acid rain, or snow). Be certain that all active components move freely. If the lock is inoperable, it can be rapped with a mallet, sprayed with silicon, oil, or graphite to loosen stuck pins, or heated if

cold. Be careful not to apply too much heat as this may destroy the springs and melt components. If oil is used to clear or clean the lock, insure that it is completely removed from any external surfaces, as it will destroy the "O" ring in a pick tool.

29_7.6.5.2 General Rules Applicable to all Axial Lock Picks

All axial pin tumbler lock picks follow the same design and contain the same components. The following rules apply generally to their use. Special tools and procedures are detailed elsewhere in this section.

- **Practice is required prior to becoming proficient;**
- **Do not use force;**
- **Do not apply too much torque to the tool; it is not designed for heavy rotational pressure. Improper tension is the greatest problem in manipulating axial locks;**
- **All feelers should be placed in the extended position, then zeroed until flush with the end of the shaft;**
- **Insert the tool straight into the keyway and apply slight tension. Angles will cause extreme problems;**
- **Picking is done with an in/out motion, no more than 1/16" change. Practice a smooth in/out motion, with no angle of attack;**
- **Pick the lock until open;**
- **Carefully remove the tool so that decoding of the key is possible;**
- **The application of inward pressure without torque will accomplish nothing;**
- **Collar pressure on the feelers must be fairly high in order to retain their position and simulate proper impressioning of the pin tumblers;**
- **A pick may be inserted into the lock to depress each pin for a determination of spring tension. Tension is correlated to pin length: if tension were applied at random, these locks would be quite difficult to pick. In general, short pins are harder to depress because they must be pushed farther into the chamber. Longer pins will generally have less**

spring bias. With practice, it is easy to determine spring tension and thus the approximate pin length for a given chamber;
- **Try picking in the alternate direction if there is a problem opening the lock.**

29_7.6.5.3 General Procedures for Picking Axial Locks

- **Check all of the feelers on the pick. Their resistance should be about equal to the spring bias on tumblers within the lock. To add tension, add a rubber band rapped around the body of the pick;**
- **Push all feelers downward so that they extend past the tip of the tool. Depress the face of the tool against a flat surface to "zero" all of the feelers;**
- **Hold the tool between the thumb and index finger;**
- **Apply a slight torque;**
- **Withdraw the tool about 1/16," allowing the pins to reach their normal position;**
- **Pump the tool in and out. That is, move the tool back and forth, always maintaining a straight approach; never at an angle. In effect, all tumblers within the lock are being impressioned simultaneously through the action of the feelers;**
- **If the pick slips out of the lock, carefully reinsert so as not to disturb the feelers;**
- **Longer pins will require more movement to set than shorter pins;**
- **If picking a padlock or spring loaded-mechanism, more pressure will be required. The shackle may be depressed to relieve some of the tension;**
- **Once the lock is picked, withdraw the tool, applying a slight rotation of the shaft so it sets between the first and second tumbler position; note the depth for each pin;**
- **After successful bypass and slight rotation of the plug, "zero" all tynes on the pick. Then reinsert the tool with no tension applied so that the exact position of each pin can be determined;**
- **Decode the pick before using it as a key;**

- **Cut the key based upon the code information;**
- **When picking, set the feelers of most tools flush with the edge of the pick, except for mushroom pins. In these cases, the feelers should be set back at the #8 cut position;**
- **Mushroom pins will not cause any more problems to pick if they are properly identified.**



**Figure LSS+2910 The axial pin tumbler key and lock. These diagrams show the key,
and locks in a locked and partially picked position. The pick decoder tools are all
designed to manipulate each of the pin tumblers to shear line in order to rotate the
plug. Through a series of pumping actions, individual shims make contact with the pins
and actually impression each tumbler. Shown is the standard seven pin configuration.
Courtesy of HPC Interactive Learning Series.**

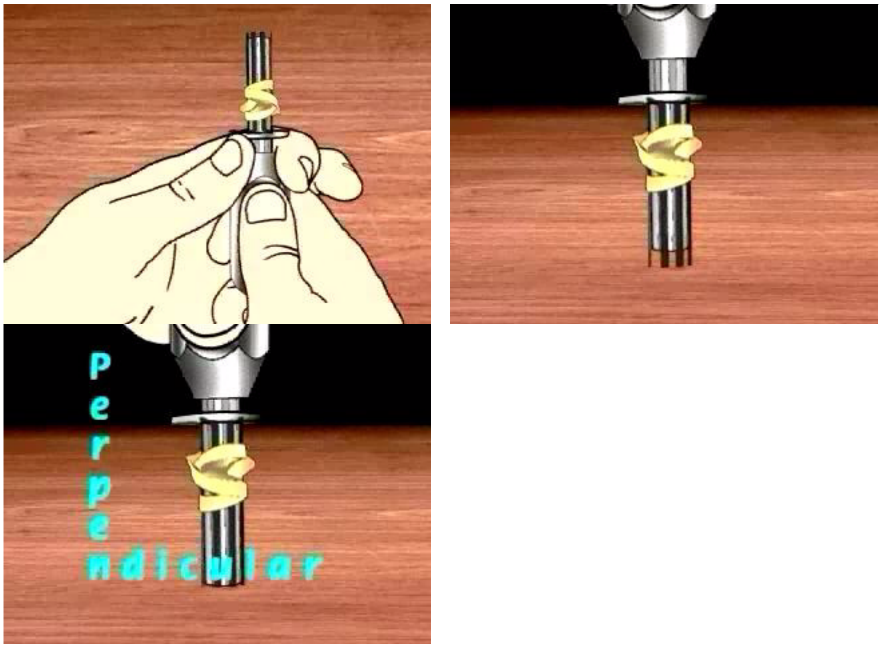
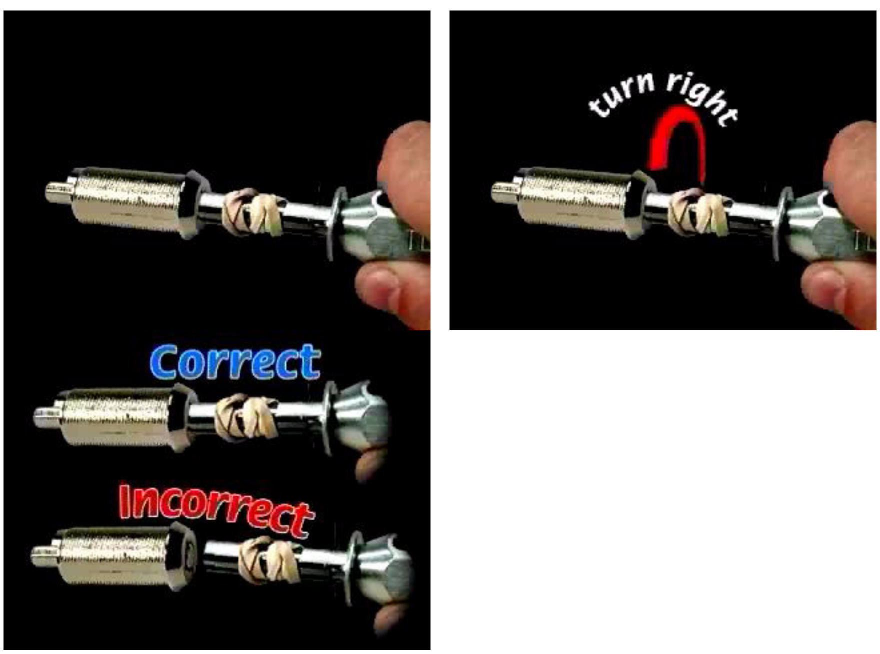


**Figure LSS2911 A rubber band is utilized to provide tension to the tynes and to
retain their position during decoding, while allowing movement as pressure is applied to each pin. The end of the tool is pushed against a flat surface to align
all tynes to the same position. Courtesy of HPC Interactive Learning Series.**



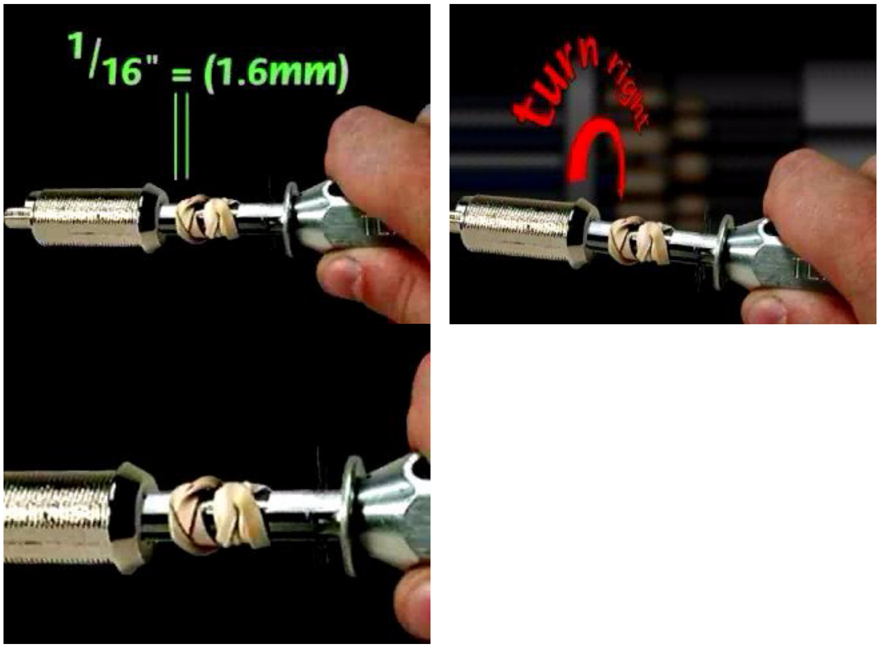


Figure LSS+2912 The pick decode tool is inserted into the lock at a perpendicular angle to a depth of approximately 1/16". A turning and pumping action is applied to, in effect, impression each pin. A series of such actions will cause each pin to move to shear line, with a corresponding movement of the tyne associated with each tumbler. The rubber band will maintain the position of the tyne, while allowing it to move slightly with the pin. Courtesy of HPC Interactive Learning Series.



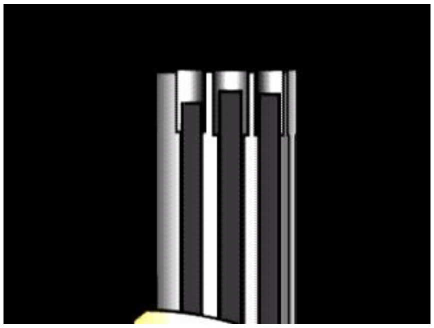



Figure LSS+2913 Once the lock has been picked and decoded, the pick decode tool is pressed against the tumblers to set the tynes to the exact pin depths. This is accomplished by slightly rotating the plug to a position where the pins are not aligned. Pressure may then be applied to the tool fully inserted into the lock, so that to the bottom set of tumblers are firmly forced against the shell. The tension on the tynes is increased to insure that their position is maintained. Courtesy of HPC Interactive Learning Series.

29_7.6.5.4 Picking UL Listed High-Security Axial Locks

High-security axial locks generally have ten or eleven pins, with three or four of those utilizing a telescoping design. The primary difference between these locks and conventional tubular mechanisms is tolerance, added pins, and the use of the telescoping design. The locks pick in conventional fashion: each tumbler must be individually manipulated. Often, the telescoping pins must be picked last.

29_7.6.5.5 Picking Axial Locks with Security Tumblers and Other Features

High-security axial locks will contain security pins resembling traditional mushroom, spool, and serrated designs. These will not cause any more difficulty when incorporated in axial locks than in traditional pin tumbler mechanisms if they are identified and picked properly. The procedure for picking tubular and standard pin locks is the same. It is quite difficult to determine which name-brand cylinders contain security pins, especially because locksmiths may replace standard pins in the field. The procedure for bypassing locks with mushroom and spool security pins generally requires the following procedure:

- **Determine which are security pins. There will never be more than two or three within any axial lock. Mushroom and spool pins are only used in driver**

position; serrated may be used for both bottom and top pins;

- **When utilizing a bypass tool, insert and withdraw in very shallow steps, only about 1/32". This procedure will prevent mushroom tumblers from catching. Pumping too far will cause the pins to catch at shear line;**
- **Pick the standard pins in the conventional fashion. When the lock is partially picked, the plug will shift approximately 5° toward the open position. Continue picking, depressing each feeler individually;**
- **Feelers located adjacent to mushroom or spool tumblers will indicate some movement as they are pushed toward shallower depths;**
- **Reset the pick and set all pins to "0" (at the edge of the tool), except the security tumblers, which are set to a depth of "8".**

In locks containing serrated pins, picking requires:

- **Locating which chambers contain the special pins;**
- **Decreasing the amount of torque;**
- **Picking each pin individually.**

29_7.6.6 Decoding Axial Pin Tumbler Locks

LSS204: Harry Sher on picking axial pin tumbler locks





Figure LSS+2940 Two examples of axial pin tumbler lock picks and decoders, produced by A-1 (left) and Peterson Manufacturing.

When these locks are picked with impressioning and decoding tools, the pin depths must be determined in order to produce a key after the bypass process has been successfully completed. Decoding occurs while the lock is in a picked status; generally, the core is rotated so that it sets **between** pin chamber positions. Pin depths can be derived either from the decoder tool or from a key that operates the lock intermittently (if it is damaged or chipped). Depths are approximately 1/64" per cut.

The **HPC TKPD-1** tubular key and pick gauge is a stainless steel device, having eight depths; number eight is a pin within a pin. This tool may be used for all standard small, large, left and right-hand UL tubular keys. Keys are read clockwise from the front. Remember to keep the corners sharp, do not use a wire brush, and read the key at the corners.

29_7.7 Picking Magnetic Locks

Magnetic mechanical and card locks can be categorized in five primary configurations as detailed in **Chapter 19.** Some configurations can be decoded, others, such as employed by Evva and Chubb, cannot. The basic principle of all magnetic locks rests upon the law of physics regarding magnetic energy: that like poles repel and opposites attract. All magnetic mechanisms rely upon this theory to communicate information and motion between a key and internal parts.

It appears that the first commercial magnetic lock may have been developed in Japan, about 1959, by K. Wak. It was based upon the

traditional pin tumbler design, but the pins were magnetic rather than spring-biased. They were raised by repulsion of the magnets embedded within the key. For many years, magnetic locks did not gain industry acceptance until the development of rare-earth materials and the integration of sophisticated sidebar locking systems.

There are a number of potential security problems and bypass techniques for these types of mechanisms:

- **Magnets jammed in the lock;**
- **Demagnetize all pins;**
- **Remagnetize all pins;**
- **Decode and read the signature;**
- **Copy a key and simulate it;**
- **Read each tumbler, then construct a key.**

The security of all magnetic locks ultimately rests upon the determination of the polarity and location of each magnet. In certain high-security designs, magnetism is used as a medium to cause the movement or rotation of secondary locking devices, such as the Evva, Ikon, and Chubb sidebars. They actually rotate discs, much the same as in the mechanical Abloy disc lock.

Several techniques have been developed for bypassing magnetic locks, although most require decoding the location and polarity of each magnet first. In certain locks, keys can then be simulated with matching magnets to either attract or repel all pins. The following traditional methods are well known:

- **Remagnetize all pins using an extremely strong field introduced into the lock;**
- **Read the magnetic signature and then simulate the location and polarity of each magnet;**
- **Read the signature on the key card and duplicate;**
- **Demagnetize all pins, then rap the lock open;**
- **Sense each magnet's position and polarity by listening and feeling; then simulate with a key or through the use of a Hall-effect probe;**
- **Electronically bypass, by introducing rapidly pulsating fields, to fool the magnets or Hall-effect sensors. This technique requires the construction of a strong electromagnet. This is done by using at**

least 1500 feet of #34 gauge insulated magnet wire wound around a soft steel core, minimum 3/4″ wide and 1/32″ thick, and approximately 8″ in length, folded in half.

A potential of 110 VAC is passed through a rectifier and coil, creating a very strong field. The tip is moved back and forth through the lock to neutralize all magnetic pins. A solenoid coil with the core removed and a rod inserted through the center can be effective. A multivibrator circuit can be employed to drive the field.

Some magnetic locks can be picked by utilizing a very small magnet on the end of a wire to sense the polarity and position of other magnets by listening and feeling their movement. Clark invented a magnetic lock pick (**4073166(289)**) in 1978.

The author has developed a sophisticated procedure for decoding and opening many mechanical and electronic magnetic locks. This technique will provide immediate placement and decoding information for all magnets, allows for the decoding of master keys in card-based systems, and will make possible the generation of a key. See **LSS+/**[x] for a complete description.

29_7.8 Picking Dimple Locks

29_7.8.1 Introduction

Dimple locks contain one or more rows of pin tumblers in either a horizontal, vertical, or combined orientation. They may utilize solid pins, or a pin within a pin (telescoping), for high-security applications. Generally, the locks can be picked and easily impressioned. The locks are so named because the keys have bitting that resembles a series of dimples or indents on one or more surfaces. These dimples perform the same function as the bitting on a traditional key. Unlike conventional pin tumbler locks, however, the pins are all aligned in one or more straight rows, generally at the 12, 3, and 9 O’clock positions, or radially, at 4 or 5 positions.

Dimple locks can be picked, raked, impressioned, or vibrated open. In the photograph below, a Lips dimple lock was the subject of attack at the Antwerp diamond exchange in Belgium during a $100,000,000 burglary in 2003. The tool is a modified Allen wrench that is used to rake the tumblers. Using this tool,

investigators were able to open these locks with no lock picking skills.



Figure LSS+2942 A rake pick, fashioned from an Allen wrench, can easily open dimple locks.

Depending upon design of the keyway, orientation and placement of

the tumblers, and special security features, these locks can be simple to extremely difficult to bypass. They generally have very limited tumbler depths as compared to a conventional lock but will contain many more pins. The locks are provided in cylinder and profile configurations.

It is important to note that the pins and springs may not be at the top of the keyway as might be expected, especially in the profile design. Often the drivers are attached to the springs. Several manufacturers produce machines capable of duplicating dimple keys. For laboratory or field work, the author recommends the Silca SLX for its versatility and reliability.

29_7.8.2 Conventional Bypass Technique

The proper method to pick a “conventional” dimple lock requires the use of a small tension wrench and a half or full-ball pick. Tumblers can be picked individually or raked, depending upon the factors noted above. If dealing with a profile lock, it must not be picked more than 20° in either direction, or there is a risk of losing pins. In fact, in some locks it may be possible to actually remove pins from the lock during bypass.

Picking requires very little movement of the pick tip to simulate the shallowest cut on the key and to move between tumblers. The main obstacle in bypassing dimple locks is to manipulate individual tumblers without disturbing or raising adjacent ones. An “in and out” and rotational motion is generally employed in a modified raking action to open dimple locks with solid pins. Telescoping tumblers can present much more difficulty. There are, however, tools available to bypass certain of the high-security dimple locks. See **LSS+/^{x}** for a full description.

29_7.8.3 Forensic Examination

Care must be exercised in disassembly. Some of these locks contain uneven space sliders. Each must be replaced in the proper place and order or the lock will not work. If conducting an examination for evidence of bypass, look for elongated or distorted chambers or deformed or crushed pins. This is highly indicative of impressioning. So also, there may be wax, tape, or other residue within the keyway. See **Chapter 26** regarding forensic analysis.

Residue may be present when a dimple lock has been bypassed. Courtesy of

Hans Mejlshede.

29_7.9 Picking Best Removable Core

Best Lock Company was perhaps the first to introduce removable-core cylinders. Although many other vendors now produce similar and often interchangeable products, Best still is one of the leaders in the industry. The concept is simple: a sealed module, containing the plug, control ring, control pins, drivers, and springs, is housed within the shell. In effect, the removable core is a self- contained lock with a cam and special locking tab to prevent removal of this assembly without the use of a control key.

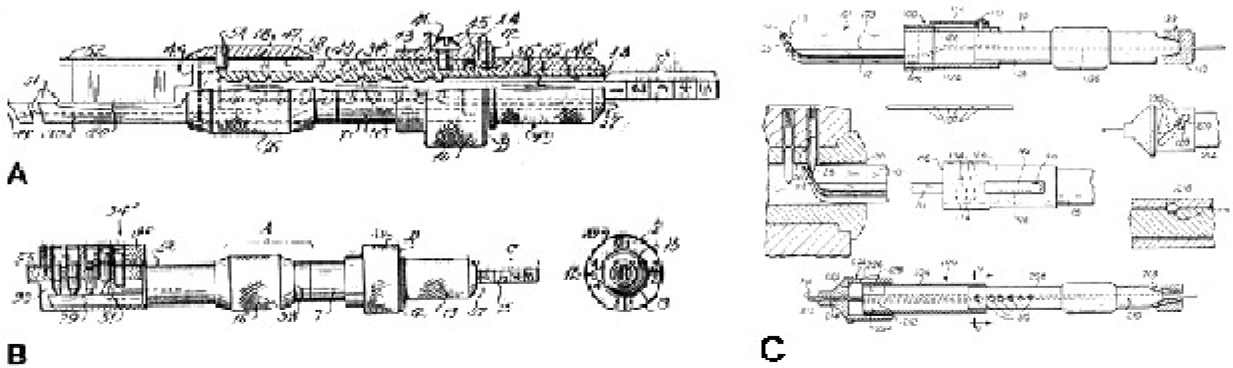
The core can be withdrawn from the lock by inserting the control key, which raises tumblers to a second shear line created by a control ring. The control ring in turn will allow the rotation of a locking tab that ordinarily prevents the core from being removed. In regular use, the change key or master key is inserted. This raises a set of tumblers to the shear line associated with the plug. It is impossible to remove the core by picking the pins to this shear line. The control key raises the tumblers to a second, higher shear line created by the addition of a ring surrounding the plug. This resembles the Corbin Split Ring design used for master keying which is discussed elsewhere in this text. The control shear line splits the pins between the control ring and shell.

The difficulty in bypassing removable core locks is twofold. Providing the proper torque can be a problem, because there is a tendency to rotate both the plug and control ring. Physically, there can also be a problem with the proper seating of the tension wrench. In the case of Best, the chamber holes at the bottom of the keyway are open. A special tension wrench has been designed that penetrates these holes in order to allow picking of the control ring.

Care must also be exercised to utilize picks with small tips. Pins are spaced quite closely between the regular and control shear lines; thus there is a tendency to over-raise them. Within the Best lock, it is possible to decode the control key by removing all of the top pins and measuring them. Their length will directly correlate with the control pins.

29_8.0 Specialty Pick Tools

Many specially designed picking tools are produced by John Falle, HPC, Lock Defeat Technology Corporation, MSC and other vendors for high-security locks. Some implements incorporate extremely sophisticated mechanical designs to bypass equally sophisticated locking mechanisms.

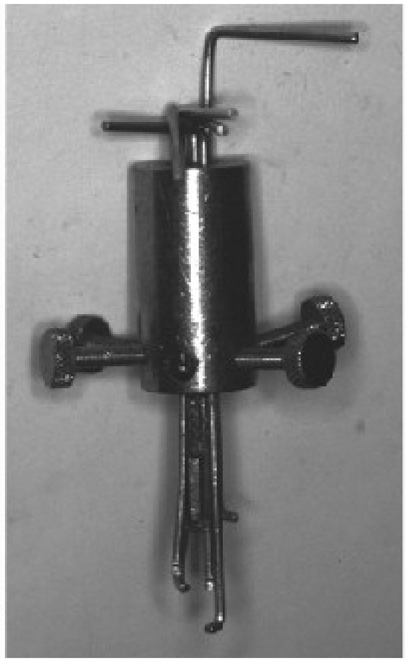
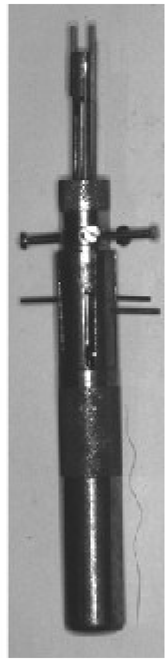


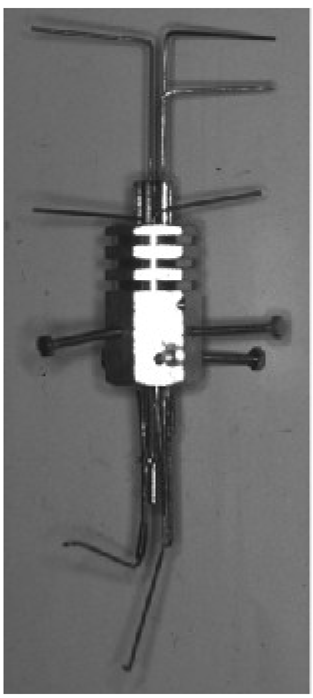
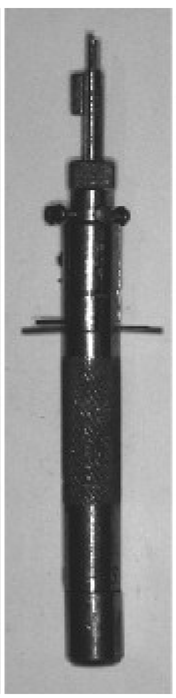
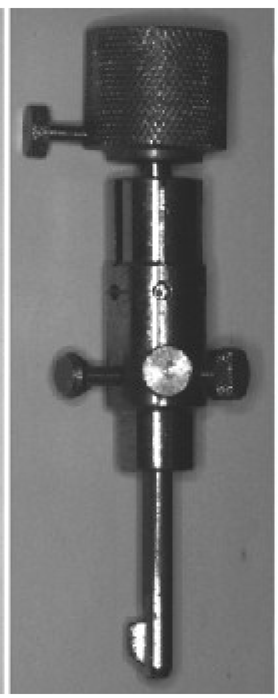
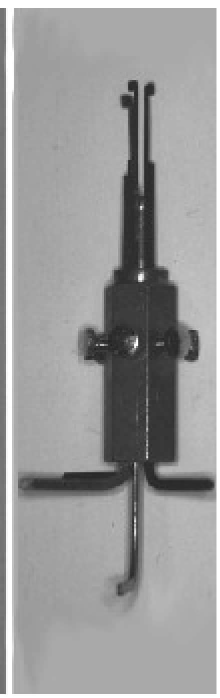
A montage of some of the most clever and innovative tools for picking locks is shown at the end of this chapter. Development of such implements began more than two centuries ago. The ingenuity of locksmiths and government operatives is evidenced by the fact that very few locks are immune to bypass with such tools.



Exploded views 1, 2, 3, 4.

Other devices for decoding and picking locks are examined in **Chapter 31.**

29_8.1 Sputnik Picking and Decoding Tool

LSS201: MSC "Sputnik" bypass tool, courtesy of MSC.

MSC and Oliver Diederichson have developed a specialized picking and decoding tool dubbed the "Sputnik" for pin tumbler locks. This device utilizes fine wires that are manipulated by the operator to move each pin tumbler, through the action of telescoping members. The name of the tool was derived from the first Russian satellite because of the antenna protrusions from the spacecraft which closely resembled the tool design. The tool closely resembles one that was described in a patent issued to Bitzios in 1992 (**5172578(290)**).

Special blanks are produced by MSC for each keyway, and will function with five or six pin locks. The tool has the advantage of allowing the manipulation of all tumblers without disturbing the relative position of any one pin. In conventional picking, the length and position of one tumbler can cause the resetting of all other tumblers as the operator attempts to lift a particular pin. The Sputnik provides a way around this problem. Picking is accomplished by sensing the position of each tumbler as the wire associated with it is moved, causing the pin to reach shear line. Use of the tool is fairly straightforward, and is shown in the video demonstration.

Once the lock is picked, the position of each telescoping section can be locked in position and decoded.

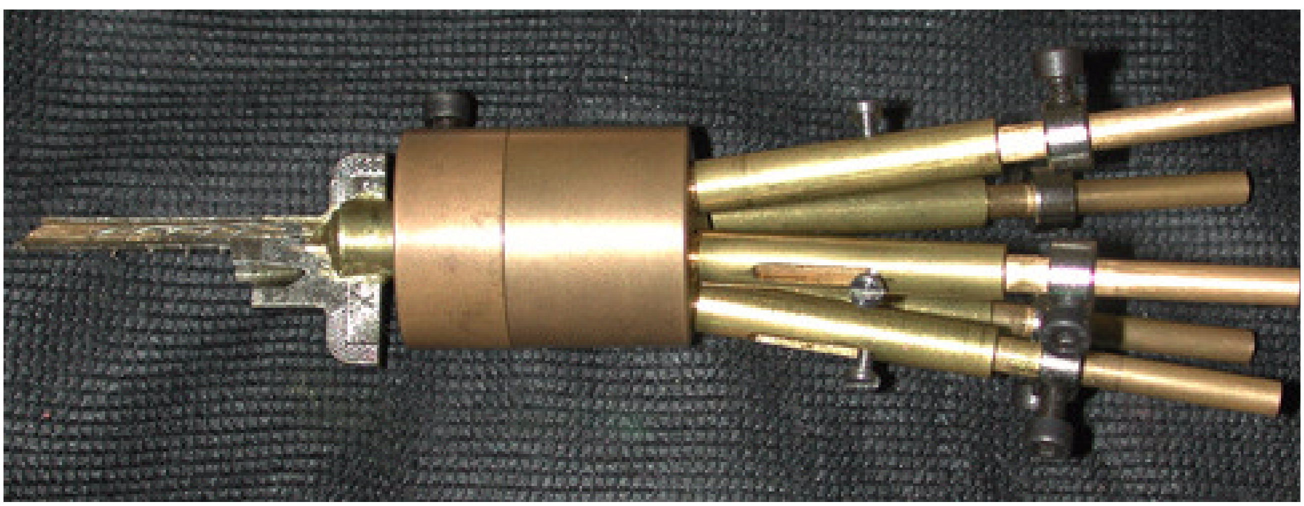


Figure LSS+2914 The MSC Sputnik tool can manipulate all pin tumblers simultaneously.
Each telescoping tube controls an individual wire. The setscrews determine the relative
position of each wire, and can be locked in place to decode the lock after picking.

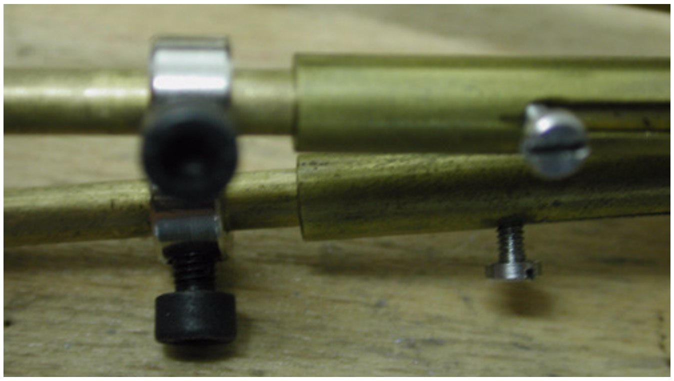




Figure LSS+2915 Each member of the Sputnik controls an individual wire shim. The moveable ring is secured by an Allen screw to lock the member into position for later decoding. A locking screw retains each shim wire in position.

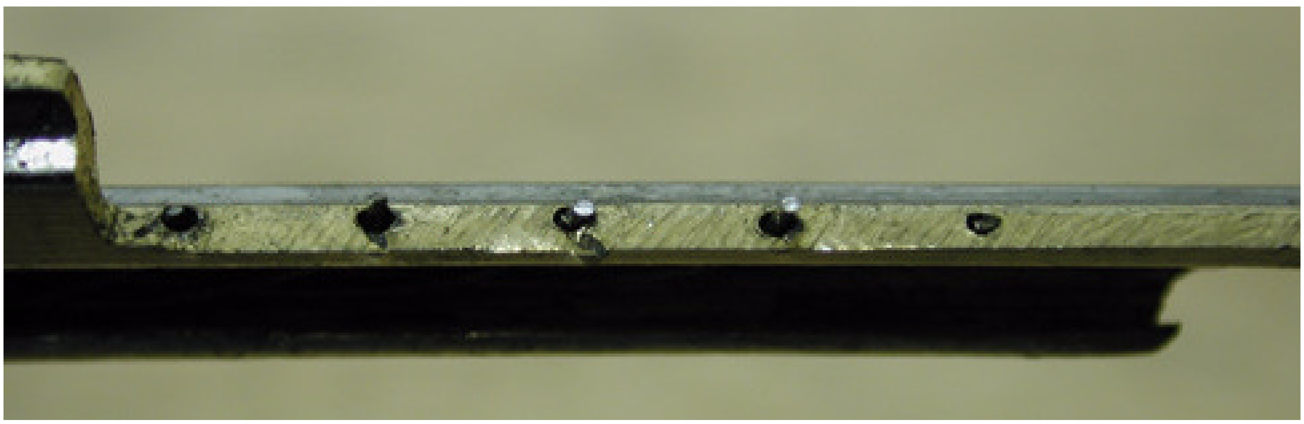


Figure LSS+2916 A blank key with the correct keyway profile must be produced by MSC
for a specific lock. A hole is drilled to correspond with each pin chamber.



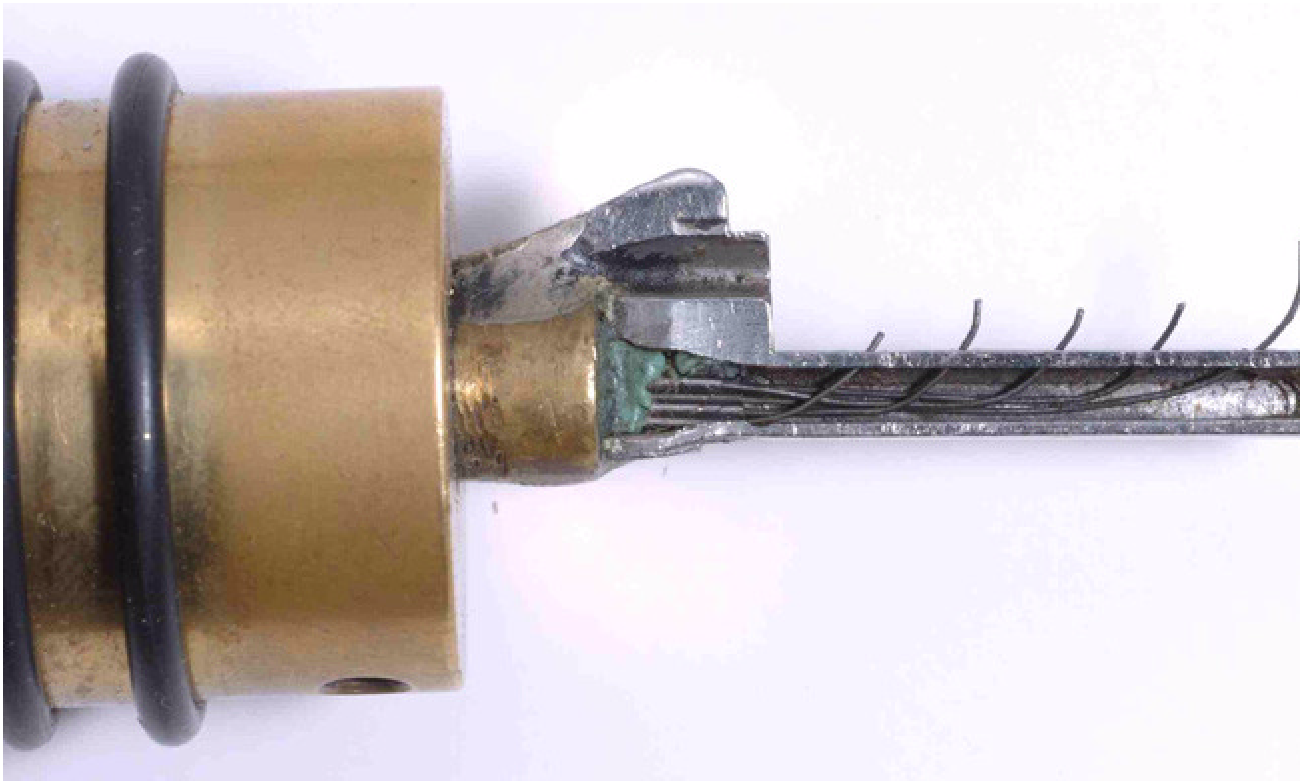


Figure LSS+2917 This photographs shows how each shim wire is associated with a chamber.
The wires are utilized to force each pin to shear line.

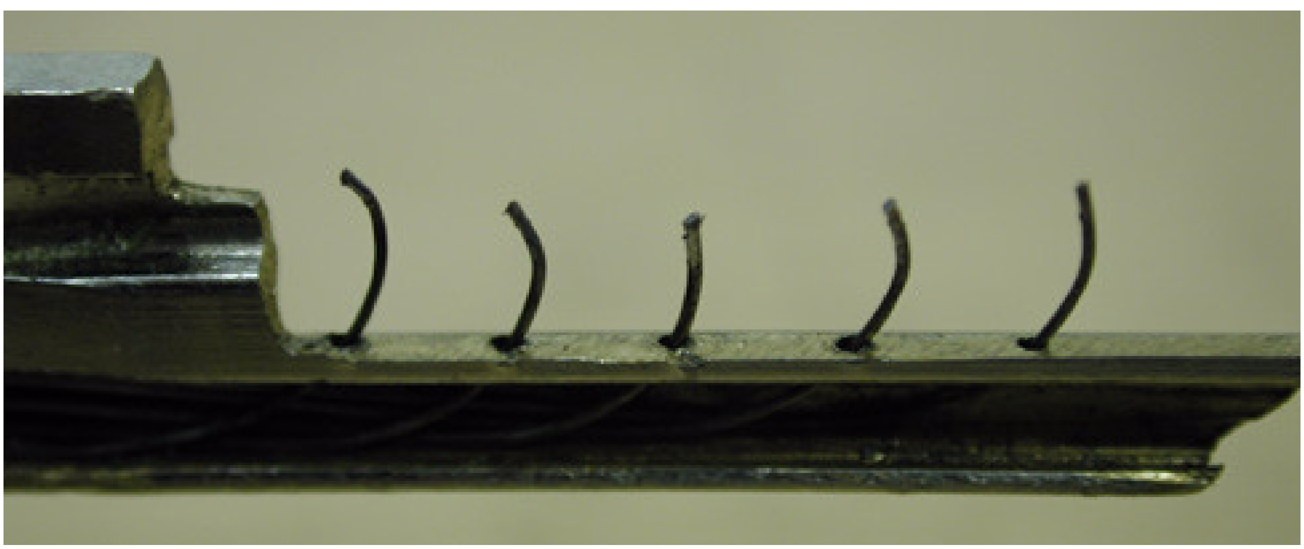
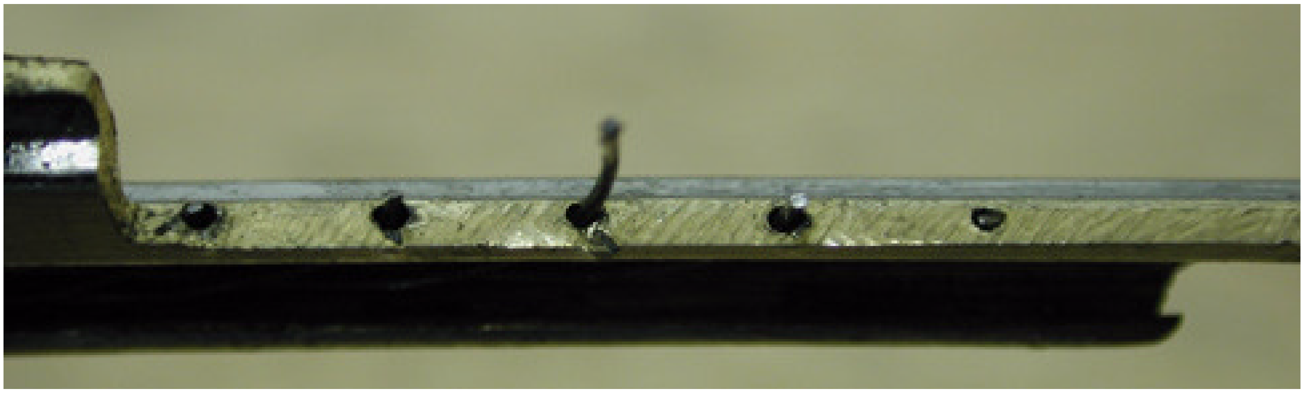


Figure LSS+2918 This photograph shows all shim wires fully extended.



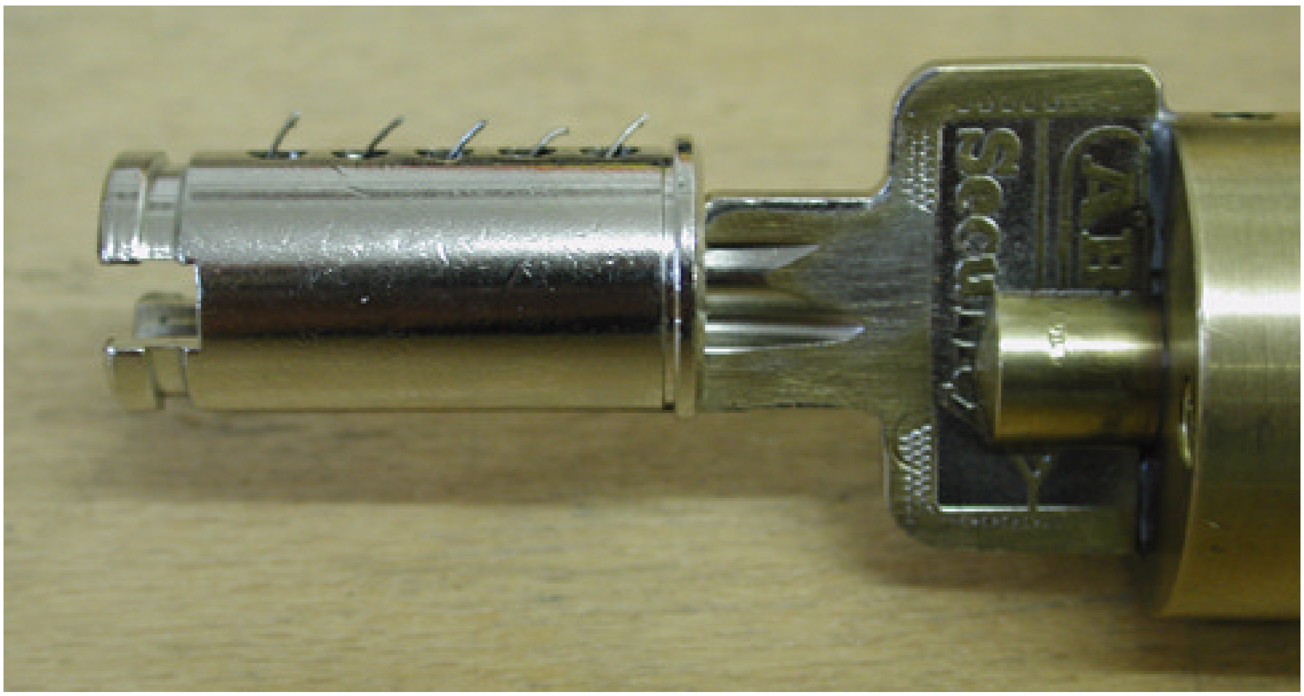


Figure LSS+2919 Any one or more shim wires can be manipulated individually while picking a lock.

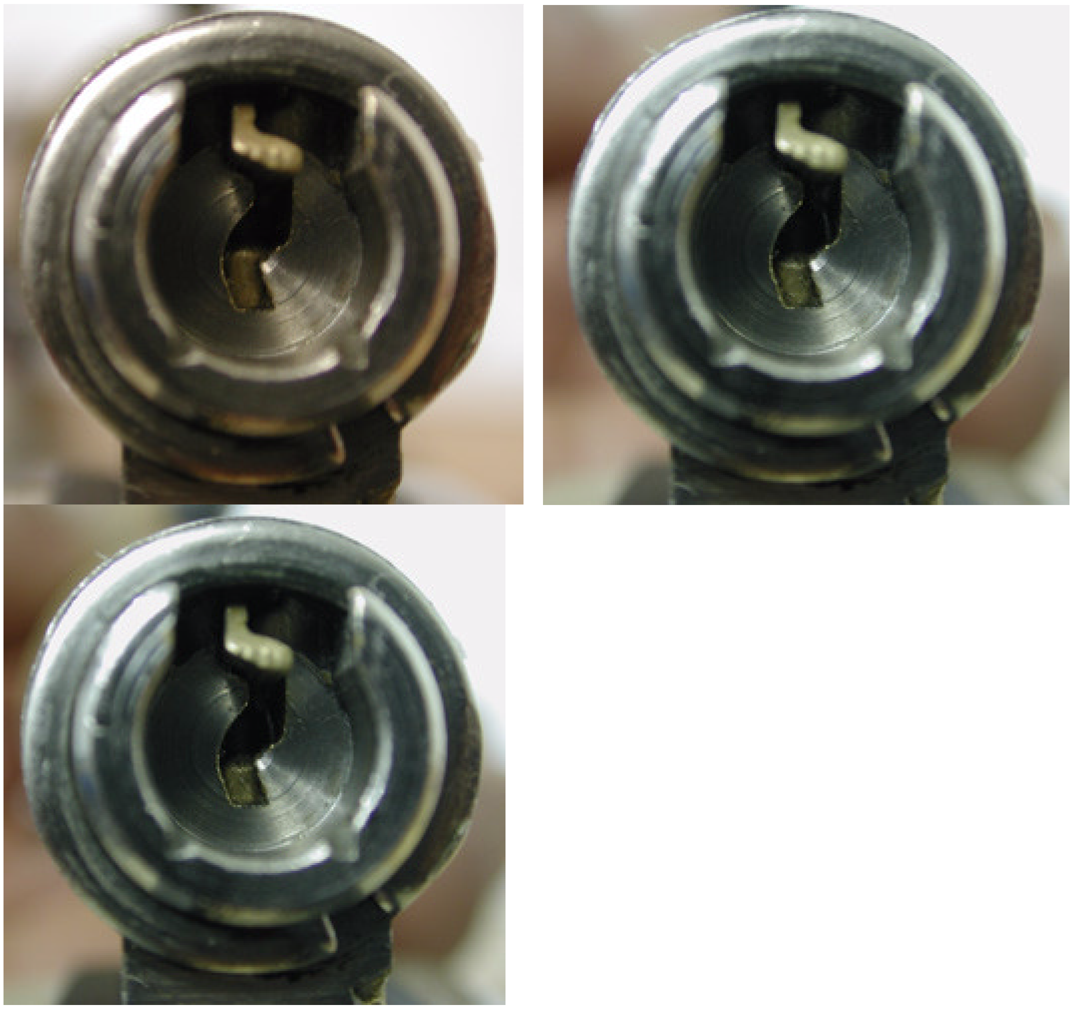
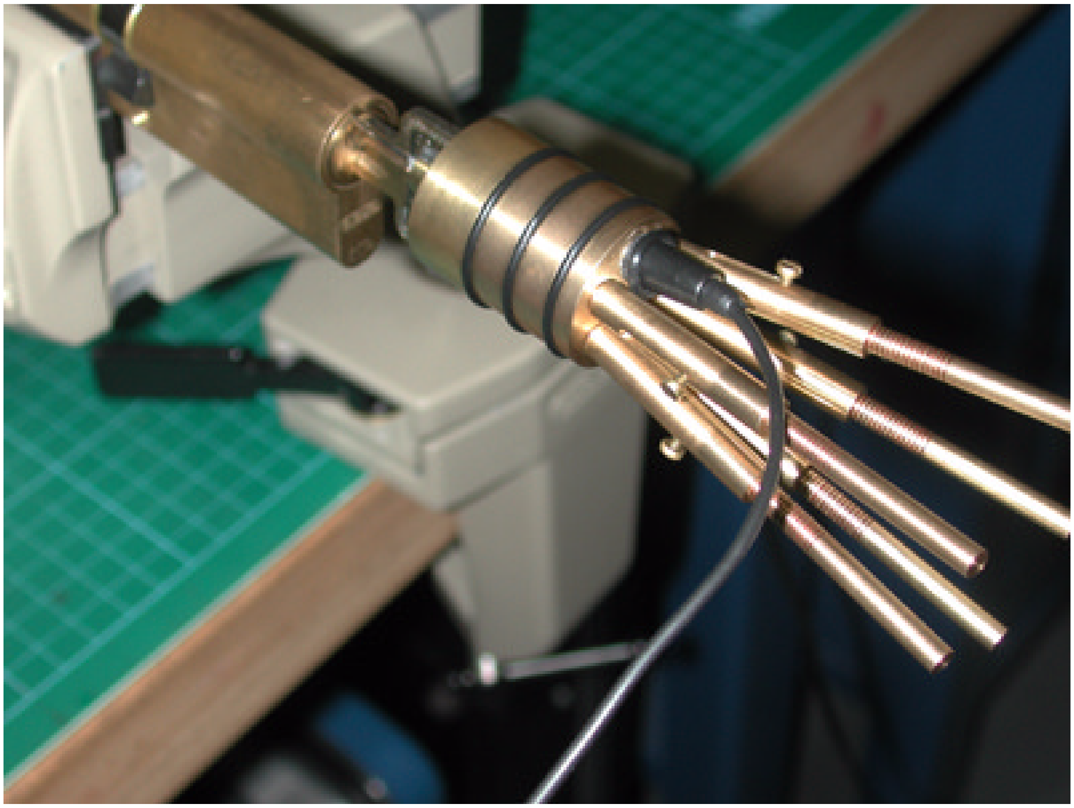


Figure LSS+2920 The Sputnik tool can manipulate each tumbler to any position within its chamber.
In the photographs above, three different positions of the last pin in the keyway are shown,
as the shim wire is moved up and down.

A modified version of the Sputnik was released in 2003 that incorporates a microphone into the system. This provides excellent feedback on the status of set pins at shear line.

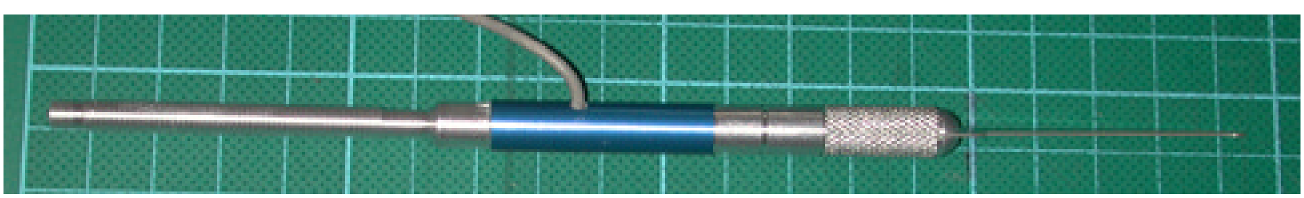


LSS204: MSC Sputnik II with audio probe

29_8.1.1 Acoustic Feedback Incorporated Into Picking Tools

MSC has incorporated a microphone into a traditional pick to provide a better indication of the status of setting pins. The audio feedback can make the picking process easier.

LSS203: MSC Acoustic picking tool demonstration



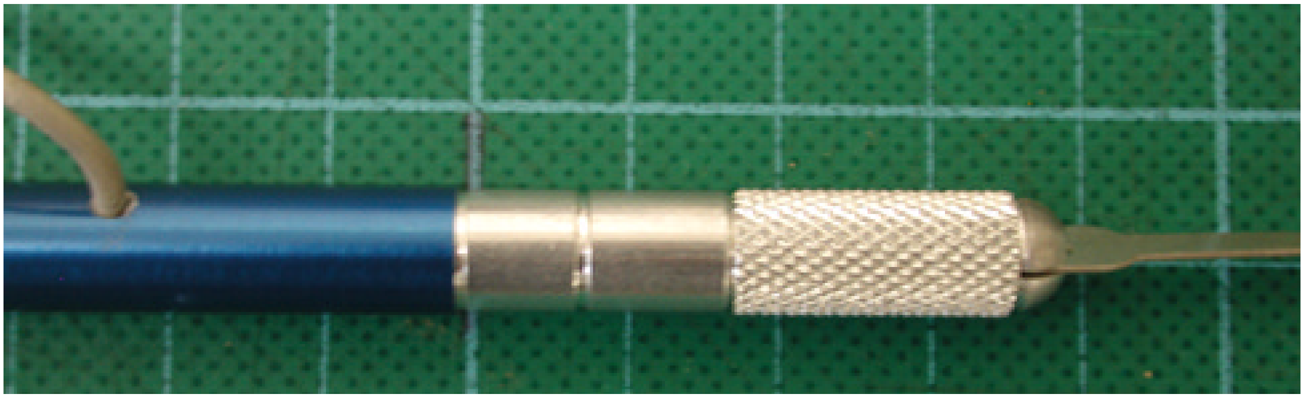
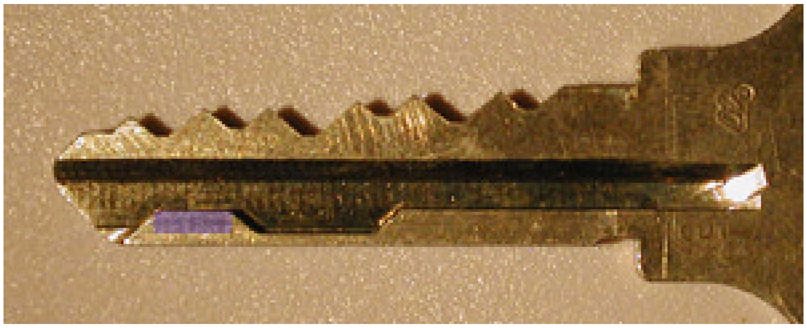


Figure LSS+2933 MSC acoustic picking tool.

29_8.2 Schlage Everest Cylinders

See section **6_4.4.3.1** for a description of the Schlage Everest mechanism. These patented cylinders can be picked in the same manner as other conventional locks, with the exception that the spring biased check-pin must be raised to allow the plug to rotate. **Peterson Manufacturing** has developed two unique tools to make bypass of this lock quite simple and straightforward. The ET-2 provides tension and also raises the check-pin. The ET-1 is a single formed piece of spring steel that enters the keyway within the undercut area and raises the pin to allow tension to be applied to the plug. Its use does not interfere with picking or the application of torque.

In the view of the author, these cylinders should not be utilized in any high security application. Other than the increased difficulty in replicating the blanks, the only distinguishing feature is the requirement that the check-pin must be raised to allow the plug to rotate. All Everest cylinders appear to have the check-pin located in the same position; thus, the blanks are all identical with regard to the side channel. Even if the manufacturer were to change the position of the check-pin, its operation would be the same with regard to bypass. The shaded portion of the undercut channel in the photograph below shows where contact with the check-pin occurs. See **Chapter 8** for a description of the use of the Easy entrie profile milling machine for replication of a blank that will allow rapid bypass of these cylinders.




A Schlage Everest blank can also be utilized as a tension wrench by removing the bitting portion of the key and utilizing the bow to apply torque. Lock shops that routinely service these cylinders have reported this practice.

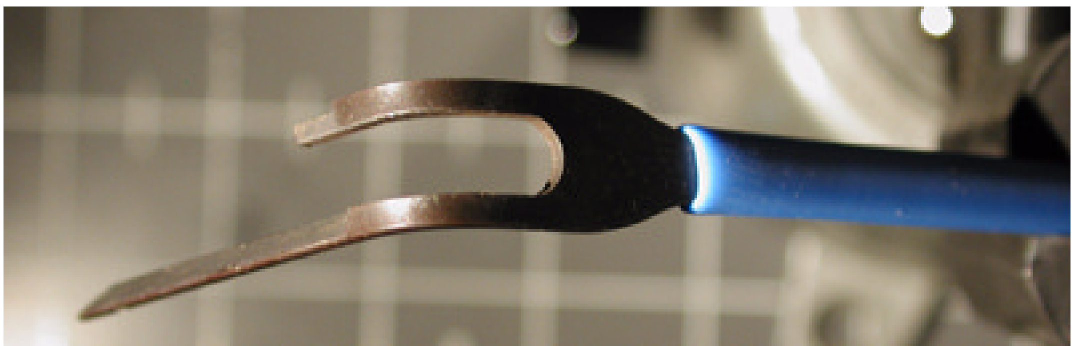





Figure LSS+2941 The Peterson pick tools for the Schlage Everest cylinder. The ET-2 is a combination tension wrench and second prong to raise the check-pin, while allowing ample room to insert a pick into the keyway. The ET-1 is an individual insert that enters within the undercut portion of the keyway to raise the pin. A separate tension wrench is inserted to apply torque.

29_8.3 Immobilizing Pin Tumblers

A process was developed by Israeli covert entry specialists that locks the top pins in position within each chamber, while at the same time allowing the bottom pins to drop below shear line. As described to the author, this procedure requires the injection of a spray material into the plug so that it permeates the upper and lower portion of each chamber. The chemical is like a glue that retains the pins, once they are forced upward by the insertion of a special blank key. Then, a special element is inserted into the keyway which allows the bottom pins to be very rapidly heated. This will break the glue bond and allow the pins below shear line to drop, thus allowing the plug to be turned. A solvent can be

used to release the top pins.

CHAPTER THIRTY: KEYS FROM IMPRESSION

Impressioning

Master Exhibit Summary

A clever device for impressioning lever locks has been developed in Bulgaria. Courtesy of Hans Mejlshede.

A discussion about impressioning, by Harry Sher.

The usefulness of the impressioning technique. Courtesy of Hans Mejlshede.

How does impressioning work? A discussion by Harry Sher.

LSS301: Foil impressioning system, by John Falle

LSS304: DOM Dimple foil impressioning system, by John Falle

Section 1: Theory of Impressioning

Theory

30_1.0 Introduction

How does impressioning work? A discussion by Harry Sher.

Impressioning is a process that encompasses various techniques for deriving a specific key for a given lock, without the requirement of drilling, picking, or disassembly. In certain instances, it may be impossible to remove the lock to produce a key; thus, impressioning becomes a necessity.

Outwardly, it is difficult to know if a lock has been impressioned; a forensic analysis described in earlier chapters must be conducted to make such a determination.

The usefulness of the impressioning technique. Courtesy of Hans Mejlshede.

There is evidence that the original Egyptian pin tumbler lock was first impressioned using wax. The art was improved upon when warded mechanisms became popular and was perfected with the introduction of the lever lock.

Early in the nineteenth century, there were two large gold bullion thefts in England. Twelve thousand pounds sterling was stolen on a railroad shipment between Britain and France using a key that had been copied by impression. A second major theft followed; this time from a bank vault in England. These popularized the technique of **copying** keys through impressions in wax.

This chapter is primarily concerned with making keys from impressioning of the internal components of a lock, not copying them. See **Chapter 8** for detailed information about impression copying techniques. Although the principles of impressioning have not changed, the techniques have been modernized. Now, there are special tools for handling blanks during insertion into the lock. There are also keys made of composite materials that can make

impressioning a great deal easier. Systems based on the use of pressure-responsive materials have also become quite popular.

Impressioning is perhaps the most valuable skill of the covert entry specialist and the locksmith. Once the technique is acquired, it will provide a working key. Whereas many locks cannot be picked for a variety of reasons, impressioning is a method to bypass almost every locking mechanism, even if certain security enhancements are present. While most locks can be impressioned, certain mechanisms such as sidebar can be extremely difficult and require a combination of procedures to produce results. UL (in Standard 437) and most other testing laboratories rate locks for their resistance to impressioning as well as picking, drilling, and other entry methods. Locks that are capable of impressioning include:

- **Warded locks;**
- **Wafer locks;**
- **Abloy disc locks;**
- **Ava wafer locks;**
- **Chicago double-bitted eleven-wafer locks;**
- **Double-sided wafer locks;**
- **Lever locks;**
- **Tubular locks;**
- **Pin tumbler locks;**
- **Dimple pin tumbler locks;**
- **Medeco and other sidebar locks.**

Many techniques and systems have been developed to impression locks. They all, however, rely upon the same principle: **except when they are at shear line, properly bound active locking components (tumblers, levers, or wafers) will be immovable.** This chapter will describe the proven methods for impressioning and underlying theories. Procedures, problems, practices, and techniques for each primary kind of locking mechanism are presented.

As in lock-picking, a great deal of skill is required to successfully produce keys. Patience, practice, and persistence will yield large dividends and allow the bypass of most of the mechanical locks described in this book. Whenever the term "pin" or "pin tumbler" is used, it should be considered synonymous with "active locking component." The material in this book primarily relates to pin tumbler locks, except when otherwise noted. **Active**

locking component refers to wafers, levers, wards, discs, or other mechanical parts that block rotation of a bolt or other mechanism by its movement, and which is controlled by a key.

30_1.1 Overview of Impressioning

A discussion about impressioning, by Harry Sher.

A blank key, often specially prepared, is used to provide an indication as to which pins are binding and which are set at shear line during the impressioning process. The proper selection, preparation, and filing of the bitting surface are critical to a successful opening. In practice, a key is prepared, then inserted into the lock using a special holding tool to control and apply proper torque and rotation. The key is turned in order to bind the pins with specified controlled vertical and horizontal movement. If the procedure is carried out properly, tumblers that are binding will produce markings on the key; there will be a corresponding **absence** of marking for pins that are **set** at shear line.

The process of impressioning simply requires that sufficient **samples** be taken of bitting depths (through insertion of the key and binding of the pins to cause marking) to assure that each pin (or other component) has had an opportunity to reach shear line. Thus, the craftsman files the key in small increments, taking continuous readings for each pin that is marking by repeating the insertion-binding process. Often, keys will be cut or filed to known code depths for a given lock during the procedure. This will be explained later in the chapter. As long as marks continue to be produced, the key blade surface is filed. Theoretically, when all pins stop causing marks, the lock will open. Of course, there are many variables in this equation.

30_1.2 Marks: How and Why They are Produced

In order to impression a lock, a key blank is systematically and methodically filed at each tumbler position until the correct bitting depth is determined. How much metal to remove and at what position on the key is a function of marks produced by active locking components. So, how exactly are these marks produced? An understanding of the concept of marking is critical to successful impressioning; it is often not communicated by the instructor and is misunderstood by student.

Impressioning provides a direct indication of the position of active locking components at shear line, or in another position. As has been noted, there is a positive correlation between pins, wafers, discs, or levers that are precisely at shear line and the **absence** of any marking on the surface of the key. Conversely, marking at any tumbler position **must** indicate that a locking component is located other than at shear line. **These two absolutes make impressioning a science, in contrast to picking, which is considered an art.**

So, why are marks produced upon the surface of the key. The answer relies upon the following mechanical characteristics of the lock, key, and their interaction during impressioning:

- **The tolerance between the keyway wards and the mating pattern of the key;**
- **The amount of vertical tolerance in the keyway;**
- **The amount of longitudinal tolerance or "play" along the entire surface of the key;**
- **The precise indexing of the key during impressioning;**
- **Alignment of locking components with reference to centerline of the chambers, gates, slots, or shear line. In picking, this would be referred to as "order of picking." It relates to the deviation from perfect alignment from an imaginary centerline;**
- **The amount of torque applied to the plug;**
- **The hardness of the key;**
- **The dimensions and angle of the contact surface of the active locking component in relation to the bitting surface of the key;**
- **The position of the tumbler with reference to shear line.**

Marks are produced because the bitting surface of the key and the active locking component cannot occupy the same space at the same time. That is, if the impressioning process is executed correctly, the bitting surface of the key is actually forced into the position occupied by one or more tumblers. In this circumstance, one of two things must occur: either the active locking component will **move** when the key is lifted, or material upon the surface of the key will be **depressed** or **displaced**.

30_2.1 Tolerance Errors and Impressioning

The following tolerance errors are significant to the impressioning process.

30_2.1.1 Plug-Shell Tolerance

The gap between the plug and shell will determine the possible vertical travel, or float, of a **set** pin or disc. Likewise, the tolerance between racking stump and gate will determine how the key marks in the lever lock. High-security cylinders can be more difficult to impression because:

- **The plug-shell tolerance is extremely close, minimizing the possible vertical travel of locking components when at shear line for a correct reading;**
- **Indexing of the key to the keyway is more precise, thereby minimizing vertical travel of the key;**
- **The complex paracentric design of the keyway further limits vertical movement of the key.**

30_2.1.2 Movement of the Key During Impressioning

There must be sufficient tolerance error to allow a key blank to move vertically, albeit very slightly, within the keyway. During the impressioning process, the key is used as a wedge, attempting to raise pins, discs, wafers, or levers while they are frozen in position by virtue of applied torque. If the indexing of the key is so precise that it cannot move, then impressioning will not be possible. Note, however, that there must not be excessive vertical movement of the blank, either, or false marking will occur. This is because the vertical travel will exceed the clearance between the plug and shell.

A properly designed keyway is difficult to pick and impression. Angled rather than square wards are employed for closer indexing between key and keyway. This forces the key to the bottom of the keyway to create closer tolerance. Very close indexing can cause serious problems during impressioning and may require milling of the longitudinal grooves in the key to provide some vertical play.

30_2.1.3 Alignment of Locking Components

The misalignment of active locking components determines which of those components will mark the key and in what sequence. It is the same theory as "order of picking" covered in **Chapter 29.** Those pins or other devices that are most out of alignment will bind first. **Only pins that can bind cause marks on a key.**

30_2.1.4 The Amount of Applied Torque

The amount of torque will determine which pins are bound. If slight torque is applied, then fewer pins will be trapped between plug and shell. In theory at least, it is impossible to apply too much torque during impressioning. The primary purpose of this action is to securely bind pins and prevent their vertical movement. In contrast, picking seeks to marginally bind pins in order to retain them at shear line while **allowing** vertical movement.

30_2.1.5 Metal Content of the Key

The hardness of a bitting surface is critical to the production of marks. Soft metals such as brass and lead are preferred to harder materials, such as nickel silver. Special composite blanks have been produced specifically for impressioning using brass and lead. See the Martin patent (**4400956(291)**, **4817406(292)**).

30_2.1.6 Contact Juncture of Active Locking Components

The dimensions of the contact point of the active locking component will determine how the marks appear on the bitting surface. Thus, marks may appear as pinpoints, flat spots, or other shapes, depending upon the design of the pin or surface. Pins having pointed or sharp tips will produce excellent marks and indicate how much material to remove. This is especially true for newer locks.

Chamfered surfaces will be less exact and more forgiving. Flat tops will require more precise filing and often produce marks that are harder to read. If the tip of the pin is rounded, marks will be broader and more difficult to discern. Generally, the flatter the tip of the pin, the poorer the mark. Remember that the bottom of the locking component actually makes an "impression" or depression upon the bitting surface. It is that impression which is being interpreted to indicate the position of

the component with respect to shear line.

30_2.1.7 Active Locking Component Position

The vertical position of the active locking component, with respect to shear line, will determine if a mark is produced. Marks will only appear from those pins that are not at shear line.

30_3.1 Basic Impressioning Theory

The fundamental theory for all impressioning techniques is quite simple and often eludes both instructor and student. A lock can be impressioned when two mechanical conditions occur: **active locking components (wafers, levers, discs, and pins) must be immovable when they are <u>not</u> at shear line with binding force applied; these same components must be capable of slight movement when they <u>are</u> at shear line.**

Theoretically, all impressioning techniques rely upon the fact that the bitting surface of the key and the active locking component cannot occupy the same space at the same time. Thus, when the components are properly bound after the application of torque and the key is lifted, an extremely slight amount of metal must be displaced from the key, equal to its vertical travel.

Impressioning relies upon binding of active locking components. In the case of pin tumbler locks, imperfections in manufacturing allow both top and bottom pins to bind. When the key is lifted and the pin, disc, or lever remains in a fixed position, only two options are possible: a depression is created on the bitting surface of the key, or the locking component is moved upward, thereby diminishing the produced mark.

This is the reason why new, sharply pointed pin tumblers will so effectively mark a key during impressioning. An actual **depression** is produced in the bitting surface that exactly corresponds to the vertical travel of the key. The plug must be strong enough to allow sufficient torque to be applied in order to bind active components and permit marking. In order to impression a lock, then, the following must occur with respect to its mechanical characteristics and the key that is used during the procedure:

- **Pins, wafers, discs, levers, or other active locking**

components must move to a "shear line" through normal operation;
- **These active components must block rotation or movement of the bolt-actuating device (plug, cam) until properly aligned;**
- **There must be a tolerance between moving components;**
- **When sufficient torque is applied to the plug or its equivalent, the active locking components must be capable of being "frozen" in position, preventing any movement whatsoever;**
- **When the active locking components are precisely at shear line (or its equivalent), there must be sufficient tolerance to allow very slight travel of these pins, levers, discs, or wafers; the only time that any movement is allowable for active components is when they are at shear line;**
- **The key blank must fit properly into the keyway;**
- **The key must be made of metal that is soft enough to allow marking by binding pins, and yet strong enough not to break or fracture.**

30_3.1.1 Active Components must be Immovable when not at Shear Line

The first mechanical condition that must be met requires that when a binding force is applied to wafers, discs, levers, or pins, they must be capable of being "frozen" in all positions **except at shear line.** If sufficient torque is applied to the plug when one or more moveable locking components is not precisely at shear line, those components will be incapable of any vertical or rotational travel. That is because they will be bound between a fixed (shell) and moveable (plug) surface.

As described in **Chapter 29**, the design of mechanical locks is based upon active components preventing movement or rotation of a plug, cam, or other device until all are "set" at shear line. This is the fundamental principle of all modern locks: **pins, discs, levers, or wafers must all be properly aligned in order to create a shear line or break-point that corresponds with the contours of the moveable part (key) that controls the bolt or other locking device.**

30_3.1.2 Movement of Active Components at Shear

Line

Pins, wafers, discs, or levers **must be capable of slight travel or movement when at shear line.** This critical design characteristic makes impressioning possible. Pins at shear line must **not** bind; they must be able to move a few thousandths of an inch (at least .015") or more.

30_3.1.3 Time Required to Impression a Lock

There is no accurate means to gauge how long it will take to impression a lock. Sometimes, a completed key can be produced in as little as five minutes. In part, it depends upon preparation of the blank, the type of lock, the design of active locking components, and other variables detailed below.

30_3.2 Definitions

30_3.2.1 Active Locking Components

See **Chapter 29**. Active locking components such as pins, wafers, discs, or levers, block rotation or movement of the plug or bolt until aligned at shear line.

30_3.2.2 Components of the Key

There are five critical components of a key that are considered as suitable for impressioning.

30_3.2.2.1 Blank

This is an uncut key with no portion of the bitting surface removed.

30_3.2.2.2 Bitting Surface or Blade

This is the portion of the key that comes directly into contact with the active locking components and from which material is removed in order to produce a working key.

30_3.2.2.3 Depth of Cut

The depth of cut can be measured from the top or bottom of the blade to the base of the valley. Generally, code depths are

computed from the bottom of the blank.

30_3.2.2.4 Keyway

The keyway is formed by protruding wards within the plug and is the opening through which the key enters the lock. Corresponding grooves milled into the sides of the blank will index with the wards to provide for proper alignment.

30_3.2.2.5 Tip of the Key

The tip of the key is at the end of a blank, opposite the shoulder. It is the first part of the key to make contact with the keyway.

30_3.2.3 Detainer Lever

A detainer lever has an open-ended gate.

30_3.2.4 Impressioning

Impressioning is a combination of techniques whereby a key is derived through a sampling process that produces definable marks upon the bitting surface of a key blank. These marks directly correlate to the position of active locking components and their physical relationship to shear line. Impressioning does not require disassembly of the lock in order to produce a working key.

30_3.2.5 Marking of Key

The key blade surface is marked by the base of the bottom tumblers or other active locking component during the impressioning process. Marks are produced as a result of the intentional binding and lifting of pins.

30_3.2.6 Shear Line

See **Chapter 29**. The shear line is that point between fixed and rotating materials where all active locking components must be aligned before the lock can be opened.

30_3.2.7 Tang (File)

The tang of a file is the tapered end to which a handle is

attached.

30_3.3 Tools Required for Impressioning

In any instance where a key is to be created by physically removing material from the bitting surface, there are two primary tools required to properly impression the lock: **files** and an instrument to **hold** the blank key. Other tools discussed below can aid and speed the process.

30_3.3.1 Files

The file must perform three critical functions: removal of bitting material, shaping of the cut, and polishing the bitting surface. Files are defined by their shape, length, tang, cut, and coarseness.

30_3.3.1.1 Shape

Files come in many shapes, including round, half-round, Pippin, flat, square, three-square, and warding. The **Pippin** teardrop shaped, #4 Swiss pattern fine slim taper (Nicholson 40524 8" 2-XF) and **round file** are probably the most popular to use for impressioning.

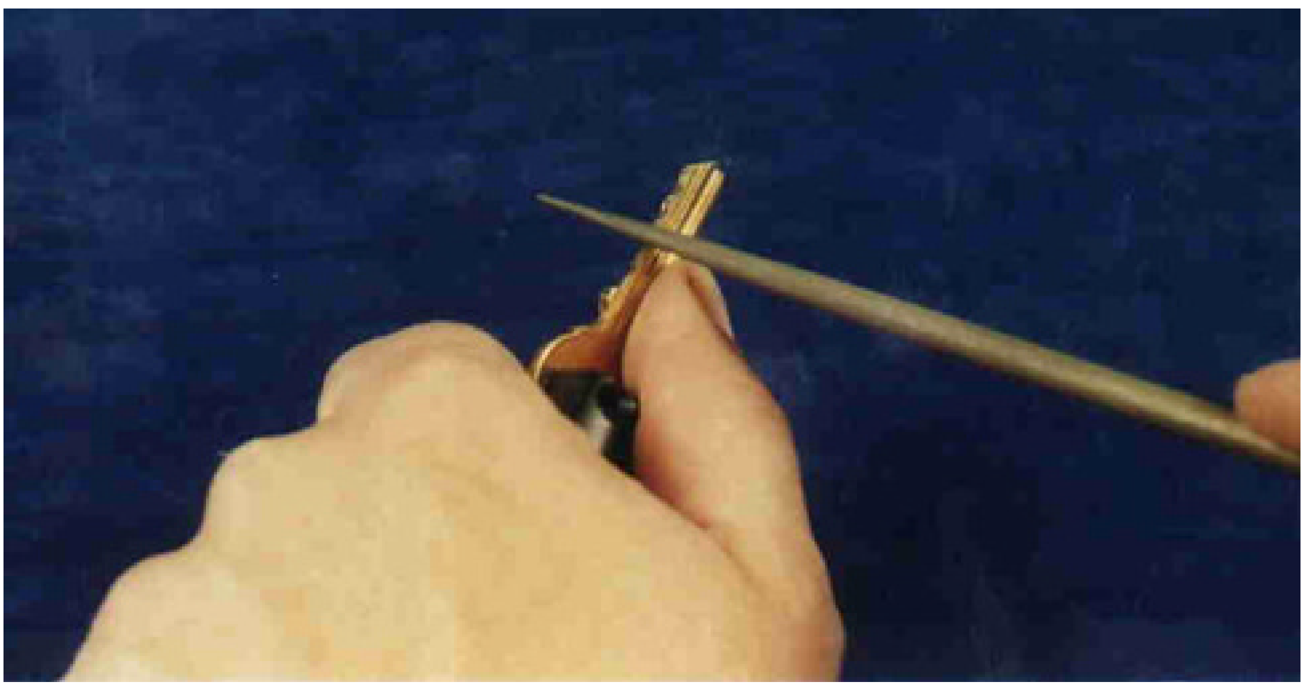
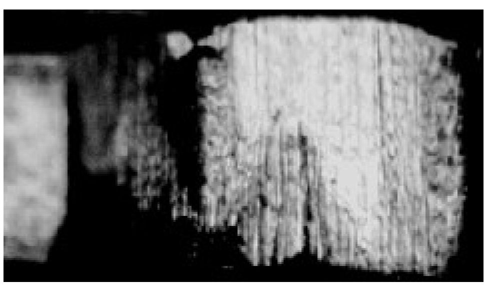


Figure LSS+3002 Use of a pippin file for impressioning.

These files taper down to a smaller cross-sectional size towards the tip. Although some craftsmen utilize the #2 Swiss pattern, the coarseness of the cut makes reading marks more difficult and is not recommended by the author.

The Pippin file resembles a teardrop cross section, rounded on one side, with two flat surfaces meeting at a knife-edge on the opposite face. The flat surfaces are similar to the flat file and are used to shape the sides of the cut. This file is ideally suited for impressioning because it creates a very fine dull finish and slightly ridged surface on the blade, thereby allowing observation of marks made by the pins. Proper filing technique continually renews the dull finish.

If a round file is employed, it must generally be used in conjunction with a small flat or triangular file for shaping the ramps of the cuts. In addition, both 4” and 6” warding files (.045"-.050" thick) can be used. Files suitable for impressioning may be obtained from locksmith, jewelry and machine shop supply houses.



30_3.3.1.2 Length

The length of a file will generally vary from 4" - 8". Sometimes, a file 8" in length actually measures 6" but has a tang extending the remainder. Files may also be tapered so that their dimensions change over the entire length.

30_3.3.1.3 Tang

The tang is the uncut portion of the file and is used to enhance control and to attach to a handle.

30_3.3.1.4 Cuts

There are two worldwide rating systems for cuts and measurement

of coarseness: Swiss and American. The number of teeth per inch determines the ability of a file to remove metal. The Swiss utilize a numeric rating system of #00 - #6, (00, 0, 1, 2, 3, 4, 5, 6), denoting the number of teeth-per-inch in relative terms. In the Swiss system, a 00 cut is the coarsest; the #6 is a fine cutting file.

The American system utilizes three primary cuts to define how much metal will be removed: bastard (equivalent to Swiss 00), second cut (Swiss 0), and smooth (Swiss #2). Files can have more than one set of teeth, meaning that there are two or more separate sets and angles of cuts on the surface. The number of teeth-per-inch will vary, based upon the length of the file and coarseness, and can range from 30 to 295.

30_3.3.1.5 Removal of Bitting Material

How a file removes metal from the key depends upon many factors, including: design, shape, coarseness (teeth per inch), applied pressure, movement, and bitting material. If the file is too smooth, it will not cut or will require too much time to remove metal. In addition, the teeth can clog. If too coarse, it will not polish a surface properly, which is particularly important when impressioning. A coarse file will remove too much metal and cut faster, and will create more dramatic striations on the surface of a key. This will diminish the clarity of impressioning marks.

30_3.3.1.6 Required Files

Depending upon the lock, the following files are most often required for impressioning:

- **6″ Pippin #4 file;**
- **6″ Round file;**
- **100 mm warding file;**
- **150 mm warding file;**
- **200 mm warding file.**

30_3.3.2 Instrument to Hold the Blank Key During Impressioning

Many tools have been developed or modified by locksmiths to hold a key for impressioning (**5058465(293)**, 855280, 1427668, 1933748,

4384499, 4815346). To work properly, these tools must accomplish the following functions:

- **Allow the key to be firmly retained without slippage;**
- **Allow the key to be precisely controlled during movement within the lock;**
- **Extend the centerline of the plug to avoid excessive stress on the key, and enhance sensitivity;**
- **Allow the key to be horizontally and vertically rotated during impressioning;**
- **Avoid creating discomfort to the operator during repeated use of the tool.**

Three tools have achieved popularity in the trade: modified vice grips, pull grips, and specially designed round holding tools.

30_3.3.2.1 Vice Grips

Four or six-inch vice grips marketed by HPC (KIP-1) have been modified so that the grip portion is completely smooth and perfectly parallel. The design allows for great holding strength. In the author's view, this is an acceptable compromise but not optimum for impressioning.



30_3.3.2.2 Pull Tool

The old "pull tool" was a specially designed gripping plier that would allow locking of the key into position during impressioning. Squeezing the handle would cause a pin to be ejected at the base of the blank key into the face of the plug. It forced the key to retract slightly from the cylinder (about 1/16"). This tool was the standard for many years in the locksmithing industry and has been available since the Second

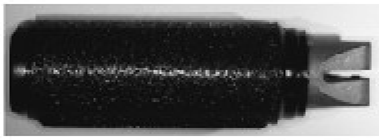
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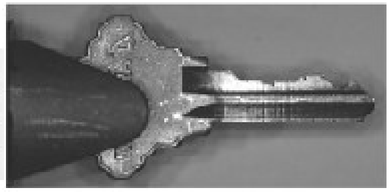


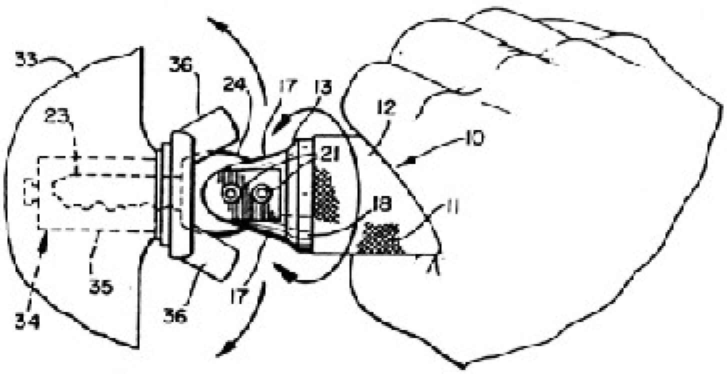
Although awkward, a vice grips can be used in conjunction with a screwdriver to accomplish the same result by wedging the screwdriver between the key and plug in order to slightly retract the blank.

30_3.3.2.3 Round Holding Tool

The author prefers the round plastic or metal holding device. It allows the clamping of the key by setscrew or automatically. The tool, which measures several inches in diameter, provides a firm grip and precise control during movement of the key. The drawback to some of these devices is the coarseness of the exterior knurl pattern, especially when made of metal. The pattern tends to cut or irritate the hands during repeated use and can become extremely uncomfortable.







30_3.3.3 Other Tools

A number of other tools and implements can make impressioning a great deal easier. It is recommended that the following be obtained:

- **File handles: Files are generally fitted with handles for greater control and comfort;**
- **File card: A special brush (file card) is used to clean the teeth of a file, because they have a tendency to become clogged during impressioning. This can affect the appearance of the blade surface and thus the ability to properly interpret marking;**

- **60-100x handheld magnifier: This is an extremely valuable aid to viewing marks, especially for the older craftsman;**
- **UV light and pen for marking the blank;**
- **Special composite material blanks (if available);**
- **Calipers;**
- **Spacing gauge.**

The following tools are recommended to impression lever locks:

- **100 mm warding file;**
- **150 mm warding file;**

- **200 mm warding file;**
- **Hacksaw;**
- **Combination pliers;**
- **Side cutters;**
- **Penlight flashlight;**
- **300 mm lengths of 1.5 mm music or spring wire for applying tension to the lock bolt;**
- **An assortment of key blanks;**
- **Portable vice.**

30_4.0 Impressioning Procedure: Seven Steps

There are seven theoretical steps required to impression a lock, regardless of the particular technique employed. Both the theoretical procedure and practical application is presented for the different impressioning methods. Note that this discussion does not precisely apply either to dimple locks or to the Martin or Falle-Safe specially prepared blanks for use in conventional locks.

- **Select and prepare the blank key;**
- **Bind active locking components;**
- **Move the blank key within the lock to produce marks;**
- **Interpret marks;**
- **Remove bitting material from the blank key;**
- **Stop removing bitting material from the blank key;**
- **Produce a working key.**

30_4.1 Theory: Select and Prepare the Blank Key

Select the proper blank. If special blanks have been designed for impressioning a specific lock, those may be utilized. Prepare the surface of the key to enhance the ability to read marks, removing any aberrations or artifacts.

Practice: Select and Prepare the Blank Key

Key blanks for impressioning should be made of soft metal such as brass, avoiding nickel silver, steel, or Avional. Blanks must be

strong enough to withstand the application of torque, but soft enough to mark from the pressure of the active locking components. It is suggested that inexpensive blanks be selected because tolerances are not as closely maintained.

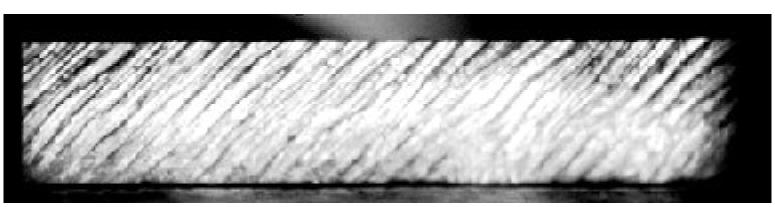
A few patents have been granted for key blanks designed for impressioning. Martin received two U.S. patents (**4400956(294)** and **4817406(295)**) for special keys suitable for impressioning. One utilized metal foil; the other, a soft metal bitting insert, set within brass. Other patents have been issued for impressioning tools and decoders (**5058465(296)**, **4300416(297)**, and **2763027(298)**). In 1996, Falle introduced a series of blanks utilizing metal foil, that were patterned after his dimple lock impressioning system.

30_4.1.1 Indexing

Be certain that the key properly indexes to the keyway. If necessary, slight side-milling may be required to provide for vertical play. Also, verify that the blank is long enough for the keyway. A five-pin blank cannot be used to impression a six-pin lock. Forward pressure must be applied during movement. This is to insure that the key is indexed properly to the active locking components and that, for every sampling, the marking will appear in precisely the same position on the surface of the bitting.

30_4.1.2 Surface Appearance

A slick surface will not easily show impressioning marks. During the manufacturing process, keys are made smooth as the punch forces the brass stock through the die. Key blanks are burnished and deburred in a tumbling process after being milled. The surface is polished to a smooth finish by this procedure.



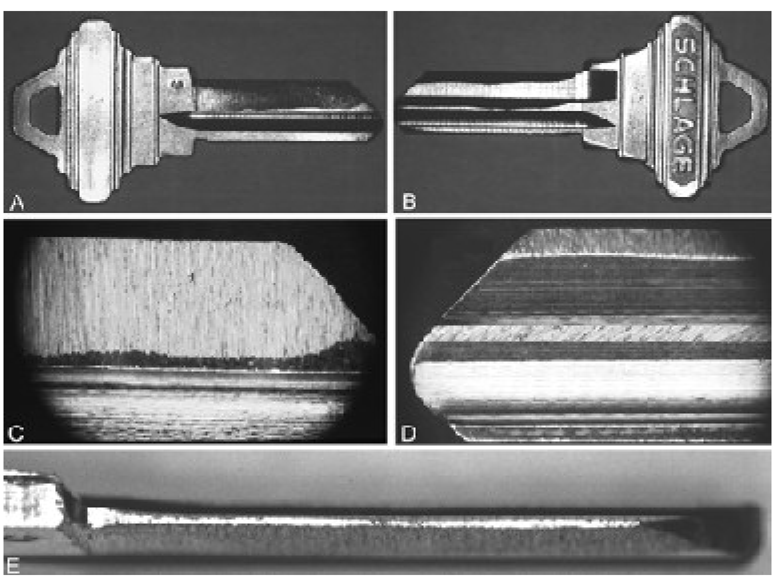
If brass blanks have been plated, remove the surface cover by filing in long, angled, even strokes from the shoulder to the tip, thus providing a uniform texture for the brass. Be careful not to remove any excess material, as some lock manufacturers

utilize the full height of the bitting for a zero-cut. It is required that a uniform texture be created with sharp microridges. A few light file strokes are all that is necessary.

The area that makes contact with the active locking components must be perfectly smooth in order to show marks. Very lightly buff the bitting with a file; just enough to create a smooth appearance without removing any significant material. It is desirable that minute striations be visible upon the bitting surface. Gently file the top surface to read tumbler spacing after the first sample is taken. Remove less material than the depth of the shallowest cut to establish proper spacing.

30_4.1.3 Surface Preparation

There are two primary methods for the preparation of the bitting surface of a blank key for impressioning: reduce the blade width or knife-edge the material. In either case, the premise is based upon the notion that it is easier to deform a thin piece of metal than a thicker one. It also follows that it is easier to view the marks produced on such metal.



30_4.1.3.1 Surface Preparation: Narrowing the Bitting Surface

One method to prepare blanks for impressioning requires that the width of the blade be reduced. Thinning weakens the key but makes it easier to move in the keyway. Thinning requires that

the lateral surfaces of the blade be reduced. This does not extend to that area immediately adjacent to the shoulder that remains at the entry point of the keyway. A great deal of stress is placed on this point, and it is where fractures are most likely to result.

30_4.1.3.2 Surface Preparation: Knife-Edging

Knife-edging or blading is quite popular, especially where an older "pullout" tool is utilized. The technique has the advantage of producing clearly defined tumbler spacing, and accentuates marking. The key is prepared with either a single or a double knife-edge as described below. New locks will generally produce marks without blading a key due to the relatively sharp points at the base of the tumblers. However, once pins show some use, the key should be bladed to improve marking. Ultraviolet ink may also be employed to enhance visibility.

The procedure requires that the top portion of the blade be thinned almost to a point or knife-edge in order to make marking more visible and pronounced. Thinner material will bend easier under the pressure of pins. Depending upon preference and technique, file the surface on one or both sides of the top of the blade at about a 45° angle. When the key is placed in the lock as described below, the marks will be much deeper and easier to produce. Care should be taken to maintain the sharp angle on the blade sides throughout the process, because eventually the key will always mark there.

30_4.1.4 Problems Encountered with Blanks

The most prevalent problem encountered with blank keys is fracture. During impressioning, there is a great deal of stress, especially at the juncture of the shoulder and bitting surface. Should a fracture begin, it is imperative that the key be removed and duplicated prior to severance. Fracture can be caused by the application of too much torque or turning a blank hard in one direction and then the opposite way. In addition, it can occur if a cut is made too deeply, especially toward the bow.

If the bitting is cut too deep, the material can be formed with a small hammer or pin punch just below the cut. Solder may also be employed but it is not particularly effective. A key machine, key micrometer, or carbon blackening can also be used to make a copy. With practice, fracturing will become rare. In the beginning, it is inevitable.

30_4.2 Theory: Bind Active Locking Components

The blank key is inserted into the lock and then a horizontal rotational force is applied in order to bind active locking components.

Practice: Bind Active Locking Components

The essence of impressioning theory requires that active locking components be bound between moveable and non-moveable parts of the lock (i.e., the plug and shell). It is therefore of critical importance that the internal mechanism of the target lock be understood so that the craftsman is aware of which components must be bound in order to create markings on the key.

Sufficient torque must be applied against active locking components in order that they are frozen in a fixed position. They must be immobilized while the key is manipulated. The amount of tension to be applied is generally more than required for picking but not enough to fracture the blank. Movement of the key must cause the active locking components to bind in order to induce marking. This requires sufficient torque to trap the pins, levers, wafers, or discs against the fixed portion of the lock so that they cannot move vertically.

The precise amount of applied torque is difficult to specify. It must be sufficient to immobilize the active locking components but not so severe as to inhibit vertical movement of the key. With practice, the correct force can be easily determined. The characteristic of the binding process will change, depending upon the position of the tumbler or other locking component during the impressioning process.

When active locking components are in a position other than at shear line, they will be bound against the walls of the shell or plug chamber. Such binding will present a solid, immovable object against which the bitting surface of the key will interact. This circumstance causes discernible and often deep impressions on the key. As the plug is able to turn to a greater degree when more components reach shear line, there is a corresponding increase in the resistance to vertical movement of the key. This will create marks that are even more readable.

As moveable components reach shear line, an entirely different interaction occurs between the key and such component. When the

tumbler, lever, or wafer is precisely at shear line, it is bound neither by the shell nor by the plug chamber; it is free floating within a very narrowly defined space. So long as the distance of vertical travel of the key (when it is lifted) does not exceed the "free space" between plug and shell, there will be no resistance to movement of the pin, lever, or wafer. Only when the locking component is **stopped** from moving will a mark occur.

The difference in impression marks between a pin that is at shear line and one in any other position is quite pronounced. The pin at shear line will create a very slight mark, whereas the pin presenting an obstruction to movement will actually displace a very slight amount of metal. This is particularly evident when impressioning with the Martin patented key using a lead-bitting insert.

30_4.3 Theory: Move the Blank Key Within the Lock to Produce Marks

There are three recognized methods to create marks: **bind and lift** (often called wiggling), **bind and pull**, and **bind and tap**. Each one of these techniques will produce marking on the blank key. **Bind and lift** requires that the key be turned to apply torque, then moved in an up and down motion.

Bind and pull is a modification of the bind and lift technique. It requires a specially designed gripping tool that physically withdraws the key a very short distance from the plug. This causes marks on the ramps of the cut.

The **bind and tap technique** generally involves the use of a cylindrical rod, such as a file, screwdriver, or long Allen wrench placed through the bow of the key. It is then twisted to apply torque. The top and bottom of the key shoulder is then tapped with a mallet or similar object to cause up and down motion of the bitting surface. Whichever of the above techniques is employed, the proper blank key must be inserted into the lock, rotated, and then moved to cause marking on the surface of the key blade.

Practice: Move the Blank Key Within the Lock to Produce Marks

Successful impressioning is based upon the proper insertion and movement of the key blank within the lock. This action is based upon three critical stages: **indexing** of the proper blank in the

keyway, **binding** of all active locking components, and proper **movement** of the blank to produce marks.

30_4.3.1 Physical Control of the Key During Movement

Control must be maintained over the key while it is inserted in the lock in order to obtain the best marks on the bitting surface. Holding the blank close to the shoulder is preferred both for sensitivity and to reduce stress to the key. Wrist control, rather than use of the elbow, is more effective when moving the blank. A snapping action during up-and-down movement is preferable to simply lifting and lowering the key.

30_4.3.2 Movement of the Key

Perhaps the most critical action is the movement of the key within the lock. Often misunderstood, this process must be correctly repeated for every sample reading. It requires that a **key holding tool** be utilized that will in effect extend the centerline of the lock through the axis of the key. This must occur so that rotation and movement becomes an extension of the plug.

Movement must be accomplished in such a manner as to insure contact between each bound active locking component and the bitting of the key. In addition, the **sequence** of movement in relation to binding of components must be correct to insure marking. There are four distinct planes or positions to insure reliable contact and marking. This is especially true in the pin tumbler lock. Because of difference in tolerance, alignment, and concentricity of pins and chambers, only one or more of these positions is sure to cause marking for any pin. Thus, it is imperative that all four points of contact are accomplished, or the key will not mark properly or consistently.

To insure that both the front and back portion of the key is contacted by pins, the key must be placed in the following positions during each sample:

- **Right rotation;**
  - **tip raised;**
  - **shoulder**

raised;

- **Left rotation;**
  - **tip raised;**
  - **shoulder raised.**

Not only must the key be lifted in the proper planes or orientation, the sequence of binding and lifting must be correct. This requires that for each of the four positions, the torque be **released**, then reapplied prior to lifting. This function is often misunderstood by beginning students and leads to erratic marking. The proper procedure is:

- **Briefly release torque on the key;**
- **Place rotational torque on the key, either left or right, to bind active locking components;**
- **Move the key to attain one of the four positions as described above;**
- **Briefly release torque on the key;**
- **Place rotational torque on the key, either left or right;**
- **Move the key to attain the next one of the four positions;**
- **Repeat the above procedure until all four positions have been attained.**

Depending upon the lock, it is often desirable to lift the key more than once in each plane during the above-described sequence in order to enhance marking. Active locking components must be "reset" each time they are bound and lifted or they may not mark correctly. This is because there may be a very slight gap between moving component and the surface of the key, occurring from the last sample.

Be certain to continually examine the key near the shoulder for fracture. This problem requires constant attention. If the blank begins to split, duplicate the cuts onto a new key and continue the process. Actual physical movement of the key is usually accomplished in one of three ways: **oscillating** (wiggling), **tapping**, and **pulling**.

30_4.3.2.1 Oscillating or Wiggling

Oscillating or wiggling requires the application of torque, then movement of the blank up and down. This causes the bitting surface to make contact against the active locking components.

30_4.3.2.2 Tapping

Tapping is slightly different than wiggling. This procedure requires that the blank be inserted into the keyway while placing a steel rod through the bow of the key to provide torque. A small mallet is used to tap on the top and bottom of the bow to mark the bitting surface. Tapping on the top raises the tip of the key; tapping on the bottom lifts the shoulder. This technique is particularly effective and is preferred by the author to the use of special key-holding tools, especially when the lead bitting composite key is used.

30_4.3.2.3 Pullout Method

The **pullout** method is only effective when the bitting surface has been cut to at least the first depth for all pin positions. This technique works well in pin tumbler locks by applying rotational torque, then slightly withdrawing the blank. Likewise, a C-clamp may be used to hold the blank, then a screwdriver employed as a wedge to slightly extract the key.

Remember, however, that the marks will not precisely correspond with the center-point of the pins but will be related to how far the blank is withdrawn. In addition, marking may not be constant because the blank may be pulled to a slightly different position for each sample. The method should not be used for wafer and disc locks because of the potential for distortion of components.

30_4.4 Theory: Interpret Marks

Read the marking for each sample taken. Repeat the process until no more marks appear and the key opens the lock.

Practice: Interpret Marks

Marks will indicate the position of active locking components,

whether they have reached shear line, and, in some cases, how close they are to shear line. Theoretically, all active locking components that are not at shear line will cause marks to be made upon the surface of the key. However, there are several practical problems involving the interpretation of marks, order of marking, location of the marks, readability, and visibility.

30_4.4.1 Interpretation of Marks and Artifacts

Many artifacts may be present or imprinted on the surface of the key. They are caused during manufacturing or preparation of the blank for impressioning and from insertion, removal, and filing.

30_4.4.1.1 Artifacts

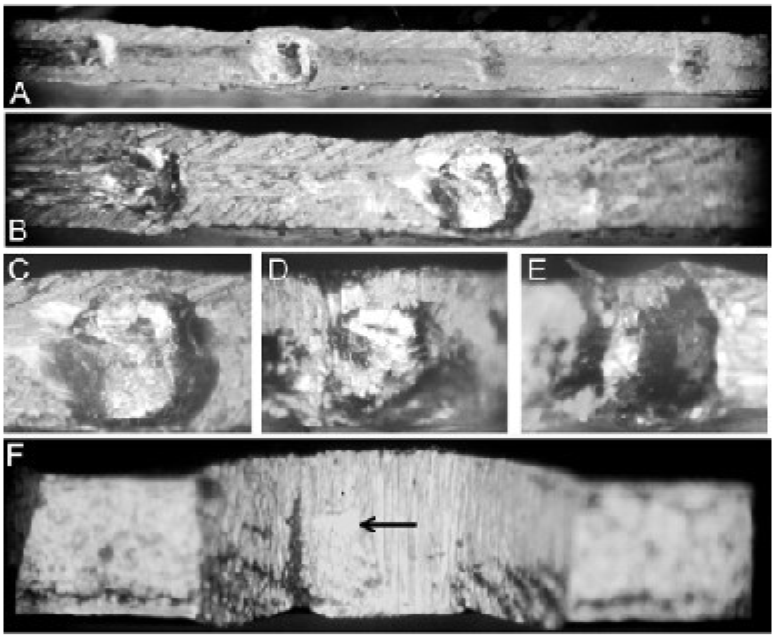
If the bitting surface is not filed properly at the outset, then uneven areas, ridges, marks, scratches, pits, or other irregularities may be present. Streaks may also be visible, caused by pins running across the specially prepared surface. The craftsman must be familiar with the appearance of all artifacts so as not to be confused with actual marking by active locking components. There should be no preconceived idea as to how the impression marks will appear.

30_4.4.1.2 What Marks Look Like

The question as to what "actual" marks look like is difficult to answer because marking will differ depending upon the design of the pin, wafer, lever, or disc. The answer becomes even less clear when the metal content of the key, the method of filing, binding pressures, and rotational forces are considered. Further complicating the issue is the consideration of **when** during the impressioning procedure the marks were made.

Generally, marks will be less pronounced at the beginning of the impressioning cycle and much more visible when several tumblers are at shear line. An evaluation must constantly be made to determine if marks are significant, strong, or not important. If the marks are slight, then less material should be removed than in the case of heavy or pronounced marking.

Marks may appear anywhere in a predefined area for each cut under the active locking component. There is no clear definition or rule as to how the marks will appear, although they are generally evenly spaced.



They can look like pinpoints, flat depressions, indentations, or burnished marks. Although impression marks cannot be defined as scratches, nicks, scrapes, or gouges, they are in fact an indication of metal binding against metal.

If impressioning is done properly, marks will be left from tumblers binding against the blade and will only appear under active locking components. Marks that are on the side of the key or near the edge of the chambers are not relevant. An effort should be made to keep marks directly below the active locking component, as they will have a tendency to drift depending upon filing technique.

Generally, marks are very subtle depressions in the bitting surface, although actual concave points will be present in some locks. If the material has been prepared and filed properly, the marks may simply cause a change in the reflectivity of the surface. Filing should leave a slightly dull finish. This characteristic may change during impressioning and is caused by burnishing of the metal by the contact or rubbing of the locking component.

The appearance of marks will differ, based upon the type of locking mechanism (pin tumbler, lever, wafer, disc) and are often more pronounced as locking components come closer to shear line. As noted earlier, the shape of the moving component will affect the appearance of the mark; pin tumblers will generally mark as

points, whereas wafers appear linear in shape. When interpreting marks, do not be confused by long dark bands across the surface of the blade. They are caused by insertion and removal of the key as the pins track against the blade.

30_4.4.2 Order of Marking

Depending upon alignment and tolerance, some active locking components may not immediately produce marks. The rule of practice states: **file only those positions where marks appear**. As pins reach shear line, new marks may appear.

30_4.4.3 Visibility of Marking and Enhancement of Marks

Depressions are often quite subtle and difficult to see. The author sometimes uses a high-intensity light or UV source with a magnifying visor to view marks. In other cases, a low light level is preferred. Sometimes, a 60-100x hand-held magnifier is also helpful. The orientation or angle of the blank may also be changed to alter its reflective characteristics. The lighting must be direct and not diffused. Unfrosted incandescent bulbs or halogen is recommended.

A rough blade surface will diffuse light, whereas a polished spot on brass can reflect the light and make a mark visible. Ideally, marks will appear bright against a dark or dull background. Remember that marks may be extremely small and very subtle. There is always a temptation to attempt to interpret artifacts and metal imperfections as tumbler markings. If the blank is prepared properly, the marks actually caused by binding will be most visible. Various techniques have been utilized to enhance marking and facilitate reading of impressions. These include:

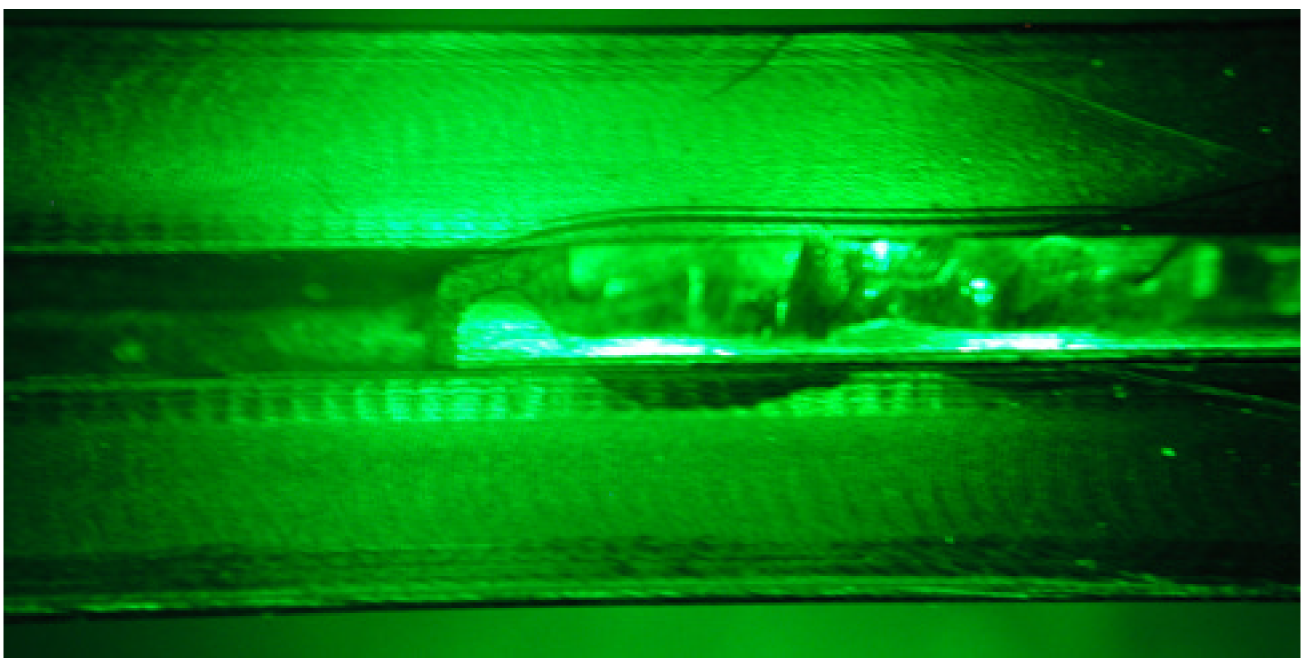
- **Magnifying loops;**
- **Smoking" the blank as described earlier;**
- **Application of nail polish;**
- **Use of inks to cover the surface of the key and application of ultraviolet light to see disturbance of the ink;**
- **Use of plasticine, lead, plastic tape, or foil.**

The employment of such aids is a matter of personal preference; some work and some are not effective.

It may be necessary to buff cuts with a file to insure that the surface will permit proper marking. Remember, when removing material from the key, be certain only to file at tumbler positions and not the entire surface.







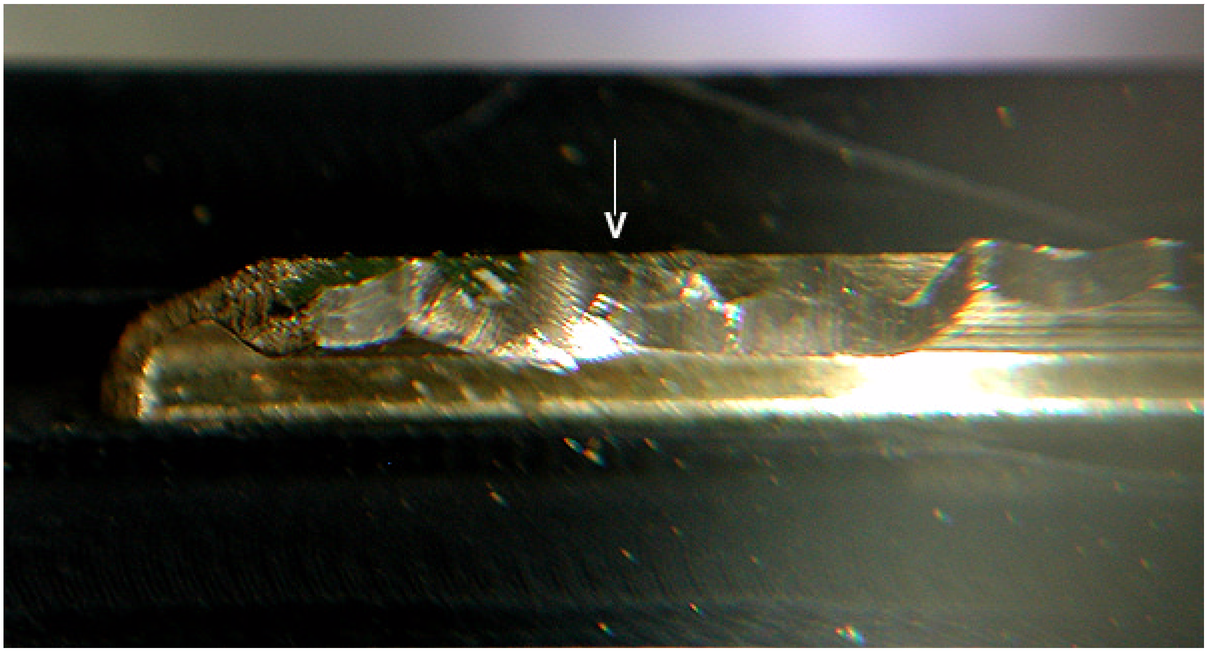


Figure LSS+3001. The impressioning light box, available through John Falle, makes impression marks more visible, especially in covert entry operations. This device allows viewing of a key in any orientation under white, green, and blue light. Shown is a key during the impressioning process with a mark clearly visible.

30_4.5 Theory: Remove Bitting Material from the Blank Key

Bitting material must be removed from the surface of the blank, corresponding to active component marking. If standard depth coding is followed by the manufacturer, then metal should be removed to the next depth for each mark.

Practice: Remove Bitting Material from the Blank Key

How much material to remove and where and when to remove it is the essence of impressioning. This discussion actually relates to the use of files, the interpretation of markings, and the shaping of the cut for each active component. As will be noted, the selection of the proper file is critical. Conventional practice has suggested that the Pippin #2 or #4 file be utilized for impressioning. The author and other craftsman have also utilized a square-cut file, slightly narrower than the width of one depth-cut, to create perfectly flat valleys. This technique has the advantage of enhancing the ability to distinguish active component marking, especially where special composite keys are

utilized. Soft lead composite blanks can be used to produce easily read marks.

30_4.5.1 Standard Depth Coding

A lock that is keyed pursuant to standard depth and spacing specifications is easier to impression than one that has been randomly pinned, because the craftsman knows exactly how far to file for a given depth position. So long as the disc, wafer, lever, or tumbler continues to mark, material can confidently be removed to the next depth without concern regarding those regions in between. The author recommends code cutting the key to the first depth prior to impressioning. This will provide the proper spacing and indicate where to look for marks. Use a code punch machine, file, HPC 1200, or equivalent cutter. It is also useful to draw vertical lines on the side of the key with a felt marker, corresponding with each pin. This practice will help maintain the lateral position of each cut in a straight vertical line.

If a depth and spacing reference guide is not available for a specific lock, such information can be determined from other keys for the same lock. Optimally, a key micrometer, caliper, key punch, or key machine can be used to make cuts during impressioning. After the first sample is taken, it is especially critical that each tumbler position be filed only to the first standard depth. If a cut is made too deep at this point for any tumbler, then the lock can never be successfully impressioned. The time required for impressioning can be reduced if material is removed to specific factory depth coding, rather than simply removing material without correlating such filing to precise depths.

30_4.5.2 Principles and Guidelines for the Use of Files

Selection of the proper file is required in order that:

- **The proper amount of material can be removed to insure that bitting is not improperly reduced beyond the correct depth;**
- **More than one pin position can be filed for each sampling. Every position that marks can be filed;**
- **The cut can be shaped properly so as not to overlap to adjacent areas. This is especially critical in cases where there is a long pin next to a short one.**

Too wide a cut will affect the next position;

- **The cut is smooth, with a dull, flat, and constant finish to allow reliable viewing of subsequent marking. Some craftsmen prefer a mirror finish to enhance visibility;**
- **The cuts follow standard specifications in terms of ramp and valley angles for smooth insertion and removal of the key.**

The true craftsman understands the proper and efficient use of a file. The following principles and guidelines apply when removing materials from key blanks:

30_4.5.2.1 Use of the File

- **The work piece must be properly supported at the correct working height;**
- **The file must be held correctly with the cutting stroke properly guided;**
- **When the work is small and delicate and the filing is done by the motion of the hand or the hand and arm alone, the work should be held at a level that allows close scrutiny and control;**
- **Lift the file during the return stroke;**
- **Filing with a seesaw motion should be avoided, as it produces a convex rather than flat level surface;**
- **Keep files mounted on a rack or with their tangs placed in a row of holes drilled into a block of wood;**
- **Keep files in a dry atmosphere to avoid rusting;**
- **Files should be used with handles to facilitate control, although some craftsmen prefer to impression without them. In such cases, a protective cover such as electrical tape is advisable so that excessive force is not utilized when filing. This permits more control;**
- **Never hammer or pound the point of a file to seat the tang in a handle;**
- **It is desirable that the file produce a smooth surface that will allow contrast for easy viewing of marks;**
- **Do not saw or drag the file as it is brought back**

for the next stroke;
- **Learn proper filing technique and how much material to remove per stroke.**

30_4.5.2.2 The Type of File

- **Select the proper file for the job according to the type of metal to be filed, the amount of material to be removed, and the size and contour of the piece to be worked;**
- **Use a rat-tail with a #2 or #4 Swiss cut pattern to produce smooth surfaces when impressioning;**
- **A round file should not be used as a reamer to screw into a hole to enlarge it, nor as a pry bar;**
- **Do not place files on top of each other in a tool box; they will become dull;**
- **Only use Pippin files on brass;**
- **A Pippin file, preferred for impressioning, will allow the creation of both flat and curved cuts;**
- **Use a round rat-tail file with a #2 or #4 Swiss cut pattern for disc and wafer locks.**

30_4.5.2.3 Exerting Pressure While Filing

- **The proper pressure must be applied during the cutting stroke;**
- **Too much or too little pressure can cause damage to the teeth of the Swiss file. Only use enough pressure during the forward motion to maintain cutting during the entire stroke;**
- **Too little pressure on the cutting stroke can quickly dull the teeth of the file;**
- **Too much pressure will result in excess metal removal and will cause the teeth of the file to become pinned;**
- **The key may be filed horizontally to change the angle of cut without affecting the depth;**
- **A file cuts only during the forward stroke;**
- **Push the file forward slowly and evenly with gentle cutting pressure, and draw back the file without any cutting force;**

- **Do not apply pressure when drawing back the file, as it tends to polish the surface of the blank (a dull surface is needed when impressioning);**
- **Hold the file with an extended index finger pushing down on the top edge to control cutting pressure;**
- **Light cutting pressure will produce the finest finish for producing visible marks;**
- **Use heavier pressure to remove material rapidly, followed by lighter strokes to finish the surface for marking;**
- **Do not attempt to remove too much material during each stroke. A lighter, more even pressure on the file is desirable.**

30_4.5.2.4 Removal of Material

- **If the file is too coarse, more material than desired will be removed, and dramatic striations will be created on the surface of the key that can diminish the clarity of markings;**
- **If the file is too fine, it will require a greater amount of time to remove material and the teeth will tend to clog; however, the result will be easy to read in terms of marking visibility;**
- **Be careful that cuts are not made too deep so as to create a back-cut key that can be extremely difficult to remove;**
- **Be certain not to remove too much material on keys for high-tolerance locks;**
- **A code machine with a milling cutter may be effectively used in place of a file.**

30_4.5.2.5 Cleaning of the File

- **The file must be clean;**
- **Proper cleaning of files with both a file card and chalk will help maintain the finish of the work and reduce scratching;**
- **Chalk will reduce chip build-up in the teeth of the file;**
- **Use chalk and an oil brush to remove oil and grease**

from the file.

30_4.5.3 Filing the Marks

The removal of bitting material is straightforward. Whenever a mark is observed, file to the next depth. Do not guess as to marking; **if not sure, do not file.** If movement of the key is accomplished by the pullout method, remember to file where the actual pin centers are located and not where the mark appears. File so as to remove a minimum amount of material, taking care not to go below the next standard depth. Two or three strokes should be sufficient before looking for marks. Consult the depth-coding chart for the particular lock to determine the distance between positions.

Pay attention to the shape of the cut; as each position is filed deeper the ramp angles will increase until tumblers become trapped. Use the side of the Pippin or a flat file to create an angle of about 45° for smooth operation of the key. Remember that the width of the cut need only be slightly wider than the pins.

Often, a pin will stop marking prior to reaching shear line. If this occurs, stop filing and move on to other pins. At some point, the pin will begin marking, wherein filing may be again commenced. In an emergency, bitting material can be replaced using solder. This may be particularly helpful in covert operations where the supply of blanks has been exhausted.

30_4.6 Theory: Stop Removing Bitting Material from the Blank Key

If no mark is visible after binding the key, **do not file any further** for that particular tumbler position.

Practice: Stop Removing Bitting Material from the Blank Key

Impressioning theory is quite simple: any active locking component that is at shear line will **not** cause a mark to be made on the surface of the key. Thus, if there is no marking, assume that the component is at shear line.

Remember that impressioning, like picking, is based upon an alignment order of active locking components. Thus, certain pins may not bind until others have reached shear line. Therefore, do

not assume that because a pin has not thus far marked the key that it will not do so subsequently. Until the key opens the lock, nothing is final.

30_4.7 Theory: Produce a Working Key

When all active locking components are brought simultaneously to shear line, the lock will open.

Practice: Produce a Working Key

When the key has been filed so that each active locking component is resting at shear line or its equivalent, the lock should open. However, remember that each component may not be precisely **centered** at shear line during the impressioning process. Cumulative tolerance error may require the key to be jiggled and adjusted in order to open the lock.

The key may be measured against a known standard to produce a proper working key, based upon manufacturer's depth and spacing. Remember that during impressioning, the key was moved within the lock to cause marking. If there was a variance in interpretation of those marks, the bitting may be slightly high or low, or cuts not centered with reference to shear line.

30_5.1 Difficulties Encountered During the Impressioning Process

Many variables can be encountered prior to and during impressioning, especially involving pin tumbler locks. This can cause erroneous readings, resulting in improperly cut keys that will fail to open the lock. The following summary details the difficulties inherent in the process.

30_5.1.1 Improper Use of File

Improper use of a file or the use of the wrong file can make impressioning difficult or impossible. The selection of the proper file is critical; a Pippin #4 is recommended, although the author also suggests a small warding file to flatten the cuts prior to taking samples.

Use of an improper file in terms of shape, coarseness, or cut can result in the removal of too little or too much material. It can also cause the obliteration of marks through a failure to create

a smooth surface and thereby reduces contrast. If the file is too coarse, then excess material will be removed and dramatic striations will be created on the bitting surface. This will diminish the clarity of markings. Conversely, too fine a file will remove too little material, require excessive time, and will clog the teeth.

30_5.1.2 Good Lighting: Illumination is Essential

Movement of the key in different orientations is generally required to interpret and view the contrast between actual markings and artifacts.

30_5.1.3 Verify that the Lock is Mechanically Functional

All active locking components must be working properly in order to successfully impression a lock. Preliminary to taking any samples, the integrity of the mechanism should be determined.

30_5.1.4 Bore Centering

If the bores that form pin chambers (pin tumbler lock) are not in perfect center-to-center alignment, pins will bind based upon the relative location of each bore, from an imaginary centerline running the length of the plug. This is the equivalent to "order of picking." Thus, some pins may not mark until other pin positions are filed to the proper depth. The problem of bore centering then becomes a complex issue. Pins whose bores are most out-of- alignment will bind before those that are closer to centerline. Those pins closest to perfect alignment cannot bind until other tumblers whose bores are misaligned are correctly brought to shear line by filing the key.

If pins that are not actually binding are incorrectly believed to be producing marks, then the key is cut improperly. The entire process is then corrupted, resulting in wasted time and the necessity to start over with a new blank. Conversely, if binding pin positions are filed to the wrong depth, then other improperly aligned pins will never mark the key.

30_5.1.5 Point Contact Definition and Surface

The wear, dimension, and shape of the active locking component and the hardness of the key blank will affect the position,

depth, size, and shape of the marks. Severely worn tumblers can be difficult to impression because of their inability to properly mark the blade. This results from the imprecise surface contact and interaction.

30_5.1.6 Applied Torque

The amount of applied torque will determine which pins bind, how many pins or active locking components bind at the same time, and how the marks are created. The characteristics of the impression markings are directly related to the amount of torque placed on the pins. Not only must the proper torque be utilized, but also it must be applied equally in all four directions (upward left, downward left, upward right, and downward right). It is preferable to get as many pins to bind at one time as possible.

While impressioning pin tumbler locks, the plug may turn with hard torque as the key is close to being cut correctly. Do not continue to rotate the plug when this occurs, but continue the impressioning process. Failure to adhere to this rule can result in breaking the key or plug and scoring of the cylinder walls.

30_5.1.7 Security Tumblers

The size, shape, and design of the security tumblers determine how they bind and the marks that they create. Security pins shaped in the form of a spool that are positioned in upper chambers present little problem during impressioning. That is because the head of the pin should never travel below shear line. However, a few locks contain spool pins in the lower chambers. A probe can determine if such pins are present.

If there are spools in lower pin positions, remove bitting material for those specific cuts until the pin stops marking. Then, impression all other pins normally, ignoring the spool tumblers momentarily. When only the spool tumblers remain, the plug will slightly turn, catching the heads of the spools. Then, file down the cuts until they start to mark again. Continue filing slightly until shear line alignment is proper.

30_5.1.8 Preparation of the Bitting Surface of the Key Blade

The key must be prepared properly in order to optimize creation and viewing of the marks. Any distortions, irregularities, or imperfections on the surface caused by scratches, gouges, filing

marks, or artifacts can make impressioning more difficult.

30_5.1.9 Plug-Shell Tolerance

The tolerance between plug and shell or equivalent will determine how marks appear, the amount of binding force required, and the exactness required when removing bitting material. A theoretical problem with markings can arise in a situation with the following factors:

- **The plug-shell tolerance is extremely close;**
- **The indexing of the key to the keyway is relatively loose (thereby allowing greater than normal vertical movement of the key);**
- **The center-to-center chamber alignment is almost perfect.**

In this scenario, pins may actually be lifted **through shear line. This can occur because the vertical movement of the blank is greater than the gap between plug and shell.**

30_5.1.10 Device Used to Hold Blank Key

There are many devices for holding keys during impressioning. In the view of the author, most of these suffer certain defects that may make the process more difficult. Pliers, vice grips, special impressioning holders with forward moving pins to automatically withdraw blanks, round gripping tools, and similar implements are all designed to allow for the precise vertical, horizontal, and rotational movement of the key. Some work quite well, others are marginal.

30_5.1.11 Blank Milling and Indexing

The milling and indexing of grooves of a blank can be critical, because the key must be free to move in the keyway during impressioning. As noted previously, the key must not move so much as to lift tumblers **through** shear line, although it must be capable of lifting pins sufficiently to cause marks to be produced. Too much movement that allows excessive motion can allow a blank to mark after the pin has reached shear line. If no vertical movement is possible, then no useable marks can be produced. The design of the keyway will be a serious factor in the ability of a key to move both vertically and horizontally.

It is axiomatic that the correct key blank must be used if possible. The number of pins, wafers, discs, or levers must be determined in order to assure that the blank is long enough. A common problem is to find that too short of a blank was employed, thereby making impressioning impossible.

30_5.1.12 Movement of Key During Impressioning

The key must be moved uniformly and properly during the impressioning process in order to make consistent marks.

30_5.1.13 Failure to Release Torque

Failure to release rotational pressure between samples will result in erratic or invalid markings. Torque must be released and reapplied prior to lifting the key.

30_5.1.14 Impressioning Technique

As will be subsequently explained, there are a number of different methods of impressioning. All are valid and, in large measure depend upon training and personal preference. Whichever method is chosen, it must be capable of consistently producing readable marks in direct correlation to the position of active locking components.

30_5.1.15 Removal of Bitting Surface During Impressioning:

The amount of material that is removed during each sampling is critical. It directly relates to the time required to produce a key, the accuracy of the key, and the success of the procedure. Not only must the proper amount of material be removed in terms of depth of bitting surface but the angle and width of the cut must be correct. If the cut is either too narrow or wide, off-center, filed at an angle, or there are depth and spacing errors, the locking component will not seat properly.

Assuming the lock was pinned by factory coding, the craftsman should strive to make cuts correspond with established bitting depths. This will eliminate the problem of over or under cutting during sampling. Ideally, a stamp or code-cutting machine should be utilized to remove bitting from the key. The use of non-standard depth coding can cause too much bitting material to be removed during each sample.

30_5.1.16 Broken, Warped, Angled, Worn, or Crushed Locking Components

Damaged locking components can seriously affect the ability to mark reliably. If the top of the bottom pin tumbler has been filed by hand and is angled, then marking may occur erratically and unreliably. Tumblers that are severely worn can likewise cause marking problems because of poor contact between pin and key.

30_5.1.17 Pin-Stack Orientation

Orientation of the pin-stack, and long pins next to short ones, can cause errors in the impressioning process due to excess removal of bitting material.

30_5.1.18 Key Blank Material

In order to mark properly, keys must be softer than the active locking components but strong enough to resist breakage or fracture. Nickel silver blanks are generally too hard; aluminum too brittle. Brass is generally preferred.

30_5.1.19 Dirt, Residue, or Contaminants

The presence of dirt, residue, other environmental contaminants, or broken or weak springs can create difficulty in reliably marking the key. Small specks of debris or the introduction of oil can also make reading of marks more difficult.

It is not desirable that the lock work smoothly during impressioning. The use of either wet or dry lubricant is not recommended because they can leave a residue on the key that must be removed to see markings. The blade surface should be wiped clean to insure that what is viewed as a mark was actually produced by impressioning. Covered elsewhere in this text are proper methods and materials for cleaning locks.

30_5.1.20 Obliteration of Markings

There is a temptation to insert and remove the key during impressioning more often than is necessary. This practice can destroy or obstruct fragile marking. When applying torque and lifting the key, only insert once per sample. It is not necessary to insert and remove each time this operation is

accomplished.

30_5.1.21 Short Pins

Sometimes extremely short pins are used in the pin-stack. These can often be viewed if in the first tumbler position, and the "split" can be seen and decoded. If this information is available, it speeds up the impressioning process. An otoscope, flashlight, and pick can be used to identify short pins. Simply lift all pins and then release each in sequence from the back of the keyway and look for a visible split. The depth and position can be estimated. Conversely, if no splits are visible, then all cuts can be initially filed to a position that would exclude short pins.

A straight pick-probe filed to a sharp point may also be employed to locate splits in pin stacks. This type of instrument is calibrated so an accurate determination can be made with regard to the active tumbler. The point is scraped across the face of each pin after all are lifted, then individually released. A forensic examination of the lock will reveal the use of such a probe. Minute scratches will appear on the sides of the tumblers.

30_5.1.22 Master Key Systems

Impressioning of master key systems is no different than making keys for standard configurations. The produced key may actually be a cross-key combination, or master key rather than the actual change key. Unless the mechanism utilizes a master ring or similar scheme for preventing cross-keying, there is no way to determine the relationship between the impressioned key and the actual change key. Impressioning more than one lock in a master keyed system can yield the actual master key combination.

30_5.1.23 Precautions Relating to Common Errors

The following precautions should be observed:

- **Be certain that the plug is being turned in the proper direction to open;**
- **Do not impression plastic locks;**
- **Examine the plug to be certain that it is strong enough to withstand the torque of impressioning; some keyways may split. Be especially careful in**

the case of wafer locks. If discs are bent, the lock will not open;

- **A pin may ride on the ridge of the key, making the mark difficult to observe;**
- **Do not rotate the plug to the unlocked position until the key fits properly;**
- **When the plug finally turns, do not rotate to an open position prior to insuring that the key is working properly and not binding;**
- **Manufacturing tolerances will cause certain pins to bind first, then others later. This is normal, and should not be cause for concern.**

Section 2: Opening Specific Locks

Impressioning Specific Locking Mechanisms

In order to properly impression a lock, a thorough knowledge of its mechanical design characteristics is required in order to understand how marks are produced. See Chapters 13-16. The following discussion provides information regarding the production of keys for basic types of locking mechanisms, and certain unique ones.

30_6.1 Impressioning Warded Locks

The very first locks to be impressioned were warded. Today, they are the easiest to open due to the simplicity of their construction. Rim and mortise warded locks can be found in older homes and hotels, especially in Europe. Inexpensive warded padlocks are still very popular.

In order to impression these locks, the wards, their position and shape, and the position of the throat cut must be determined. Originally, wax was used to find the position of the wards. Today, the accepted technique is to “smoke” a clean blank with the tip of a flame, thereby depositing a thin carbon coating evenly along all bitting surfaces.

30_6.1.1 Bit and Barrel Keys

Certain warded and lever locks use bit or barrel keys. These are

easy to impression because the manufacturing controls are not precise. A bit key has a solid flag; the barrel key fits over a post. A summary of the procedure for producing keys for these locks is presented:

- **Trim the length of the key to allow rotation in the lock;**
- **File smooth the bitting surface of the flag;**
- **Insert the key into the lock and rotate until contact is made with the wards and the key is stopped. This will mark the blank at every contact point, indicating the position of the wards. Simply file the key at each of these points, on both sides, to form deep square cuts;**
- **Use a warding file to make each cut in the shape of a square;**
- **Insert the key and rotate, causing new markings to be made;**
- **Repeat the process;**
- **Do not apply excessive torque on the key;**
- **Do not file if a mark is not present.**

When bitting material has been removed to clear all wards, the key will turn. Generally, square cuts must be made in symmetrical form on both sides of the flag. Be certain to file straight down into the blank and not at an angle. Care must be exercised because the file will tend to drift.

30_6.2 Warded Padlocks

Internal wards block the rotation of the key. Therefore, corresponding square cuts on both sides must be present in order to clear all wards and release the shackle. Remember that keys for warded padlocks only have "cuts" and "no cuts." Remove material only where marks are visible, and use the proper warding file. It must be equal to the dimension of one ward.

Be certain that the cuts are wide and deep enough to clear the wards. Do not weaken the key by making the cuts too deep or wide; they must also be perfectly symmetrical. It is important to insure that the key blank is long enough to bypass all wards and reach the locking bands, and wide enough to spread the bands to release the shackle.

30_6.2.1 Procedure for Impressioning Warded Padlocks

The procedure to produce a key for a warded padlock is straightforward and requires the following steps:

- **Always make the throat cut first;**
- **Place the key completely into the lock and turn sharply without warping or twisting the metal;**
- **Small spots will be observed to indicate throat and wards contacting the side of the key;**
- **Use a warding file to remove material on both sides of the key;**
- **All cuts will be the same depth;**
- **The width of a cut will correspond with the dimensions of a ward;**
- **A skeleton key for warded padlocks will have all ward positions removed. It will be comprised of raised areas only in those positions that are required to spread locking bands.**

30_7.0 Impressioning Lever Locks

Lever locks are extremely popular for use in safe-deposit boxes, safes, vaults, coin telephones, and mailboxes. In other than the United States, they are the primary lock for residence and business access control. They can be impressioned using hard keys, special brass blanks, or plasticine. If metal blanks are utilized, they are produced in much the same fashion for pin tumbler and wafer mechanisms.

The difficulty of the task will in part depend upon the number of levers and their design. Keys can be produced for locks having levers that have both a standard “H” gate, referred to as closed or secure levers, and open gates. Soft impressioning using plasticine is also popular, where the lever bellies are non-uniform. Several decoding techniques are also available for producing keys. These rely in part upon traditional impressioning theories, covered in **Chapter 31**. Decoding allows keys to be quickly produced for most locks, even those having up to nine levers used in safes and vaults.

Other sophisticated techniques have been developed by John Falle,

Martin Newton, and others.

A clever device for impressioning lever locks has been developed in Bulgaria. Courtesy of Hans Mejlshede.

30_7.1 Identification and Definition of Lever Lock Components

The following definitions describe components within a conventional lever lock. See **Chapter 14** for detailed explanations. They are repeated as a matter of convenience to assist in understanding the material.

Belly

The belly of the lever is one of the most critical components. It is essential to understand its function and design in order to successfully impression these locks. The bottom portion is formed in the shape of a concave arc. It allows the key to control and lift the lever and hold it at a constant height as the bolt is moved horizontally. Because the angle of contact changes as the key is turned, the arc of the belly must track this change simultaneously. Thus, the angles, shape, and size of the belly will vary according to the height to which the lever is to be lifted. A long belly is required for **high-lift levers**; a short belly for a **low-lift lever**. The parameters will range between these two extremes, based upon the precise placement of the gates.

The straight edge or end near the lever pivot may also vary in length to compensate for the difference in swing. Differs are created by the variance of the distance from the belly to the gate. The key bitting determines how far the levers are raised and thus the position of the gate. In a six-lever lock, there are approximately 10,000 useable permutations.

Bitting

The material on the part of the key that comes into direct contact with the levers. Bitting is removed from the **flag** in order that each lever is lifted to the precise alignment point.

Bolt

The bolt is the locking component that is blocked from lateral

movement when the levers are out of alignment. It forms the fastening method between the lock and the container to which it is affixed.

Bolt Stump

It is often described as a projection that is formed as part of the bolt. It acts as a fence to which the lever gates must be indexed and aligned prior to movement of the bolt.

Bolt Tail

The area at the base of the bolt where material has been removed in order to allow the introduction of the key, and thereby transmitting energy to move the bolt. The actual cutout portion is called the **talon**.

Flag (Bit)

The portion of the key that is equivalent to the blade of a pin tumbler blank key is referred to as a flag or bit. It is the projection on the lever key upon which the various cuts are made.

Gate

The precise space within a lever tumbler through which the bolt stump travels.

Post (Lever)

The point upon which the lever pivots vertically.

Monitor Lever

A lever that monitors the operation of the bolt. This is accomplished by moving a projection over the keyhole when the bolt is not fully thrown.

Shank

The shaft of the key upon which the Bow and Flag are connected.

Talon

The cutout in the bolt tail wherein the key transmits motion in

order to move the bolt.

30_7.2 Impressioning Theory for Lever Locks

In much the same way that pins must be positioned at shear line in the pin tumbler lock, all of the gates must be aligned so that the bolt stump can pass. Based upon the same principle as the pin tumbler mechanism, levers will mark the key whenever their gate is not aligned with the stump as torque is applied. Conversely, any lever that is positioned so that the gate is in line with the stump will not mark the key. Serrated or sawtooth levers will not affect the ability to impression.

In some locks, it is possible to examine the belly of each lever to determine the approximate combination of the lock.

Impressioning requires that the **position** of the gates be ascertained, rather than where the blank key makes contact with the levers. The height to which the levers must be lifted will determine when to stop filing the blank key. Any blank that has been filed to the proper dimensions with the correct throat cut can be inserted and made to revolve inside the lock. In this manner, it will engage the levers and stop upon touching the inside of the talon. This, however, will provide no relevant information as to the position of the gates. If the key were to be filed when it first touches the belly, then the flag or bit would soon disappear. This is perhaps the most common error made by the craftsman when impressioning lever locks.

30_7.3 Procedural Summary for Impressioning Lever Locks

The following provides a summary of the actions and procedures required to impression a lever lock:

- **Select the proper key blank, or produce one that will fully enter the lock without binding;**
- **Reduce the width of the key and its tip to freely enter the lock and talon, if required;**
- **Mark and cut the throat first in order to allow the key to rotate;**
- **Cut the bitting portion to bypass any ward plate;**
- **Determine where there are levers and any wards. Rotate the key several times to the point where it**

is blocked from movement. Wards will appear on the edge of the key as heavy or large impressions. They must be bypassed prior to impressioning the levers;

- **Ignore marks on the tip of the key;**
- **Impression marks must be discriminated from burnishing caused from rubbing;**
- **Be certain that the width of all cuts is equal to and never greater than the thickness of the levers. Use a warding file to make cuts;**
- **Rotate and lift the key to mark, using sharp pressure;**
- **Do not apply too much torque. Consider the weakness of throat and tip;**
- **Find the depth of each cut;**
- **The key will not stop marking, but significant marking will cease when the levers are aligned;**
- **When the key operates the lock, open it immediately.**

30_7.4 Impressioning Standard Lever Locks

Two different procedures will allow the production of keys for drawer, till, cupboard, antique, and other low-security lever locks. Such locks may be impressioned and then require disassembly in order to produce a precisely accurate key. The lock may also be **picked and then decoded.** This technique requires that the levers be properly aligned with the stump entering the gates so that they are locked in position. The height of each lever may be determined by viewing with a borescope or otoscope, causing marks to be produced on a blank key or with plasticine.

If a blank key is to be utilized, it must first be cut to the internal dimensions of the lock in order to be able to rotate against the levers. Determine the thickness of the bolt tail and then turn the key into the levers to mark each one. Blackening with a flame will assist in reading the key.

The levers should be considered as wards for this procedure: the key must be pulled against the lock case so as not to move the bolt while causing the levers to mark. Continue filing the key until it turns smoothly. Remember to remove only enough material from the flag to allow clearance for each lever. Once the key is turning smoothly, produce a duplicate onto another blank, leaving enough material to fit in the talon. A slight adjustment may be required to make the new key work properly.

30_7.4.1 Impressioning Bit and Barrel Lever Locks

Bit and barrel key locks may incorporate wards or levers. They may be impressioned or visually decoded through a viewing hole. To decode, insert the key and file the bitting corresponding with the lever closest to the sighting hole. Once aligned, the next lever is read and its gate brought to the fence. This procedure is continued until all levers are aligned with the stump.

30_7.5 Impressioning Medium and High-Security Lever Locks

Medium and high-security lever locks are impressioned differently than antique, cupboard, and cabinet locks. In part, this is because the number, configuration, tolerance, and placement of levers is altered, especially in safe and vault locks. In theory, there is no difference in impressioning detainer levers (open-ended gates) and H or closed gates. Forcing the racking stump against the lever will cause one or more of them to come into contact with the stump sooner than the others. That lever will be the one that is held at shear line. There is also no difference, in theory, between serrated and standard levers or in locks with uniform and different bellies.

A number of factors affect the difficulty and ability to impression a given lock:

- **Insure that the key gets past the talon as the first cut;**
- **Rotating the key toward the locking direction will accomplish nothing;**
- **Presence of serrations or false gates;**
- **Design of the fence or stump;**
- **Type of levers (brass or steel);**
- **Type of blank (brass or steel);**
- **Method of preparation of the blank (flat top or knife-edge);**
- **Reaction of specific mechanism to impressioning;**
- **Complexity of the mechanism;**
- **Tolerances and method of construction. Stumps are often soldered or riveted and, therefore, they never fit perfectly. Levers are never exactly the same**

size;

- **The relationship of the size of the bolt stump to the size of the gate. If the stump is very close to the dimensions of the gate, the lock will be extremely difficult to impression;**
- **How well the bolt stump is fixed into the bolt. With sufficient pressure it can break, especially if soldered in position;**
- **Product knowledge, including:**
  - **Height of the levers: for example, if it is known that the lock is a Chubb 3G114, with 5 levers, then there are 1,000 differs (5 positions for each lever). Each lever would have 7 or 8 steps, depending upon age;**
  - **Number of differs;**
  - **Measurement of each step;**
- **Condition of lock and levers;**
- **Whether the door is badly fitted. This can place pressure on the bolt, causing difficulty in obtaining correct readings;**
- **Force of the door upon the bolt;**
- **Presence of grease and other contaminants.**

A cursory examination of the lock should first be made in order to gain an insight into the number and gating of the levers. This will provide an estimate of the design of the key and can reduce the time needed to impression.

Be certain that the correct key blank is selected. If this is not possible, then it should be modified to fit. Be sure that the width and height of the flag is correct and allows proper clearance into the keyway and free rotation. The bit should be square-cut, making sure the key fits properly into the talon.

30_7.5.1 Preparation of the Key

Marks generally appear as small nicks on the edge of the bitting surface. As in other locks, the key can be prepared to enhance marking using knife-edge or flattopping. The flattop technique requires that the blade of the key be thinned. However, care must be exercised that too much material not be removed, causing weakening. Knife-edging is done in the same manner as with pin tumbler locks: the top of the blade is brought to a thin edge by

removing material at a 45° angle. The key can be blackened using a flame or marking pen to enhance visibility of marks. Carbon deposits can be created on the blade by holding a flame below the surface of the bit.

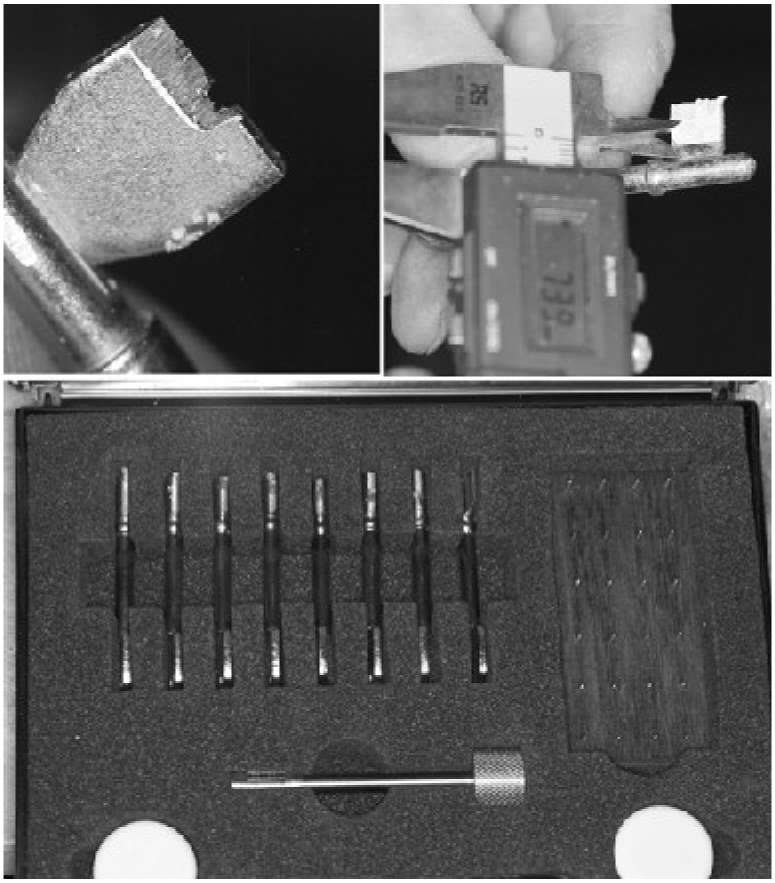
In order to obtain the best impression of the thickness of the bolt tail, the key is turned **counterclockwise** until it makes contact with the bolt. It is then filed to the shank so that it will pass over the bolt tail, thereby touching the levers. Next, insert the key again fully into the lock, taking care not to create any scratches on the surface. Then turn the key in the direction that the bolt will withdraw. It should be pulled fully against the wall of the outer lock case, thereby causing the bellies of the levers to become engaged. Some of the levers will resist lift due to the angle of contact. Thus, more torque than normal is required.

Remove the key and examine it for marks that should reveal the number and approximate height of the levers. Note that most levers are stamped from a metal sheet and are thus slightly angled on one edge. This may provide an opportunity for inaccurate spacing indication. The key is then inserted and turned against the levers. Any resistance to rotation will cause marking, indicated by a polished area on the bit. Where such marks occur, material should be removed in small increments. This process should be continued until the key turns smoothly and without resistance (other than the normal spring bias of the levers).

Although the key produced by impressioning may open the lock, it may not in fact be cut precisely to the correct depths. This phenomenon occurs because gates can be aligned at several points along the bellies due to their design and manufacture. Thus, after an initial key has been generated, the lock should be disassembled and a proper key produced based upon standard readings. In fact, the actual cuts for the key may be one to four millimeters deeper than the impressioned cuts. High-lift levers will mark closer to the real depth than with low-lift levers.

30_7.6 Impressioning Using Plasticine

Levers with bellies that correspond to the position of their gating may be impressioned with plasticine. This material resembles clay. It can be overlaid on a milled blank key to provide a soft surface to receive impressions.



Exploded view of photographs 1, 2, 3.

When a plasticine-coated key is inserted into a lever lock having non-linear bellies, the material will mark in direct correlation, as a reverse image, to the dimension between the belly and gate. From this information, a key can be decoded and produced because the amount of lift required for each lever is displayed. Plasticine allows decoding in both rotation directions. Falle has produced a combination impressioning and decoding system that utilizes plasticine (see Section **12.2.3.4)**.

30_7.6.1 Techniques for Using Plasticine

There are two methods to use Plasticine to impression and decode a lever lock. A coated key may receive an impression of the levers at the initial point of contact (at rest), or the levers are lifted to their maximum height to take the impression. Plasticine will create a reverse image of what the key looks like. Depending upon the lock, the type of levers, and whether

impressioned in the locked or unlocked position, two different readings may be taken. Because the portion of the key that controls bolt throw has already been removed, only the bitting that contacts the levers is present. Thus, the key can be turned to its maximum height.

In order to use plasticine effectively, each mechanism must be studied and a determination made as to which technique provides the most information. Some lever packs will always contain one particular lever that might have a special characteristic. For example, a lever may be thicker than all others, or it might not mark at all. Careful research will result in a lock being impressioned using a single blank. In other cases, data will indicate that a certain lock cannot be impressioned.

30_7.7 Self-Impressioning Key System for Lever Locks

Falle has developed a self-impressioning system for lever locks that employs a specially designed key with a moveable pin for each lever. Each of the pins is set in a nylon busing that provides sufficient resistance so as to allow movement only when forced against an immovable lever that is not aligned with a gate. The system, in theory, resembles a shim pick-impressioning tool for axial pin tumbler locks, wherein the moveable pins replace the tynes.

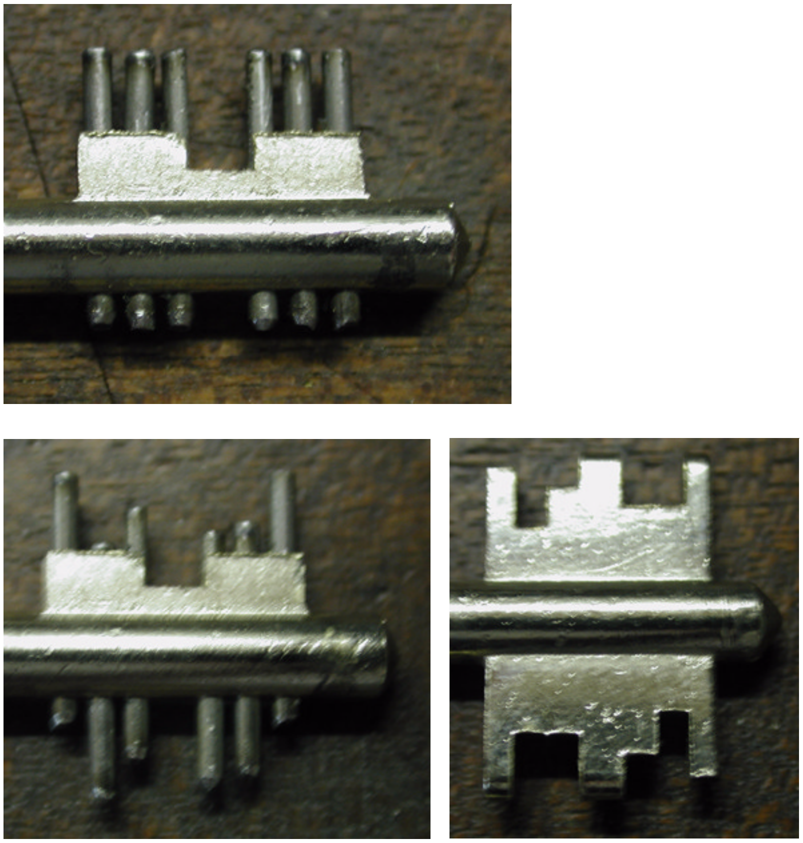


Figure LSS+3003 John Falle has developed an extremely simple impressioning system that works with virtually every European lever lock. The system is silent and leaves no trace, and can allow a lock to be opened in less than a minute. Shown is a "blank" key, having all moveable pegs set to a level position. Upon impressioning, the individual pins are moved to the proper depth based upon the depth of each belly.

30_8.0 Impressioning Disc Tumbler Locks

Disc tumbler or wafer locks are impressioned based upon similar principles for pin tumbler locks. As discussed in **Chapter 31**, these locks may also be decoded and include special high-security mechanisms such as AVA (Chubb) and Abloy. Steel keys are utilized, allowing extremely heavy torque to be applied.

30_8.1 Summary of Procedural Steps for Disc and Wafer Impressioning

- **Consider decoding in conjunction with impressioning;**
- **Be certain that the blank fits and indexes properly**

within the lock;

- **Prepare the blank using standard techniques, such as blading;**
- **Mark the blank for each wafer position in order to eliminate false readings;**
- **Insert the key and apply rotational torque;**
- **While applying torque and vertical pressure, lift the front, then the rear of the key to cause marking. Several cycles of this movement may be required;**
- **Do not apply too much torque once the key is inserted. Excessive force can damage the wafers, key, and die-casting.**

Locks are impressioned in the same fashion as the pin tumbler, although the method of applying torque must be slightly modified due to the cast metal construction. It is recommended that the pullout holding tool and techniques described in an earlier section **not be used** because of the potential deformation and damage that may be caused to the discs. Due to their construction, less torque is applied during the impressioning process.

- **Care must be exercised in the interpretation of marks because of their fragility. Generally, a high intensity light must be used to create a glare in order to enhance their readability;**
- **Marks will generally appear as straight lines, based upon the outline of the wafers;**
- **Make cuts with a Pippin file, using a forward motion;**
- **Do not rotate the plug to an unlocked position until the key fits properly. When the plug does turn, mark the key to insure a proper fit if there is any binding. If the plug is rotated to an open state, it will lock again, requiring disassembly or a repetition of the process;**
- **Forcing the plug to rotate before the key fits correctly can distort the corners of wafers. If the plug is then turned in the opposite direction, the key may not work properly;**
- **Be very careful not to bend the discs through the application of excessive torque.**

30_8.2 Differences in Marking

The marks produced from discs or wafers may appear slightly different than those made by pin tumblers or levers and are in part dependent upon the juncture point discussed above. Marks can look like small dots on the edge of the blade, or a straight line or band across the width of the bitting surface.

30_9.0 Impressioning Pin Tumbler Locks

Impressioning pin tumbler locks is covered extensively in Sections **1-5**, of this chapter. Only a brief overview of the procedure is provided here.

- **Prepare the blank key in order to make the bitting surface more conducive to impressioning;**
- **Modify the key to allow for vertical movement, if necessary, by milling. Take care not to weaken the key;**
- **Insert the key into the lock;**
- **Be certain that the key is indexed properly in the keyway;**
- **Apply sufficient torque to bind the pins;**
- **Move the key vertically in both a downward and upward motion, causing marking of the entire length of the blade;**
- **Repeat the bind-lift cycle several times before each removal of the key, to interpret marks;**
- **Once a working key is produced, duplicate it. Do not give a bladed key to a third party unless part of a covert entry team.**

30_10.0 Impressioning Sidebar Locks

Sidebar locks can utilize both traditional and secondary locking mechanisms that can make impressioning difficult or impossible. Sidebar technology is employed in pin tumbler, wafer, disc, and magnetic devices. The most popular of these are the original Briggs and Stratton automotive lock and the Medeco series of cam and pin tumbler devices.

The difficulty in impressioning any sidebar mechanism results from the inability to bind the active locking components in order to generate markings relative to their position at shear line. In the traditional sidebar lock, the shear line is secondary. There is no **direct** mechanical correlation between the position of the pins and the ability to turn the plug. In the Briggs and Stratton lock, for example, the application of torque to the plug will have no effect. The sidebar is designed to catch on the lock body unless all wafers are fully aligned. Thus, no significant markings can be obtained through traditional binding techniques.

30_10.1 Impressioning Briggs and Stratton Sidebar Locks

The sidebar lock used in all General Motors automobiles can be easily decoded as described in **Chapter 31**. Although some locksmiths claim to be able to impression them within ten minutes, the task is by no means simple or assured of success. Some of these locks can be impressioned by obtaining marks indirectly from the contact of the sidebar to the individual wafer. Pressure is exerted on the side of each wafer that then makes contact with the sidebar.

Theoretically, it requires almost the same procedure that is involved in impressioning lever locks. The “gate” or V cut that appears in one of five vertical positions on the wafer must be aligned to allow the “fence” or protruding portion of the sidebar to enter. If pressure is exerted on the wafer in the direction of the sidebar, a slight indication of the contact resistance may be registered on the key as it tries to force the wafer into the sidebar. The process is aided because these cylinders are cast and thus do not maintain close tolerances.

General Motors has a 0.5 depth-cut tolerance; thus a “1.5” cut will operate for both a “1”(.248”) and “2” (.223”) depth; a “3.5” for a “2”,”3”(.198”) and “4” (.173”) cut; and a “4.5” for a “4” and “5”(.148”) cut. These tolerances allow keys to work in the same fashion as the old tryout keys, described elsewhere in this text. To impression these locks, test depths of .235”, .185”, and .160” will work for all depth cuts. All cuts should initially be filed to a 1.5 depth. Turn the blank in the lock about 20 times to cause contact between the sidebar and the wafers. If a mark is visible, file to a depth of 3.5. If there is still a mark after repeating the insertion process, file to a 4.5 depth.

Generally, marks will appear on the top or on the corner edge of the key blade. If the mark is on either side of the wafer position or does not run all the way across the bitting surface, more material should be removed. The marks may appear as a shiny spot or dot. These locks can also be drilled with a #60 bit immediately above the protruding surface of the sidebar. A wire is inserted to place pressure against the bar. The tumblers are then individually picked until each gate locks into the protruding V cut of the sidebar. To read the tumblers after picking, use the R&D tool described in **Chapter 31**.

30_10.2 Impressioning Medeco Locks

Medeco pin tumbler locks can be impressioned in the same fashion as other pin tumbler mechanisms insofar as the **length** of the pin-stack and determination of shear line. Impressioning will not provide information as to the rotational position of the pin. This problem can often be overcome after a key has been produced with the proper depth cuts through the following procedure:

- **Fully insert the key;**
- **Apply light torque in a clockwise direction;**
- **With a small rubber mallet, repeatedly and lightly strike the face of the lock, causing vibration;**
- **Continue this process of releasing and reapplying tension until all of the pins find their proper orientation. The process may take up to twenty minutes.**

Be certain that the valleys are wide enough to allow the chisel point of the pin to rest in a flat spot rather than on a ramp. This is called butterflying and creates a left, right, and central angle for each cut.

Once the lock is opened and the plug rotated, a decoder must be utilized to determine the proper angle of rotation for each pin. See **Chapter 31** for a detailed discussion of decoding these locks.

30_10.3 Impressioning Axial Pin Tumbler Locks

Impressioning tubular locks take two basic forms: use of picking/decoding tools and the more traditional physical marking of a key. The decoding tools that are discussed in **Chapter 29**

actually impression **and** decode the lock. The picking/decoding tools can be likened to a reuseable foil system: the shims will move to the depth where no further resistance is encountered from the pin. Although no marking occurs when using these devices, the shim indicates tumbler contact through its movement.

To properly utilize these tools, torque is applied to the plug and then the pick tool is pumped. Torque is then released and the process repeated until all tumblers are aligned and no more movement of the shims is noted. At this point, the lock will open; the tool may then be decoded and a key cut by code.

30_11.1 Conventional Impressioning of Tubular Locks

Because of the orientation of the pins in comparison to standard pin locks, impressioning axial pin tumbler locks is accomplished in a slightly different fashion. The total number of pins is not relevant, although their age, condition, and quality should be considered. Some axial locks will not impression. Impressioning is preferred over picking primarily when:

- **Dead pins and security tumblers are employed;**
- **The lock is affixed so tightly that the application of sufficient tension would be impossible;**
- **The proper pick and tension tools are not available;**
- **Ball bearings or security shrouds prevent the entry of a pick;**
- **The production of a key is required.**

30_11.1.1 Tools

Required tools for impressioning include **brass blanks, holding tool**, and a **file** with a handle. A tool for firmly grasping the key must be utilized. One can be fashioned using an 8" pair of vice grips, combined with a small dent puller and slam hammer. The tool must clamp onto the body of the key, not just the head. The linkage between the head and key is not strong enough to withstand the torque that must be applied to the center of the plug in order to affect all pins. Commercial tools are available for this purpose, such as the MT-1, manufactured by Pro-Lock. A mallet and rod may also be utilized to apply torque to the key. In such case, a thin rod is inserted through the bow as described earlier in this chapter.

30_11.2 Twelve Steps to Impressioning Axial Locks

The following steps are required to successfully impression most axial pin tumbler locks:

- **Remove the protruding key guide slot from the top of the barrel. This will allow the withdrawal of the key at any position of rotation;**

- **Test each tumbler position for spring tension, the presence of security tumblers, and heavy springs. These devices will mark differently and can give false readings;**

- **Examine the keyway for dead pins and note their location. A slot must be cut into the tip of the key using a narrow warding file. These pins are simple to identify; they produce a perfect impression mark;**

- **Chamfer or file, at a 45º angle, the front of the key completely around its circumference. Do not make the bitting surface a knife-edge. There must be some flat portion remaining. The reason for creating a 45º angle is to catch the edge of each tumbler during the impressioning process. Without such an angle, the marking can be very obscure and difficult to read;**

- **Insert the prepared blank fully into the lock, then withdraw it less than 1 mm. If the key is extracted too far, top pins may bind. This makes valid readings impossible to obtain. Some craftsman make cuts to the first depth for each tumbler position prior to starting the process;**

- **Apply torque and exert forward pressure on the key;**

- **Initiate a series of rocking or bumping movements with torque applied. Tap the key with the head of a plastic screwdriver, or if using a modified dent**

puller, slam the blank into the lock. Aggressive movement is not required and in fact may damage the head of the key;

- **Release the torque for each reading (sample) taken and repeat the above process;**

- **Stop filing when there are no significant marks;**

- **Rotate the plug 20° and tap the key with a hammer to positively seat the pins in case they were cut too shallow. If too deep, file the entire tip of the key. This will then raise all of the cuts;**

- **Marks will appear as digs or moon-shaped nicks. They are caused by contact with the sharp edges of flat-topped pins. Use a warding or Pippin file, taking care not to remove too much material. Widen each cut slightly. Keep the file perpendicular to the key when filing;**

Throughout the impressioning process, the key will never stop marking. Real impressioning marks will appear as solid and quite different from marginal or false marks. The major problem encountered during impressioning is the determination of whether marks resulted from a strong spring or from the position of dead pins. In order to avoid this difficulty always use brass blanks, never steel.

30_12.0 Pressure-Responsive Material Impressioning Systems

Conventional impressioning techniques rely upon the production of extremely minute and subtle depressions or displacement of material on the bitting surface of a key blank, obtained through a series of samples of the position of active locking components. Material is removed from the key in small increments for each pin, wafer, or lever until all depth positions correspond to shear line.

There are several drawbacks to conventional impressioning techniques. These include:

- **Difficulty in seeing marks;**
- **Creation of artifacts and false marking;**
- **False interpretation of marks;**
- **Requirement to have specific blanks for a keyway;**
- **Time required producing a key.**

More sophisticated techniques for impressioning and decoding have been developed by Martin, Falle, Bates, Gruber and others. These can make the process faster and simpler and often eliminate the requirement of blanks for specific keyways. Once the theory of conventional impressioning is thoroughly understood, these advanced techniques can easily be mastered and appreciated.

Although there are many similar systems, the most popular utilize **pressure-responsive materials** whose consistency or density is altered during impressioning, based upon the relative position of the active locking component. All of these techniques eliminate the necessity of manually removing material from the key; it is inherent in the process.

In one system developed by Martin, soft lead replaces the bitting surface of the key, enhancing visibility of the marks. As discussed below, material must be physically removed when using this system. Other systems use metal foil, plastic or cellophane tape, plasticine, wax, or wood.

Axial pin tumbler locks rely upon a similar theory, discussed earlier in this chapter. Gruber developed and patented a tool that used moveable shims that were the forerunner to foil. Their position would be displaced or moved precisely correlating to the depth of the pin in relation to shear line. The only significant difference between the Gruber and Falle or Martin system is the ability to reset or reuse the pressure-responsive material. Depending upon the technique, special blanks, dies, or keys are required to hold or retain the impressioning materials.

30_12.1 Theory: Impressioning with Pressure-Responsive Materials

To understand advanced techniques, we must consider what happens during conventional impressioning: **a key is moved vertically inside the lock after the active locking components are bound.** Assuming the pins, levers, or discs are not at shear line, a depression is created upon the bitting surface corresponding to

the distance of vertical movement of the key and the theoretical corresponding displacement of bitting material. The key is filed, removing material equal to one or more depth cuts at that point where such minute depressions occur. Filing continues until there are no more depressions, at which point the lock will open.

Now consider a system that **automatically** displaces bitting material whenever a depression occurs. In fact, that is exactly what happens whenever foil and other pressure- responsive materials are employed. Special keys or dies are covered or treated with such materials. The treated key is inserted into the lock and torque is applied, generally with a separate tool. As the key is moved vertically, the displacement of material (which causes marks in conventional procedures) permanently depresses the foil or other mechanism. The material will retain the depressions throughout the process.

Repetition of the bind-lift-displace cycle is continued until a key having depressions corresponding to the position of each active locking component is achieved. At this point, the lock will open. This process can take less than thirty seconds in some dimple locks. It is silent, will not damage the lock, and has the advantage of yielding a key that can be decoded and duplicated.

The bitting surface of a key that is forced against an immovable pin cannot occupy the same space at the same time; the foil or other pressure-responsive material must yield. To produce a key, the process simply requires that the correct amount of material be displaced for each tumbler position. Once a pin reaches shear line, it does not present an obstruction to the foil, and thus, no further displacement will occur.

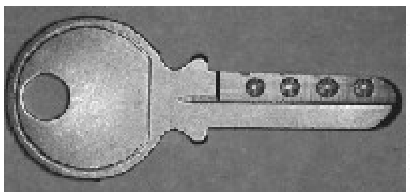
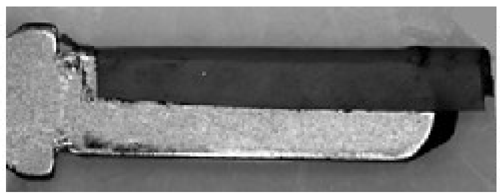
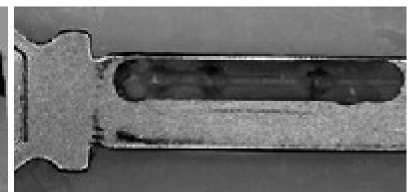
Many pressure-responsive materials have been successfully utilized. Falle uses .3 mm adhesive-backed foil; Mark Bates utilizes either wax or plastic tape. Others have even used wooden popsicle sticks soaked in alcohol until softened to accomplish the same result. The selected material must:

- **Be capable of depression or displacement with slight force while maintaining its altered shape;**
- **Fit into the keyway;**
- **Not leave a residue that would adversely affect the operation of the lock;**

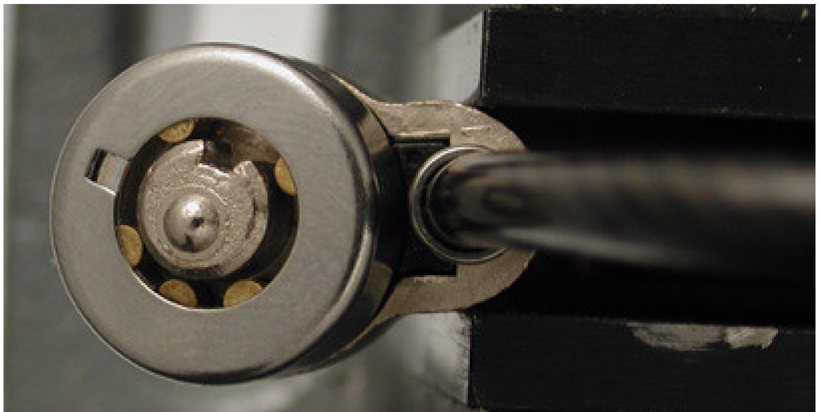
- **Provide good resolution, meaning that the material must be displaced in close correlation to the size and shape of the pin, lever, or wafer.**

30_12.2 Description and Use of Different Systems

The Martin composite blank, the Bates plastic tape system, and the Falle foil systems are described here. See **Chapter 31** for a discussion of the patented electronic pressure- sensitive system for decoding pin tumbler locks developed by the author.

A variation of this system utilizes the end of a plastic pen, such as produced by Papermate, to impression small format axial pin tumbler locks, such as used on computer locks. The inner diameter of the keyway, as shown, is almost exactly the outside diameter of the pen. To open this the lock, the end of the pen is inserted as shown, and pressed against the tumblers. Torque is applied, then forward pressure, causing deformation of the plastic to occur in relation to the length of each pin below shear line. The process is repeated, similar to that found in conventional impressioning technique, until each pin is resting at shear line, and compression of the plastic, equivalent to the length of each pin, has occurred. The reader is directed to the sections on the Falle foil impressioning systems for further insight into how this process works. The lock that is shown is produced by Kensington, and is perhaps the most popular in the industry for securing laptops. The lock can be opened within a few seconds, with essentially no skill level, using a ball point pen costing less than one dollar. In the photograph, the pins are shown in a picked state. In the opinion of the author, these locks are not secure and should not be relied upon for any level of security against theft.





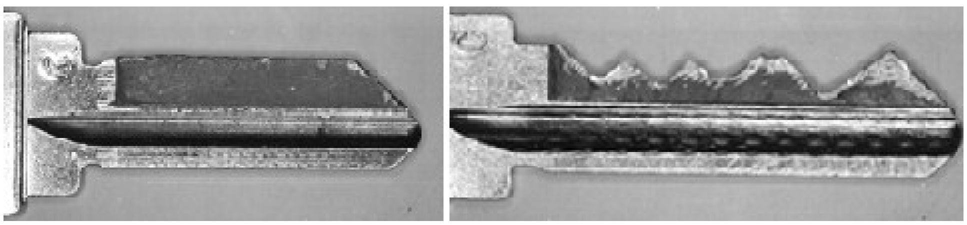


30_12.2.1 Martin Composite Blank Impressioning System

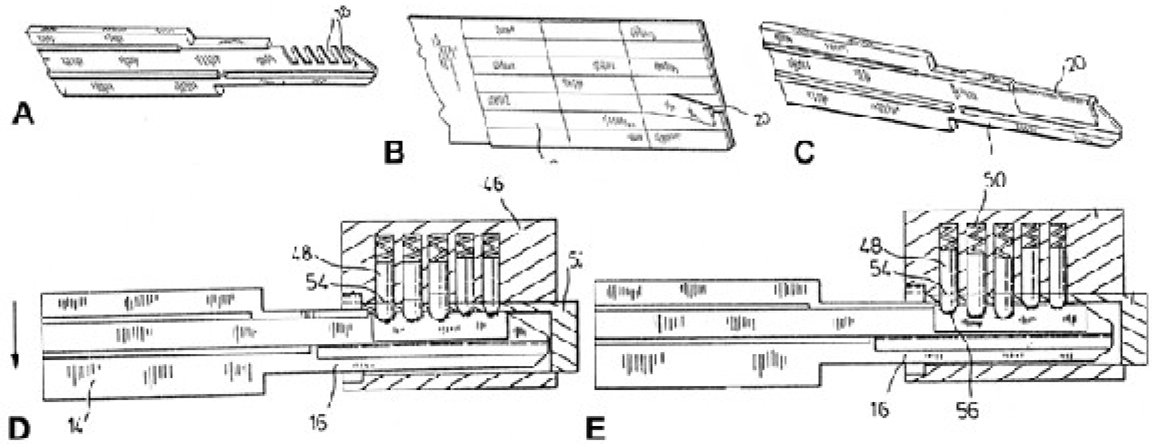
30_12.2.1.1 Introduction

Martin received two patents for his impressioning systems that were described earlier. In one system, a composite key was produced with the bitting surface replaced with soft lead. This

material makes impressioning extremely simple to accomplish by enhancing the marks produced by wafers and tumblers. Composite keys can be easily constructed by soldering a lead insert onto the blank key that has first been filed down to the wards. No special tools are required for impressioning other than a file, a plastic mallet, screwdriver, or other object to tap the top and bottom of the key.



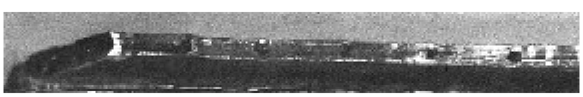
This system was never a commercial success although it works well, requires little skill, and is easily learned. It has the advantage of producing extremely readable impression marks. Standard impressioning procedure can be followed; however, a special holding tool for the key is **not** recommended or necessary, especially for insertion and removal. The use of such tools may in fact damage the blank.



To impression a wafer or pin tumbler lock using the lead composite key, the following procedure is recommended:

- **Insert the composite blank gently into the lock using light finger pressure. Reduce the pressure if tumbler resistance to the lead portion of the key is detected. Move the key from left to right and in some cases up and down until it enters easily. The lock can be cleaned with WD-40 to lessen friction;**

- **Great care must be taken when inserting the blank for the first time. Tumblers will tend to gouge or plough their own particular pathway along the top of the lead insert. To avoid dents in the metal, proceed slowly. Subsequent insertions will be faster and smoother because the tumblers will follow the original path;**
- **The tang of a file may be utilized to apply tension by inserting it through the hole in the head of the key;**
- **Move or rock the key up and down at least twice for each of four separate orientations (up right, down right, up left, and down left). The author prefers tapping both the top and bottom of the bow in each of the four orientations once tension is applied;**
- **Release the tension for each of the four samples;**
- **Wiggle the key to the left and right to loosen the tumblers from the lead and then gently withdraw from the lock. If "drag marks" occur along the length of the blank, clean the lock with WD-40. File to the next tumbler depth where marks appear;**
- **Reinsert the key;**
- **Repeat the bind-lift-tap sequence;**
- **The use of vice grips or other holding tool to control tension and lift can produce much deeper marks than the file or metal rod and will sometimes be necessary. However, such tools must not be clamped onto the key while it is being inserted or withdrawn, as it will be overbalanced. This can greatly reduce the feel of insertion resistance, potentially damaging or distorting the lead.**



30_12.2.1.2 Impressioning Wafer Tumbler and Flat-Bottomed Pin Tumbler Locks

Wafer tumbler “dig” marks appear as channels across the lead blade of the key. Wafers and flat-bottomed pins do not leave false marks, because their total spring and tumbler pressure is distributed over a relatively large area of lead. All marks may safely be filed until they disappear; never file any deeper.

Remember, a tumbler will "dig" to its proper depth and then stop. The real job of the craftsman is to interpret marks, remove lead from around the mark, and shape the valleys.

30_12.2.1.3 Impressioning Round and Pointed Pin Tumbler Locks

Round and pointed pin tumblers concentrate their total pressure onto a relatively small area of lead. This can cause light (false) marks even when the tumblers are not digging. To impression round and pointed pin tumbler locks, follow the same procedure as for wafer and flat-bottomed pin tumblers, with the below noted exception:

- **File only the deep (deepest) tumbler marks;**
- **Never file a light (false) mark until after the lock has opened;**
- **If there are only two or three equally light marks on a blank, do not cut;**
- **Obtain added samples until one tumbler produces a deeper cut. Occasionally it will be necessary to take several samples in this manner to produce reliable readings. When this occurs, use vice grips to apply tension and move the key vertically in all four planes.**

The recommended sequence is to:

- **Insert impressioning blank;**
- **Clamp vice grips to the blank;**
- **Complete the vertical movement of the key;**
- **Remove vice grips or holding tool from the blank;**
- **Withdraw the blank to remove bitting material;**
- **Repeat the process until all depths are determined.**

30_12.2.1.4 General Precautions and Comments

- **Although in most instances more than one tumbler will mark, this is not always true. File only those tumblers that produce a marking;**
- **It is normal for a tumbler to stop digging (will create false marks for a few samples) and then start**

digging again;
- **Learn to distinguish true and false marks. The distinction is quite simple: a true mark is deep; a false mark is not;**
- **Take enough samples to obtain good marking.**

30_12.2.1.5 Filing and Shaping the Key

The following guidelines apply to the removal of bitting material from the key:

- **The area under each tumbler must be wide, centered, and level;**
- **Do not allow unnecessary ramps to form on the bitting surface;**
- **Use a 1/8″ wide warding file for large pin tumbler locks and a 3/32″ file for wafer and small pin mechanisms;**
- **Do not use a round file to make cuts. Because of the softness of the material, it is important to create as few ramps as possible when shaping the key. Since concave ramps present more of an obstacle to pins than do straight angled ramps, a round file should not be used;**
- **A flat file will create fewer, lower, straighter and more gradual ramps than a round file. It is easier to observe dig marks on a flat surface than one that is rounded;**
- **Use the thickness of the file to make the starting cuts on all but the last tumbler position on the key;**
- **Slope the ramps to provide for smooth operation while taking care not to cut into adjacent depths;**
- **Prevent unnecessary or extra cuts from forming.**

30_12.2.1.6 Inserting the Impressioning Blank

Although a brass key can be forcibly inserted or removed without damage, such action will distort the soft composite blank because of the inherent resistance of the lead. Any tension on a tumbler during insertion will create resistance to movement, causing the tumblers to dig into the lead, with potential distortions as the result. In this event, the blank must be withdrawn and the dent

or distortion removed and smoothed before proceeding further. To insert the blank without causing this problem, no torque can be applied to any tumbler.

30_12.2.1.7 Drag Marks

Drag marks can occur in three instances:

- **Whenever the blank is carelessly withdrawn from the lock without removing the tension on the tumblers;**
- **Lubrication is required;**
- **Vice grips (which disguise tumbler resistance) are clamped to the blank.**

Drag marks are caused when a tumbler is under so much tension that it cannot smoothly glide out of its depression as the blank is withdrawn. Consequently, it ploughs a deep pathway from its cut to the tip of the blank. Drag marks are the chief cause of impressioning failure because they lower the overall level of the bitting surface. Tumblers that were already at shear line will become too low and start digging again.

30_12.2.1.8 Duplication of Original Lead Key

Duplicate the key on a regular blank, taking care not to exert excessive pressure with the key guide. Rough cut the key first and then slide the guide gently over the lead a second time. The guide should now leave a steady unbroken "shine line" across the lead.

30_12.2.2 Elastic Tape Impressioning System

Bates and others have developed impressioning systems utilizing plastic tape with special blanks to open dimple-style locks. The keys will not work in damaged or non-functioning mechanisms.

Plastic tape is another form of pressure-sensitive material and will deform based upon tumbler pressure. Unlike metal foil, plastic tape will not **retain** depressions for more than a few minutes once the key is produced. It does not have the same resolution as metal. It is also difficult to decode the depth of impressions with this material.

In practice, a specially milled blank selected for a particular

keyway is covered with a thin layer of tape prior to insertion. Milling of the bitting area is required in order that the tape might clear the keyway wards. Holes have been predrilled in each of the tumbler positions that slightly exceed the maximum depth-cut.

This form of impressioning follows the same procedure as used with metal foil: apply torque, lift in each of four planes, release torque, and repeat the cycle until the plug turns. No filing is required. Generally, the procedure will result in an opening in about five minutes.

30_12.2.3 Foil Impressioning Systems

Falle and others have introduced impressioning systems based upon the use of thin metal foil rather than blank keys. Whereas in conventional impressioning metal bitting is removed with a file, in these systems the foil is depressed or altered in each tumbler position. The depth of the depression will be in direct correlation to the action of those tumblers that are not at shear line. No filing is necessary.

These systems can produce keys for five or six-pin standard mechanisms, and up to sixteen-pin dimple locks within one minute, without the necessity of filing a blank key. The use of foil is silent and generally defies detection. Often, the resulting foil impressions can be decoded and reproduced on a metal blank. Foil systems graphically demonstrate the fundamental theory of impressioning described throughout this chapter. **The forced interaction of active locking components** (pins, levers, wafers) **and a bitting surface** (key blank or similar device) **will displace material equal to the vertical movement of that bitting surface**.

30_12.2.3.1 Falle Impressioning Systems

Falle has refined the use of foil to impression dimple and conventional pin tumbler locks using a process originally patented by Martin (**4400956(299)** and **4817406(300)**). John Falle has introduced two pressure-responsive impressioning systems. These are designed to replace conventional brass key blanks to open specific dimple and standard pin tumbler locks. In addition, a plasticine system is available for lever locks.

For pin tumbler locks, special **comb carriers** and tension tools are available for each keyway. The Comb Carrier system utilizes a series of .4 mm stainless steel combs designed for specific

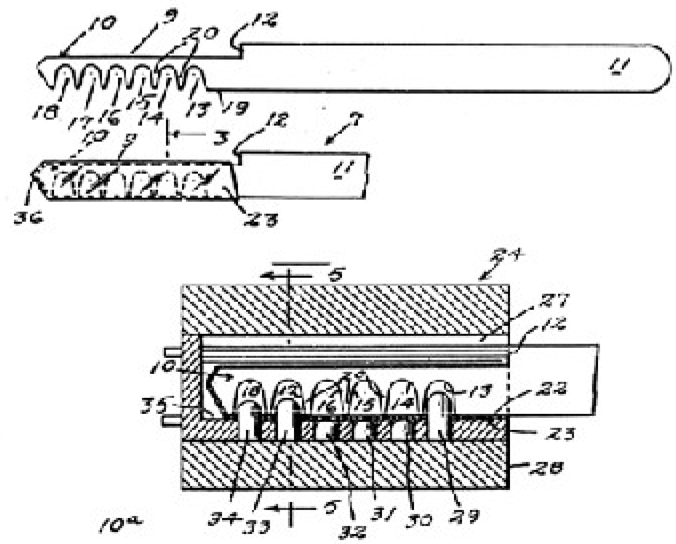
profiles. The carrier is covered with 30-micron self-adhesive foil and is inserted into the lock. Tension is applied to the plug, using a specially designed torque wrench. The comb is moved up and down, causing the foil to depress corresponding to the individual pin depths, until all tumblers reach shear line. The lock can then be opened and the comb decoded so that a key can be produced. See **LSS+/^{x} CD/ROM** for a demonstration of this technique.

The **lever lock system** utilizes plasticine in combination with a specially prepared blank. Keys cut for individual lever positions used in combination with a variable key generation system allow the production of a key based upon the information derived from the plasticine imprint. This system is described both in this chapter and in Chapter 31.

In the original Falle system, a **die** exactly the shape of a blank key, was precisely drilled to match the positions of the pins within a dimple lock. Because many manufacturers alter the placement of pin chambers to increase the number of differs, use of this tool requires information about the lock and its configuration prior to impressioning. Because of the uniqueness and utility of each of these systems and their use by the law enforcement, intelligence, and professional locksmith communities, they are described in detail here. They are the most effective way of opening pin tumbler cylinders and producing keys for them. If the fundamentals of impressioning described in this chapter are mastered, proficiency in the use of these tools can be quickly achieved.

30_12.2.3.2 Profile Comb Carrier System

The comb and foil system was first patented and introduced by Martin in 1981. It was never commercially feasible. Falle perfected the system in 1996, using etched stainless steel to create an impressioning tool fashioned in the shape of a multipronged comb. Each segment of the comb corresponds to the position of a chamber and its pin-stack within the plug of a pin tumbler lock.



30_12.2.3.2.1 Components of the System and Design Characteristics

The comb system is provided with all of the necessary equipment to open one particular type of lock. The components include:

- **Quantity of aluminum foil (30 or 40 micron thickness);**
- **Hobby knife to trim the foil;**
- **Foil combs for five and six-pin tumbler locks;**
- **Different tension bars and spacers;**
- **Insertion and extraction tools.**

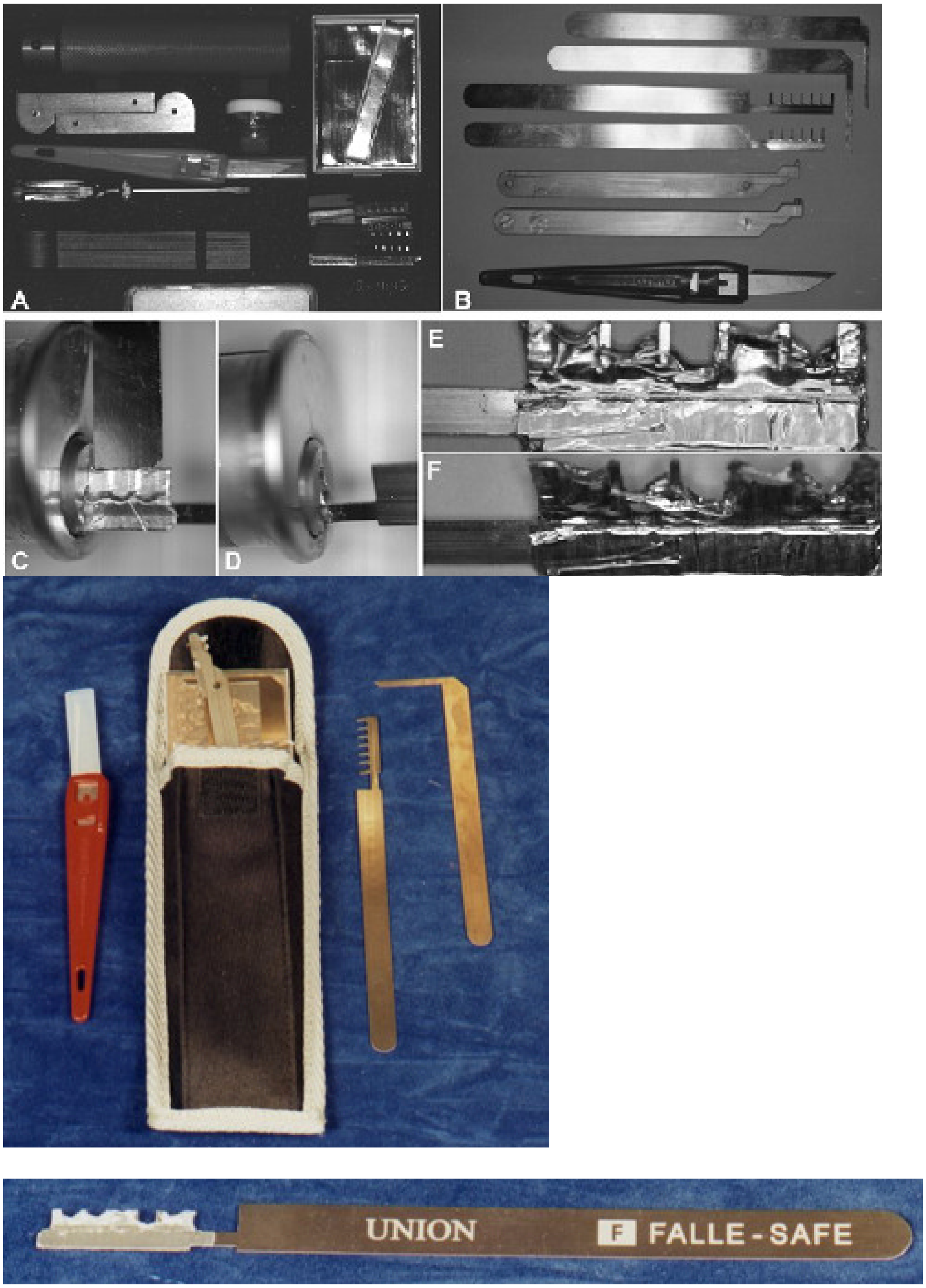


Figure LSS+3004 The Falle foil system for pin locks. Courtesy of John Falle. The completed key is a foil impression of the tumblers and simulates the original.

Profile Comb Carrier: Each foil comb is fabricated from .4 mm

chemically etched stainless steel and is created to fit a particular keyway. Depending upon the cylinder profile, two foil combs may be supplied that accommodate different ward patterns for five and six-pin configurations.

The design of the carrier provides for the creation of a channel between two vertical members (teeth) for each chamber. When these channels are covered with foil, a solid surface is presented to each pin-stack. This replicates a blank key. During impressioning, the foil is actually depressed within each of these channels, corresponding to the position of each pin.

A **tension channel** to allow for vertical movement of the carrier has been created in the same location as the shoulder on a traditional key. This channel provides clearance to elevate the tool when it is used in conjunction with the special tension wrench. It is the mechanism by which the foil is displaced during the impressioning process.

Tension Tool: Most systems are supplied with one assembled tension wrench and one extra tension bar. These allow the assembly of the tool to provide for the application of torque from either side of the keyway. This design provides flexibility as to the orientation and position of the tool and is critical when there is no clearance to one side of a door.

The tension wrench is actually comprised of two metal bars held into place by spacers. The tips have different widths; one is narrow and one is wide. The narrow portion is inserted at the top of the keyway, while the wider end is indexed to the base of the plug. This design allows the tool to be firmly anchored while impressioning. The extra bar will have a different tip width.

In each case, the lower bar will be identical in design but the width of the upper tip may need to vary depending upon the lock profile. Before attempting an opening, the user should examine the lock and its surroundings and assemble the tension tool accordingly.

Insertion/Extraction Tools: The comb as constructed presents an impassable barrier to each tumbler. It looks much like a key that has been back cut in all pin positions and in both directions. The comb cannot be removed, once the impressioning material has been exposed to the tumblers, and thus the need for the extractor.

The insertion/extraction tool allows the tumblers to be lifted to the top of the keyway in order to clear the comb prongs while the foil carrier is inserted or removed. Two different designs of the tool are supplied: one is angled and one is straight. Each is provided in two lengths for five and six-pin locks. The tool must enter the keyway to one side of the foil carrier.

30_12.2.3.2.2 Producing a Simulated Key

There are four fundamental differences between the Falle foil system and conventional impressioning:

- **A simulated key is produced automatically;**
- **Torque is not applied directly through the blank key but indirectly through a separate torque wrench;**
- **The foil carrier can be reused;**
- **The skill level required to impression is minimal.**

There are four steps to successful impressioning utilizing this system: **carrier preparation**, **insertion**, **movement**, and **extraction**.

30_12.2.3.2.2.1 Carrier Preparation

The carrier must be prepared for insertion into the keyway by covering all of the individual teeth with self-adhesive foil. A strip measuring approximately two square inches (2-2.5 cm) is cut. The backing is removed and the comb is placed onto the lower half of the foil. Then the remainder is folded over itself in order to fully enclose the teeth.

Verify that the foil is pressed firmly against the comb so that each side bonds with the other. It is very important to ensure that a solid mass of foil is created and presented to the base of the tumblers during impressioning. The foil should be trimmed as shown and depressed into each area between the teeth. Be certain that the material is removed from around the tension channel to allow for unrestricted movement. Avoid creases and bubbles that may cause tearing during insertion of the tool and result in a failed procedure.

30_12.2.3.2.2.2 Tool Insertion

Insertion of the carrier must be accomplished carefully so as not to damage the fragile foil covering. A normal key presents a 45°

angle that allows the pins to smoothly traverse the ramps. In contrast, the teeth of the comb present a **perpendicular** angle to the face of the tumblers. Thus, they must be lifted out of the way in order for the tool to enter and leave the keyway.

The procedure to insert the carrier requires the following operations:

- **Place the correct insertion tool into the lock underneath the pins. The angled point should engage the bottoms of the tumblers;**
- **Lift the insertion tool to the top of the keyway, thereby forcing the pins upwards and clearing a path for the carrier. Once this is accomplished, no pins will protrude into the plug, thus providing a clear path for insertion of the carrier;**
- **While maintaining the pins in a fully lifted position, carefully insert the prepared foil comb into the lock alongside the insertion tool. Although generally it is easier to locate the comb to the right of the tool, its placement is dependent upon the position of wards. Never force the carrier into the keyway as this will cause the foil to tear;**
- **Continue to insert the foil comb into the lock until it is about 5 mm short of the rear stop, or at the front edge of the tension channel;**
- **Remove the insertion tool;**
- **Insert the tension tool into the keyway, so that it is secure against the face of the cylinder;**
- **Push the carrier into the lock until the rear stop contacts the back of the tension tool. This is the impressioning position that aligns the channels of the carrier directly beneath the pins.**

30_12.2.3.2.2.3 Movement of the Carrier

Movement of the carrier closely resembles the actions required of

a key blank in conventional impressioning; the foil carrier is moved in four vertical planes. Unlike a key blank, however, a separate tension tool is utilized to create torque. The following operations must be performed to obtain proper contact between the foil and tumblers:

- **Press the tension tool against the face of the lock, and the foil carrier against the back of the tension tool;**
- **Apply and maintain clockwise torque to the plug;**
- **Lift the rear of the carrier upwards towards the top of the cylinder so that contact is made between the foil and those pins closer to the front of the plug;**
- **Lower the foil comb back to its original position;**
- **Release the applied torque;**
- **Execute five repetitions of the above procedure, being certain to release the torque after each vertical movement, and return the foil carrier to its home position;**
- **Repeat the above procedure, changing the direction of lift away from the pins (downward) and forcing the tip of the carrier to lift upward, thus insuring that all pins are contacted;**
- **Repeat the above procedure, applying torque in a counterclockwise direction for both upward and downward movement of the carrier;**
- **Continue to repeat this entire sequence until the lock opens;**
- **Remove the tension tool by bending the foil comb away from it until there is sufficient clearance to disengage it from the keyway.**

Twenty different movements of the carrier will have been accomplished:

- **Clockwise and upward movements**
- **Clockwise and downward movements**
- **Counterclockwise and upward movements**
- **Counterclockwise and downward movements**

30_12.2.3.2.2.4 Mushroom Tumblers

Mushroom tumblers can cause excessive depressions in the foil, resulting in the failure to produce an opening. The presence of security pins requires a different technique for the application of vertical lift of the carrier, as well as placement of the foil.

When a mushroom driver crosses the shear line, the plug will turn to a substantially greater angle than from a standard driver. This is because of the smaller diameter head or gap at the tip of the pin. The problem can generally be traced to excessive vertical travel of the comb. If after three minutes of repeated movement of the foil carrier the lock still fails to open, it is very likely that one or more of the pins has over impressed the foil. Generally, this results from the presence of spool or mushroom pins, or from new pins.

There are two methods to prevent over-impressioning:

- **Technique I**

Attempt to impression the lock again, insuring that the carrier is **not** lifted to the maximum distance permitted by the keyway. Most foil carriers are produced to a width that is approximately .4 mm shorter than the height of the keyway, thus allowing a corresponding .4 mm vertical movement. Based upon the tolerance of some locks, this distance may be too great and will exceed the plug-shell gap. In such a case, depressions will be created in the foil for each sample that is too deep. They will result in a tumbler setting above or below shear line, but never precisely **at** shear line.

Move the foil carrier less than the maximum distance. This will cause a shallower depression to be produced for each pin and will provide a greater opportunity to match the depression depth with the precise position at shear line. The problem of over-impressioning is complicated by the fact that the center pins will always receive less movement than the pins in the tip and bow positions. Thus, it is more likely that pins at either end of the carrier will over-impress.

- **Technique II**

This procedure involves a different method of applying the foil to the carrier in order to reduce vertical movement by increasing its overall width. Place the comb at the top of the strip of foil so that the excess material rests at the base of the

channels. The foil is wrapped around the underside of the comb, over the top and around the bottom for a second time. This effectively places one layer of foil over the teeth, and two additional layers around the underside (which is usually free of foil). The result of this action will elevate the "home position" of the comb. It will rest slightly higher within the keyway and thus reduce its vertical travel. This will create smaller depressions for each sample.

30_12.2.3.2.2.5 Extraction

Once the lock has been impressioned, the tool must be removed. Because the pins are trapped within the channels of the carrier, the extraction tool must be utilized to lift the tumblers above the teeth of the comb. This is achieved by the reintroduction of the insertion/extraction tool to the same position at the top of the keyway that was required when the carrier was first placed in the lock. With caution, minimal damage will occur to the shape that the foil had assumed in simulating the correct key. This will enable the user to identify an approximate pin-stack combination and code. Careless movement of the insertion/extraction tool will result in distortion and tearing of the foil, making decoding of the key impossible.

The use of a particular extraction tool and whether it is inserted to the right or left of the carrier is dependent upon the design of the keyway. Some keyways, such as the Yale 8, require a straight tool first be inserted into the keyway to the right of the foil carrier, just above the lower ward. This will partially lift the pins so that the angled extraction tool can be inserted on the left. The use of two extraction tools is only necessary with complex profiles. It occurs where the pins can fall beyond the wards where the normal tool would set, effectively preventing reintroduction. Grease or Vaseline may be rubbed onto the foil to facilitate smoother insertion and extraction from the lock.

30_12.2.3.2.2.6 Difficulties and Precautions

Certain locks may present unique difficulties when impressioning with foil. Others may not respond to the procedure at all. For example, locks that have high cuts at the tip and bow position, with low cuts in the center, are unfavorable to this technique. Difficulty may be experienced with older locks that tend to have vertically elongated keyways at the front of the cylinder. They will over-impress the foil due to excessive movement of the

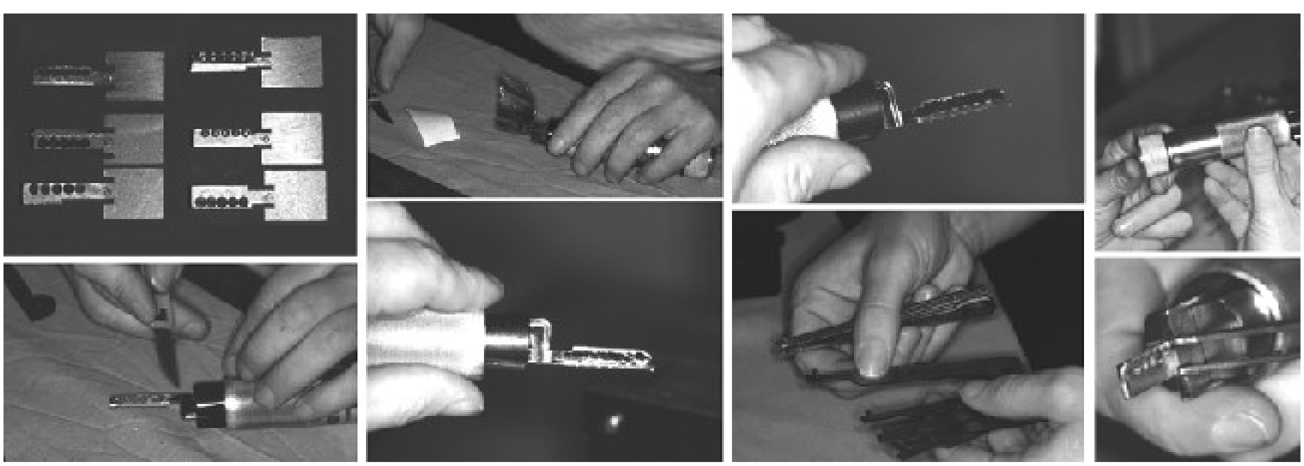
carrier. When this problem is suspected, limit the vertical travel of the comb.

Never apply excessive torque to the plug. Remember that soft metal foil rather than a hard key blank is being utilized. Only the slightest amount of tension is necessary. Too much torque will result in damage to the tension tool or the face of the lock. Never force the tool or apply excessive tension directly to the carrier. Failure to release torque between each movement and to return the foil carrier to its home position will delay or prevent success. The repetition of movements **without releasing torque** will not allow the pins to seat into the newly created depression within each foil chamber, thus preventing further impressioning.

30_12.2.3.3 Falle Precision-Die Foil Impressioning Systems

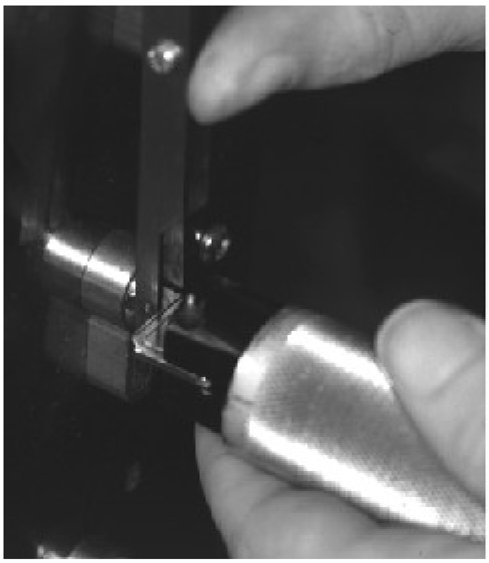
LSS301: Foil impressioning system, by John Falle

The original foil impressioning system that was developed by Falle was designed for specific dimple pin tumbler locks. It functions in almost identical fashion to the profile carrier system described above. The difference is that a specific steel **foil carrier** die must be prepared for each type of lock. The die has holes drilled to maximum depth in all tumbler positions. Falle offers **foil impressioning systems** and **variable key generation systems** for many dimple locks including Keso, **DOM, UCEM, MCM, and Azbe**. The reuseable key generation systems allow the decoding of the lock and the production of a simulated key using etched stainless steel. This process is described elsewhere in this text.



Exploded view 1, 2, 3, 4, 5, 6.

The design of the die, once covered with foil, allows each tumbler to displace the metal until the pin reaches shear line. A special tension tool must be utilized for this technique. Proper use of the tool allows the required vertical movement of the die.

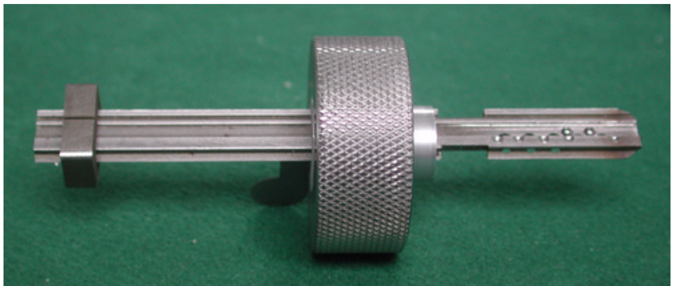


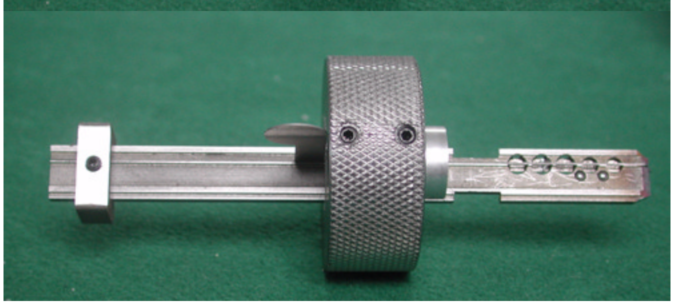


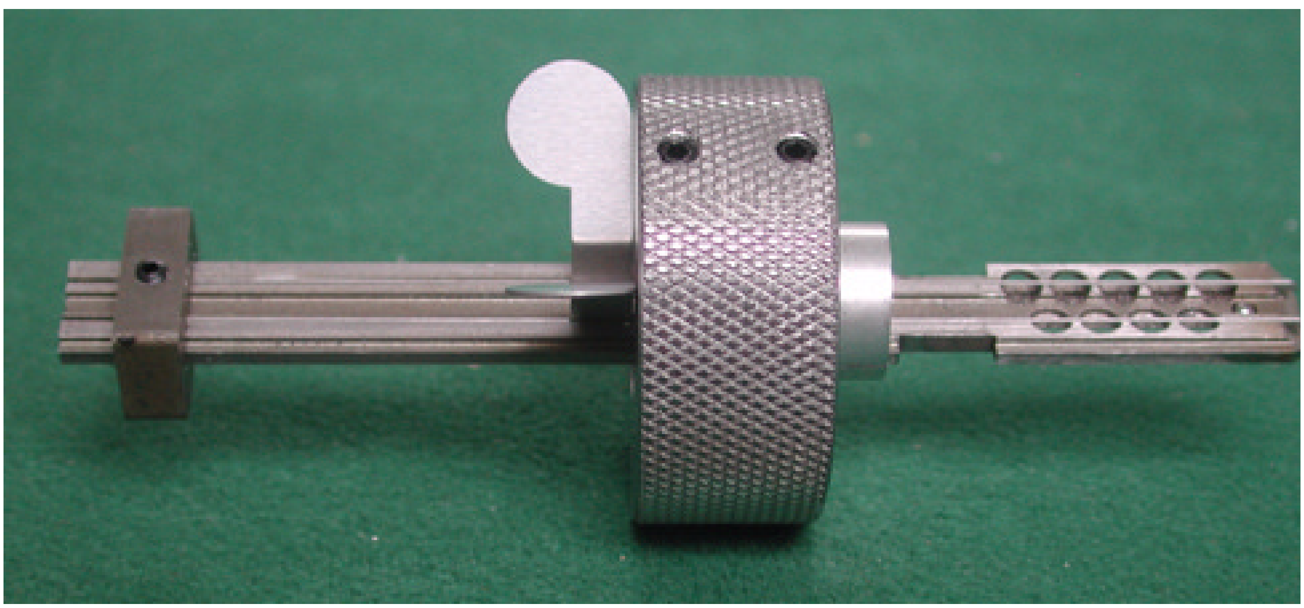

Since the second edition of ***Locks, Safes, and Security*** was published, John Falle has introduced a significantly improved foil impressioning system, shown below. The Dimple Foil Key technology contains many sub-separate systems that are designed

for use on a wide range of dimple key locks. The system allows entry rapidly, often within sixty seconds, with minimum skill level. The lock can be opened, and decoded to within a close proximity of the key, to allow generation off-site. There are certain locks that cannot be bypassed with this system.

LSS304: DOM Dimple foil impressioning system, by John Falle







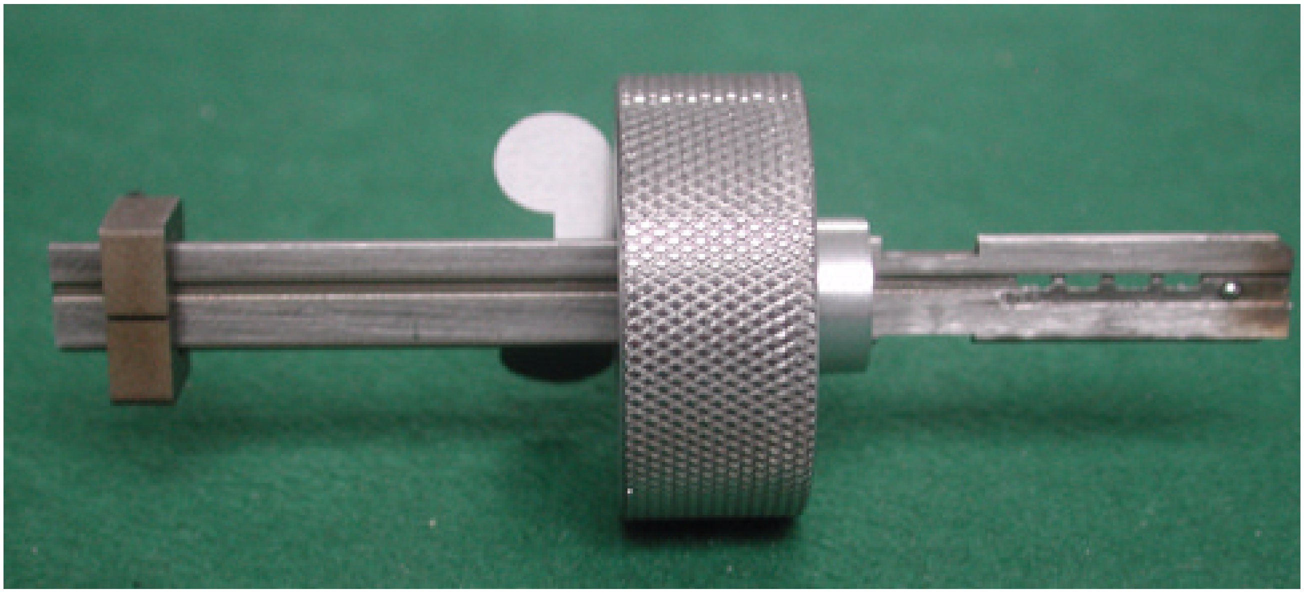
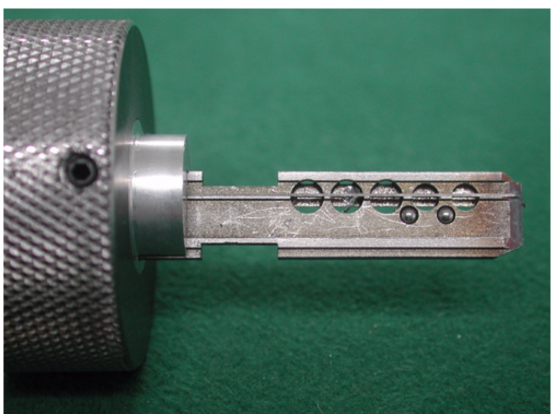
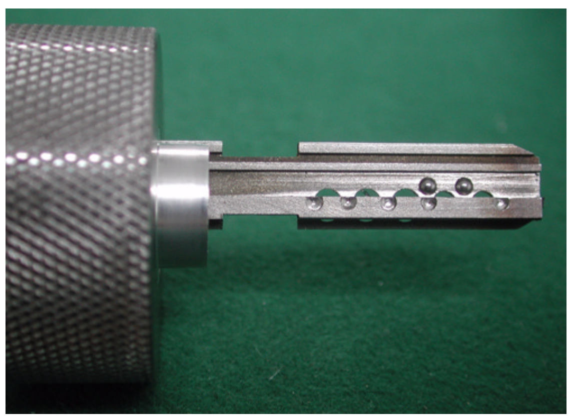


Figure LSS+3005 The carrier for the foil impressioning system, by John Falle.

Although the basic system is quite easy to learn, it is suggested that training from John Falle be required for any agency utilizing this system. In certain cases, locks can have lock-out or detector systems. Once triggered, the covert operation can be compromised by preventing the tool from being removed.





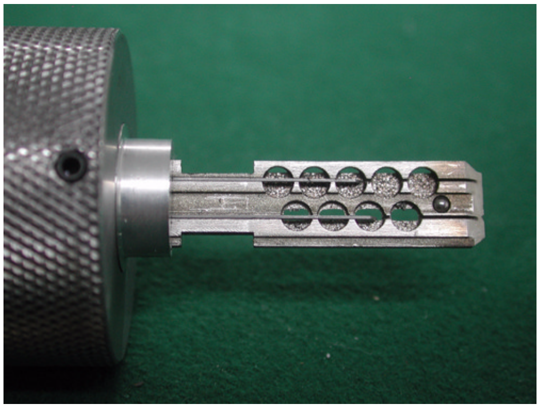


Figure LSS+3006 Specific dies are available for each lock. Note the fine wires extending through each tumbler position.

The system presently is available for use on the following locks:

STS / DOM IX (10 pin staggered);
DOM (10 Pin staggered) with ball;
DOM IX (5 pin) with ball;
MCM 10;
MCM 4SS;
AZBE HS3;
UCEM 5D;
UCEM 8D;
KESO 2000;
KESO 1000;
TESA T10 & T12;
LINCE 19D;
EZCURRA DS10 & DS15 (10 pin).

30_12.2.3.4 Falle Plasticine System

Falle has developed a plasticine impressioning and decoding system for lever locks. A collection of several different keys is provided within a kit, each of which is cut to lift one lever within the lever pack. In this manner, the lock may be decoded (see Chapter 31). A specially cut blank is also provided and upon which plasticine is overlaid. Once coated with the material, the blank is inserted into the lock and turned against the levers. The depth of each belly is defined as an impression, allowing a key to be generated.

30_12.2.3.5 Conductive Material Impressioning System

The author received a patent in 1994 for a conductive resistor impressioning system for use with Ving pin tumbler card locks (5355701(301)). This system relies upon the use of etched conductive ink, superimposed upon a thin mylar plastic base. Claims in the patent also provided for the use of carbon paper in conjunction with a fine wire rake (.020” diameter) to determine the position and pressure of each tumbler. The carbon paper enters the lock between two protective thin metal layers to prevent marking of the paper upon insertion and removal.

The top protective layer is then withdrawn and a thin wire rake moved across each row of tumblers. Those pins that present hard pressure will mark the carbon paper. The protective layer is then reinserted and the carbon paper removed. When held up to the light, the exact outline of the key is displayed.

30_13.0 Practice Locks

Virtually any lock can be used to learn impressioning, even high-security mechanisms with security tumblers (pin tumbler locks) or false gates (lever locks). In the case of pin tumbler locks, the author suggests good quality, consumer five-pin cylinders or four-pin Master padlocks. The Schlage 923 series is ideal for impressioning.

Be certain to obtain a sufficient number of brass key blanks, and have available the depth and space coding data for the lock that is to be used. Have the key that actually opens the lock visible during impressioning in order to provide feedback as to where the marks should be located and the depth of each cut.

It is recommended that impressioning be practiced in the same fashion as picking, which is described in **Chapter 29**. A lock should be initially impressioned with only two pins. Once the ability to discern marking on the key blade is mastered with only two pin stacks, then another is added, until the entire complement can be decoded.

CHAPTER THIRTY-ONE: DECODING

The Decoding of Locks: Theory, Procedures, and Technologies

Master Exhibit Summary

Figure LSS+3132 Chubb Battleship Pin and Cam system by John Falle
Figure LSS+3133 Ford Tibbe decoder, by John Falle
Figure LSS+3134 Chubb AVA key
Figure LSS+3135 Evva 3KS Pick and decode tool by John Falle
Figure LSS+3136 3KS Slider portion of pick tool
Figure LSS+3137 John Falle Pin Lock decoder utilizing pin and cam technology
Figure LSS+3138 The pick-probe tool for the advanced pin lock decoder tool
Figure LSS+3139 The Var-Key system is incorporated within the advanced pin lock decoder by John Falle
Figure LSS_3140 BMW key decoder by Silca.

Figure LSS+3141 Ford Galaxy wafers, showing indication of picking and decoding
Figure LSS+3142 HPC and other produce a complete line of axial picks and decoders
Figure LSS+3143 The Easy entrie profile milling machine can produce blanks from many sources
Figure LSS+3144 The Easy entrie and Keyway King profile milling machines
Figure LSS+3145 The Medeco M3 utilizes a slider to add another level of security
Figure LSS+3146 The Medeco M3 slider is visible from outside of the plug

Figure LSS+3147 Instakey mechanism, showing how the lock can be reprogrammed
Figure LSS+3148 A comparison of Schlage Everest profiles
Figure LSS_+3149 A comparison of Schlage Everest keyways and the bypass of the undercut
Figure LSS+3150 Mapping of a keyway from a digital image in the Easy entrie

Figure LSS+3151 The Assa V10 7000 series sidebar lock
Figure LSS+3152 Assa V10 use of balanced and unbalanced side millings
Figure LSS+3153 Assa V10 multiplex sidebar codes
Figure LSS+3154 Assa V10 sidebar code groups and keys
Figure LSS+3155 Assa V10 blocking method
Figure LSS+3156 Assa V10 individual sidebar coding
Figure LSS+3157 Assa V10 multiplex codes
Figure LSS+3158 Assa V10 multiplex codes and groups

Discussion of endoscope and borescope. Courtesy of Hans Mejlshede.

The John Falle lever decoder system. Courtesy of Hans Mejlshede.

Bypass of laser track or sidewinder locks. Courtesy of Hans Mejlshede.

Master key records. Courtesy of Hans Mejlshede.

A discussion of reading the belly of a lever. Courtesy of Hans Mejlshede.

Forensic implications of the bypass of lever locks. Courtesy of Hans Mejlshede.

Forensic implications of picking or decoding the Abloy lock. Courtesy of Hans Mejlshede.

The A-1 GM 10 cut pick system, courtesy of Harry Sher.

The Peterson PRO-1 tool, courtesy of Harry Sher.

Decoding of keys, courtesy of Harry Sher.

Reading a Chrysler lock with an EZ Reader tool, by Harry Sher

Pick tools for the sidebar lock, courtesy of Harry Sher.

LSS301: Abus decoder, by John Falle

LSS301: European lever lock decoder, by John Falle

LSS301: Ford Galaxy decoding system, by John Falle

LSS302: Medeco lock decoding system, by John Falle

LSS302: Universal pin lock decoder, by John Falle

LSS302: European lever lock pick, by John Falle

LSS302: Axira lock decoding system, by John Falle

LSS302: BMW lock decoder system, by John Falle

LSS303: Pin and cam system for CISA and other European locks, by John Falle

LSS303: BiLock decoder system, by John Falle

LSS303: Abloy decoder system, by John Falle

LSS303: Universal pin and cam system, by John Falle

LSS304: Universal belly reader system, by John Falle

LSS304: Key turning system for lever locks, by John Falle

LSS304: DOM Diamond decoder and pick system, by John Falle.

LSS304: Chubb AVA pick and decoder system, by John Falle

LSS305: EVVA 3KS pick and decoder system, by John Falle

LSS305: Pin lock decoder system with pin and cam technology, by John Falle.

LSS203: Matt Blaze on shimming a cylinder to determine all pin segments

LSS203: Brian Chan on TMK extrapolation

LSS203: Harry Sher on the decoding of a top level master key

LSS203: Matt Blaze on the extrapolation of a top level master key

LSS203: Harry Sher on covert methods of entry

LSS204: Harry Sher on picking axial pin tumbler locks

LSS204: Brian Chan on assumptions regarding master keying

31_1.1 Introduction

There are three primary means to open a lock covertly: picking, impressioning and decoding. The main reason to decode a lock is to enable the production of a change or master key for immediate or subsequent use. If a forensic examination is being conducted, then the components may be decoded in order to determine, for example, cross-keying combinations, the actual code or codes of the tumblers, and whether additional components have been added. This chapter will detail the various techniques for deriving code information from the basic types of locking mechanisms discussed throughout this text.

Decoding may involve several disciplines and is often done in conjunction with picking and impressioning. There are many systems, tools, and procedures available. Their selection and use will depend upon the kind of locking mechanism and how the active locking components interact. Decoding generally does not require disassembly of the target lock, although in some cases the lock may be picked then taken apart in order to derive the needed information. In certain instances, viewing active locking elements using an otoscope or borescope can produce keys. Depending upon the lock, impressioning may first be required, then the impressioned key is decoded.

As will be described subsequently, there are many ways to decode a lock in order to produce useable information. Various systems

have been devised to sense the position of each component, and determine its length, distance from shear line, relationship between belly and gate (lever lock), depth, and other factors. The reasons for choosing decoding as the method of entry rather than picking or impressioning are contingent upon many factors. Our discussion begins with an analysis of the motivation to decode a lock and the primary sources from which code data can be derived. The material in this chapter is presented and organized based upon tools, procedures, techniques, and applications involving specific locking mechanisms.

31_1.1.1 Purpose for Decoding

Decoding provides the means to produce a key when the original is not available. The process can take many forms. Often, picking or impressioning must first be accomplished before code information can be derived. In some cases, traditional forms of bypass are not an option, thus making decoding necessary. In certain instances, disassembly of the lock may be required. There are four primary reasons to decode a lock or its key:

- **Production or simulation of a key for immediate use;**
- **Derivation of code information for later production or simulation of a key;**
- **Derivation of information that will allow the determination of code patterns for a given lock system;**
- **Derivation of information that will allow for the production of keys for other than the target lock.**

There are usually two sources for gathering data: **the lock or the key may be decoded.** In essence, decoding involves a process wherein the key may be analyzed or the internal components of the lock can be examined for position and measurement. Many locks are subject to the decoding process, which can often be accomplished within a very short period. The decision as to which technique to use for producing a key will be dependent, in part, upon the following conditions:

- **Can keys can be copied by physical duplication using a key machine;**
- **Is it possible to derive code data using the various techniques that are detailed in this text;**
- **Are key blanks readily available, or will molds,**

milling, or other techniques be required to simulate restricted keyways;
- **Is key code information readily available from internal lists, manufacturers, or locksmiths.**

31_1.1.2 Information from Decoding

The information that is derived from the decoding process generally provides data about keys and active locking components, relating to a number of critical items:

For Keys

- **Position of each active locking component on the bitting surface;**
- **Number of active locking components;**
- **Depth of each bitting position;**
- **Design or shape of each active locking component;**
- **Presence of security enhancements such as mushroom tumblers, false gates, or serrations.**

For Active Locking Components

- **Position or distance from or with respect to shear line;**
- **Number of active locking components;**
- **Position, angle, polarity, or other feature that provides the security for the locking mechanism;**
- **Length of each component;**
- **Shape or angle of each component;**
- **Interrelationships between segments of the active locking element that vary based upon the depth coding of the component;**
- **Exact dimensions of the component;**
- **Indirect information that will allow the extrapolation of a direct code.**

31_1.1.3 Use of the Results of Decoding

There are several instances where a lock must be decoded. Usually, the principal reason is to produce a working key or the capability to do so in the future. It is one thing to

successfully decode a lock; it is quite another to translate the information into a key. Once **direct code** data has been obtained, there are several methods of using the information. These include:

- **Cutting a key by hand;**
  - **Using depth keys as a reference;**
  - **Using a micrometer or other device for measurement;**
- **Producing a key with a code cutter;**
  - **Manual code machine;**
  - **Automatic code machine;**
- **Use of variable key generation systems.**

Direct codes or precise measurements can be translated into a working key using the techniques discussed below.

31_1.1.3.1   Cutting Keys by Hand

Keys can cut by hand, using a file, punch, or variable key generation system. Cutting by hand requires a Pippin and warding file for best results. A set of depth keys that provide a reference for each cut can be used if no precise measuring instrument is available. Handheld code punches are available for many keyways and are especially popular for automobile and axial pin tumbler locks. They allow for the instant production of keys based upon direct codes. Variable key generation systems, discussed below, allow keys to be produced from predefined segments, or they can be cut using scissors.

31_1.1.3.2   Producing Keys with a Code Cutter

A more thorough discussion of code cutters is presented in **Chapter 8**. HPC, Silca, and other manufacturers produce an extensive line of cutting tools for use both in the shop and on location. Code-cutting machines are either manual or electric and can utilize dies or cutting wheels. These are calibrated by hand or computer control to precisely reproduce depth and spacing for a specific manufacturer and keyway.

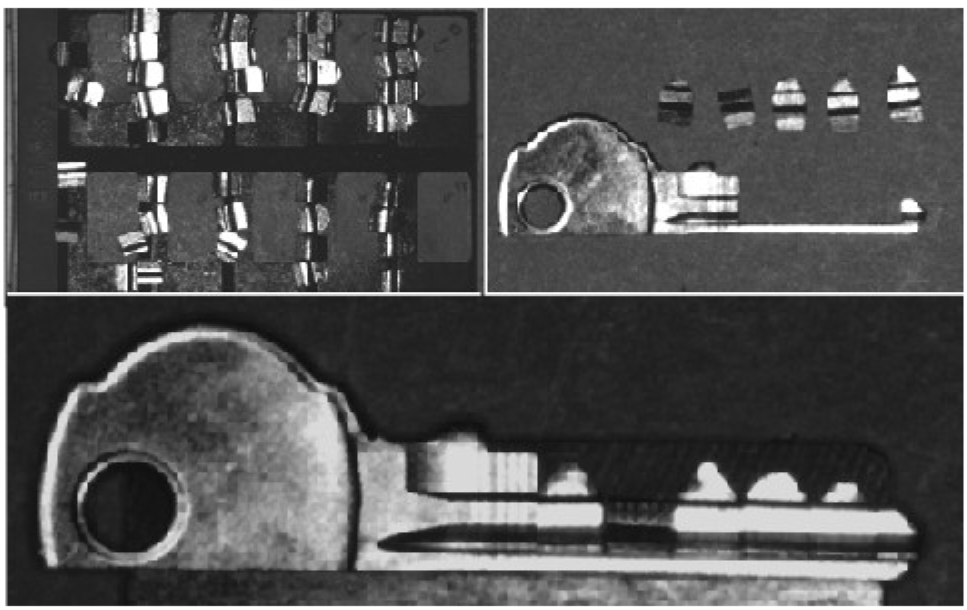
31_1.1.3.3   Use of Variable Key Generation Systems

Falle has developed two unique key generation systems for

translating information from a lock decoder to produce a composite key. One system employs magnetic keyway segments; the other uses etched stainless steel "blanks" that can be trimmed with a scissors to simulate depth and spacing for most pin tumbler and wafer locks.

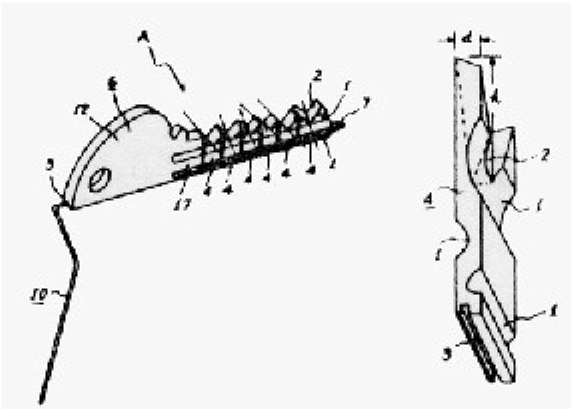
31_1.1.3.3.1 Magnetic System

The Falle magnetic system is actually a combination of keyway segments cut for each depth for an individual keyway. Once the lock has been decoded, the information for each tumbler is known. The proper magnetic segment is then placed on a key carrier and the completed key is inserted into the lock.



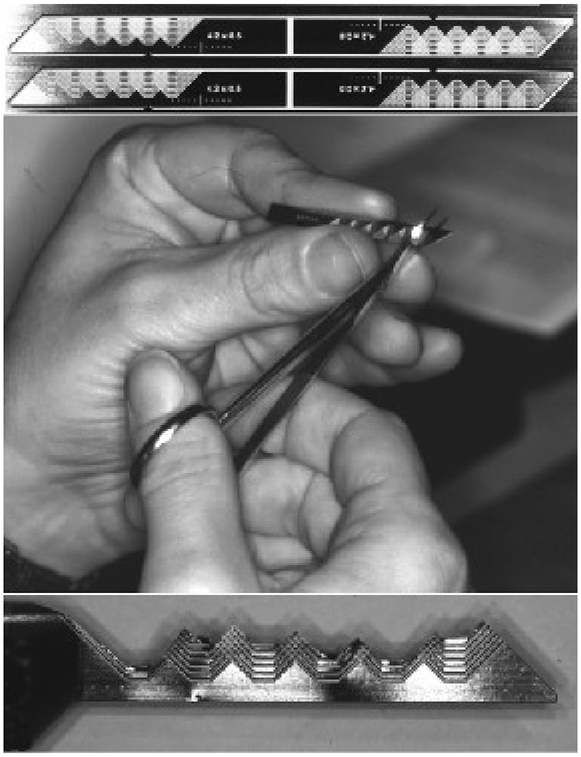
Exploded view 1, 2.

The composite resembles a key that has been vertically sliced into segments; one for each chamber. A selection of all possible depths is provided in the kit, and a key is "built" by abutting all the proper segments. This system has the advantage of providing a precisely fitting key that does not have to be manipulated to operate the lock. A Japanese patent was issued in 1975 (Kokai No. **52-51298(302)**) for a magnetic segmented key system for opening Medeco Locks.

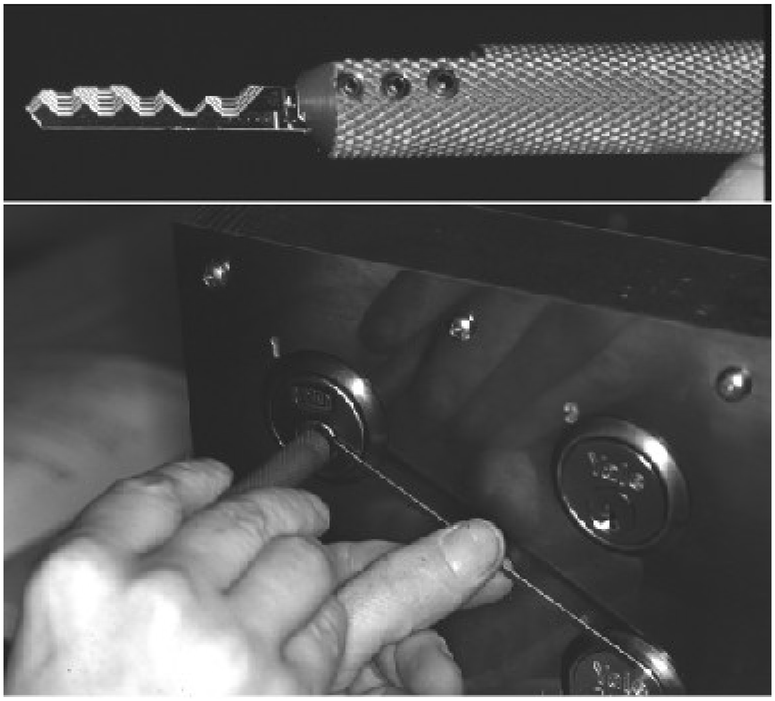


31_1.1.3.3.2 Falle Adjustable Depth and Spacing (Variable) Systems

This technique provides a rapid means for fabricating a key to a specific code. The system will work with many pin tumbler locks and can bypass most keyways, thus reducing the problems created by restricted profiles. The Falle reusable systems are available for **Mul-T-Lock**, **Euro dimple** designs, STS DOM IX, **Chubb AVA**, **Abloy Disc Pro**, and the 14 Lever Lips. Other designs may be available. The **system** may also be used when a lock has been decoded incorrectly. It will frequently open a mechanism where the extrapolated codes are off by one or two depths on several cuts, by utilizing the variable key generation system as a rake pick.



This kit utilizes etched stainless steel blanks that have been marked and scored for eight different depth and spacing parameters. Once code information is derived, a blank is cut with a scissors to form the depth and position for each tumbler. The resulting key is manipulated horizontally and vertically until the correct level is achieved, bringing all tumblers to shear line. The blanks do not have any warding; thus, there is no precise point of reference within the keyway.



In some respects, the blank is moved like a rake or rocker pick until the correct position of all tumblers is achieved. The difference between rake picking and the use of this system lies in the fact that the depth and spacing relationship has already been defined, so it is only a question of the proper vertical alignment.

31_2.0 Overview: Tools, Techniques, and Procedures for Decoding

There are several disciplines for developing coding information as well as a variety of devices, technologies, and procedures for decoding locks. Some are extremely simple; others quite complex. The primary tools and their application to locking mechanism are described here.

The reader will note that some of the information presented in this chapter has been previously discussed, with slightly different emphasis in **Chapters 29** (Picking) and **30** (Impressioning). That is because some procedures involve more than one discipline. For example, certain picking tools actually perform the tasks of picking, impressioning, and decoding. Each section integrates information regarding the various tools utilized for decoding, with applicable techniques and procedures

for their use on different types of locks. In some cases, detailed information about a particular locking mechanism is presented.

31_2.1 Primary Sources for Code Data and the Production of keys

Code information is available from many sources. The following discussion is organized according to source and will provide the structure for the subsequent materials relating to tools, technologies, and techniques.

Code data can be derived through many disciplines involving the use of a combination of tools, procedures, and knowledge. Codes for a given manufacturer and lock can identify depth and spacing parameters that will provide the means to generate keys for a specific lock. They can be obtained through impressioning, discussed in **Chapter 30**, or by physically observing numbers on keys, the bitting depths from keys or active locking components, or through disassembly of the lock. Key codes may also be obtained from the manufacturer. As will be explained subsequently, codes may also be determined through the use of special pick and decoding tools and by the utilization of simple to sophisticated optical instruments.

31_2.1.1 Summary of Code Data Sources

The following is a summary of code data sources and provides an outline of the materials that follow. Codes may be obtained from the following sources:

- **By impressioning the lock;**
- **By obtaining code numbers from:**
  - **Keys;**
  - **Locks;**
  - **Other records;**
  - **Warranty data;**
  - **Code lists;**
- **Derivation of direct code from indirect code stamped on lock or key, by using reference sources;**
- **By visual inspection of a key;**
- **Lock data from manufacturer;**
- **Information from special pick/decoding tools;**

- **Original combination from lock manufacturer wherein the settings have not been altered;**
- **From lock specifications that provide a correlation between code depths and measurement of bitting surface of the key;**
- **By shimming the lock without disassembly, through the use of a shim and depth keys.**

31_2.2 Impressioning the Lock

When a lock is impressioned successfully, a working key is produced that may be duplicated and decoded. Impressioning is actually a **combination** of picking and decoding. It is a procedure wherein the position and depth of each active locking component is determined by reading a blank or partially cut key that has been inserted into the lock and manipulated. For a detailed discussion of impressioning, see **Chapter 30**.

31_2.3 Obtaining Code Numbers

Keys for most locks can be produced by code. Direct and indirect code numbers may be obtained from many sources including the key, lock, other records, warranty data, or from internal code lists. Most padlocks and motor vehicle locks have indirect codes stamped on them.

Direct codes are often imprinted on the key, and correlate to the depth of each tumbler, wafer, or lever. They are specific to each manufacturer. Standard depth and spacing information will allow a key to be produced from a direct code number. **Indirect codes** must be correlated to direct codes with code books or other references. A key cannot be reproduced from an indirect code until it is translated to the direct code measurements (see **Chapter 8)**.

Many manufacturers, especially for high-security locks, will maintain a customer registry of code numbers for a project or facility. This information may often be obtained through unauthorized channels. Likewise, internal lists of key codes are usually stored on premises or by the locksmith responsible for installation and maintenance. In any investigation of possible entry through the use of code information, a determination should be made as to where code lists, especially of master key systems, are maintained.

Master key records. Courtesy of Hans Mejlshede.

Often, locks are set to factory default codes that must then be changed in the field after installation. When attempting to open a lock, factory codes should always be tested, especially for combination locks.

There are many references for manufacturer's codes, including HPC, Silca, and Reed. These and other sources provide comprehensive data on most locks. Much of the information is now available on **CD/ROM**, and the Internet (see **www.security.org)**.

31_2.3.1 Codes on Lock Bodies and Equipment

Direct or indirect code numbers can often be found imprinted on lock bodies, padlocks, glove compartment cylinders, file cabinets, computers, and other equipment enclosures. Once these codes have been acquired, keys can be produced. Many locks used in commercial applications have very few different keys. For example, file cabinets may use ten codes for 100,000 locks. The Yale S99 and S100 locks, used in office equipment, have very limited numbers of keys.

31_2.3.2 Automobile Locks

Codes for automobile locks may be obtained from a number of different sources, including keys, the lock itself, the manufacturer, and through the vehicle identification number (VIN). The author obtains codes directly from the automotive makers in cases involving criminal investigations by supplying the VIN. If the lock has not been altered, a key can be quickly generated in the field based upon the code provided by the manufacturer.

The procedures for obtaining vehicle lock data can become more complicated in the newer electronic keying systems, where VATS or transduced bit codes are employed. From 1935 until 1966, all Briggs and Stratton keys had an indirect code that read from 8000-9499; there were 2500 useable permutations. In 1969, the code sequence changed to three digits and a letter. The letter designation was altered yearly.

Until 1966, sidebar wafers had four depths that were denoted by different colors: Copper, Nickel, Black, and Yellow. Wafers may also have their depth code imprinted on their face; these can be

read with a borescope or ophthalmoscope. Numbers have always been stamped on lock bodies.

31_2.3.2.1 Numbers Stamped on GM Keys for Automobiles

There are special standards for automotive keys which are mandated in federal statutes. Regulations require that codes be placed on a knockout to make the theft of cars using key codes more difficult. Numbers on GM keys are indirect codes and must be translated through a reference source. The shape of the key head was changed in 1969 to signify the addition of depths. Originally shaped like an octagon, it was changed to a rectangular and oval in that year in order to denote the difference in locks.

31_2.3.2.2 Numbers on GM Automotive Lock Bodies

Until 1978, code numbers were stamped on all car locks, including glove compartment and right-hand door cylinders. Within all General Motors vehicles since 1974, the ignition cylinder is keyed by itself; doors, trunk, and glove compartments are keyed alike. After 1974, the direct reading number stamped on the glove compartment lock would only provide information regarding the last four tumblers (because these locks only had four wafers). Consequently, several keys might have to be produced in order to determine the first and second positions.

31_2.4 Visual Derivation of Codes

In many cases, codes may be derived by looking at a target key. Depending upon the bitting design, this can be a fairly simple task, especially if there is a discernible difference between cuts. The process may be aided by use of a micrometer, depth gauge, and other tools described elsewhere in this chapter.

In order to decode a key by simple observation, a familiarity with the range of differs is helpful but often not mandatory. To the trained technician, the **relationship** between cuts can be determined quite accurately. Trial keys can then be made that have that same pattern, but with different depths. For example, a source key is observed and is thought to have the code of **23467.** However, when a key is cut to this code, it does not work. The operative may then produce keys with the codes **34578**, **45689**, and

12356. In this example, the important issue is the accuracy of the reading as to the number of depths between each cut, and their **relative position.**

31_2.5 Special Pick/Decode Tools

Special picking and decoding tools will provide direct reading codes for many types of locks and are described throughout this chapter. Depending upon design, they will allow the direct duplication of a key, or the interpolation of data to derive codes. As detailed subsequently, tools have been engineered for many medium and high-security locks, including Chicago axial pin tumbler, Medeco, Abloy, Keso, Abus, Briggs and Stratton, Ford, and others.

31_2.6 Wax or Clay Impression Copies of Keys

Imprints of keys can be made quickly with clay, wax, silicone, and other materials. Precise measurements, as well as visual decoding of such impressions, can then be obtained. Often, direct copies of the target key can be produced from molds using low melting temperature metals or epoxy. Procedures for obtaining impression copies are detailed in Chapter 8.

31_2.7 Disassembly of the Target Lock

A lock can be disassembled and decoded using a variety of techniques, including measurement of active components, fitting a key to the lock, and analysis of each active locking element. Taking a lock apart is a simple procedure and requires that each lever, wafer, disc, or pin be individually examined to determine its size and position. Once disassembled, it is also a simple matter to fit a key to the individual tumblers. The color, marking, or size may also identify tumblers. In the case of wafer, disc, and lever locks, some manufacturers imprint a code on each component for identification.

The proper procedures for disassembly are detailed in the Forensics Section of this text. It is critical that these procedures be followed so as not to disturb the configuration of active locking components and the various key combinations that will open the lock. The process of disassembly becomes more complicated for a master key system. In such cases, a pin-stack containing more than one master pin gives no clue as to which pin must be at shear line for a given key. It may be necessary to

generate many permutations in order to derive the proper code.

31_2.7.1 Derivation of Master Key Codes

It is not possible to disassemble one lock in a **positional** master keying system and derive the master key coding for the entire facility. It is possible, although often difficult, to decode one lock and successfully produce a master key in a **conventional** pin tumbler lock. This is because there may be more than one chamber containing master pins, or more than one master pin for each chamber. In a lock that is keyed using total position progression or rotating constant schemes, there will be a maximum of two pins in addition to the top pin in each chamber. Thus, in a six pin lock, there will be a total of 64 possible combinations (2^6). Conventional locks can be decoded through disassembly, by extrapolation of the top level master key through the use of a change key, or by shimming the lock through the use of depth keys, without the need to disassemble the cylinder. These techniques are discussed in later sections.

Depending upon the construction of the lock and the requirements of the keying system, a lock may have several physical or virtual shear lines. Some locks, such as Corbin, may have a master ring that create two physical shear lines. The ICore lock also has two shear lines: one for operating and one for control. In order to service a cylinder that has been master keyed, both the change key and master key are usually required. A detailed discussion of master keying can be found in **Chapter 11**.

31_2.8 Electronic Signatures as Codes

Locking systems utilizing special technologies including magnetic stripe, barium ferrite cards, magnetic pins and discs, infrared, radio frequency, and proximity sensing will all have electronic signatures that can often be decoded. This subject is covered later in the chapter.

31_2.9 Common Characteristics as a Partial Code

Some manufacturers utilize a common sidebar or similar code scheme as part of the overall coding system for a lock or group of locks. Once obtained, all locks in the series will have the same characteristic. Assa, for example, will assign a common sidebar pattern to all locks located within one geographic area, or installed by one dealer. All keys for locks having a common

characteristic (dealer, geographic area, and facility) can be compromised if that sidebar code becomes known.

31_3.0 Specific Methods for Obtaining Code Data

Code information can be derived from the direct physical measurement of keys or the active locking components within the mechanism. Several methods will yield the desired data:

- **From another key;**
  - **Visually determining the bitting depths;**
  - **Micrometer measurement of the key;**
  - **Using depth gauge to measure the target key;**
  - **Making an impression copy of the key, then decoding it;**
- **By shimming the lock:**
  - **Use of a shim in combination with depth keys to decode each pin stack;**
- **Disassembly of the lock;**
  - **Fitting a key to the tumblers;**
  - **Decoding tumbler depths visually by inspection of pins;**
  - **Observing individual tumbler marking, thereby identifying depths;**

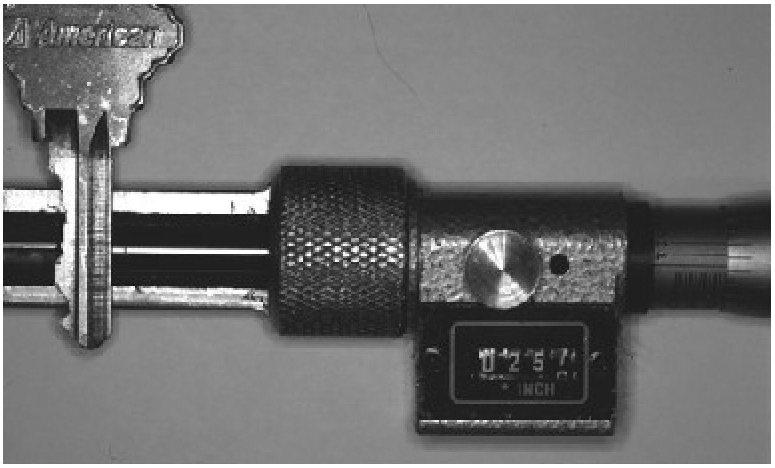
- **By fitting a key to the tumblers (impressioning);**
- **Examining the lock using external viewing means;**
- **Observation of active locking components;**
- **Measurement of active locking components;**
- **By utilizing a decoding device, such as the John Falle Pin Lock Decoder, or the MSC Sputnik for reading the length of pins, wafers, or levers.**

31_3.1 Direct Measurement of a Source Key

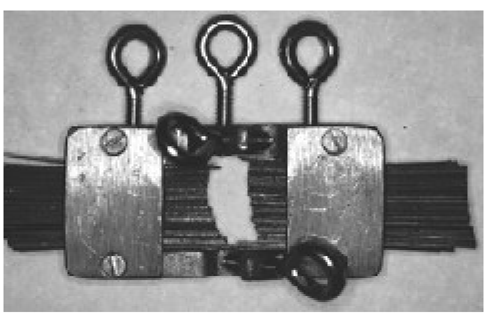
Decoding of keys, courtesy of Harry Sher.

Many instruments are relatively simple in design that can be utilized to measure both internal components and keys. They

provide dimensions, calculated in inches, or direct code correlation based upon manufacturer. The HPC SKM-20 key micrometer and the HPC HKD-75 have been specially designed for precise determination of depths for each bitting position of a key.



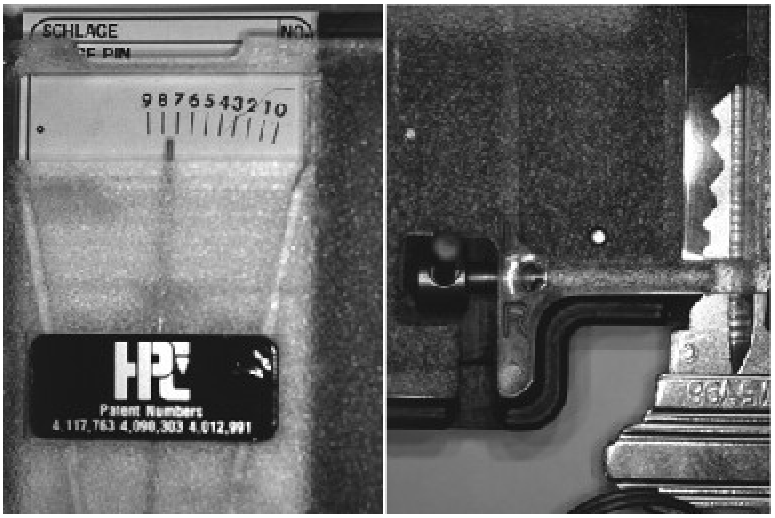
The micrometer is accurate to .01”, and may be used to measure any key with ramps and valleys. When determining the depth of a cut, be certain that the micrometer or other measuring instrument is capable of seating at the root without being affected by the ramps.



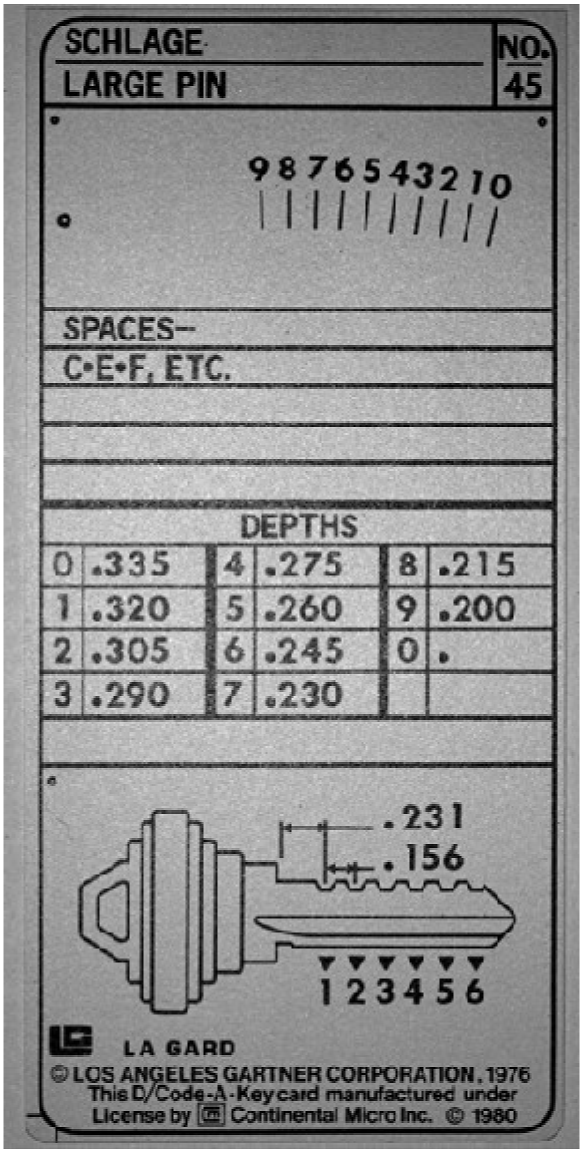
The HPC HKD-75 is an extremely versatile tool; it is a necessity for any craftsman involved in field operations. It is furnished with comprehensive manufacturing depth and spacing data for over sixty keyways. In cases where the original key is available, this tool will allow exact decoding of the depths for later duplication. The device is also capable of measuring keys with different cut angles, such as Medeco. The stylus can be set to Right (R), center (C), or Left (L) positions.

The code card for the HKD-75 is shown below. Each card has an

identifier that denotes the kind of lock or key classification is being measured. Thus, (H) refers to standard keys, (HF) foreign, (HMC) for motorcycles, (HPKS) for KABA PEAKS, and (HX) for special. Three shims are also included for measuring double-bitted keys.



Depth gauges and keys are also used for making measurements. Gauges are marked for each depth and may be utilized with keys as well as for decoding locks. Each depth may be compared to the cuts on a source key to determine precise coding for each tumbler position.



Gauges may also be inserted into a wafer lock, once picked, to determine individual wafer coding.

31_3.2 Decoding Wafer Locks by Direct Observation

This section presents material describing the decoding of wafer locks by observing the wafers through the keyway. In **Section 4.5.2,** the decoding of wafer mechanisms by **indirect** methods is presented. The two techniques differ in the type of data collected and the way in which it is derived.

31_3.2.1 Introduction

Wafer locks are probably the predominant mechanism in the world for use in access control and for low to medium-security containers. They are relatively easy to decode.

31_3.2.2 Information Required

In order to successfully decode a wafer mechanism, several critical items of information must be known before the procedure is initiated. Data can often be derived from the type of lock, where it is installed, and identification of the blank. It is essential that the following characteristics be obtained prior to decoding:

- **The number of depths or differs. It is suggested that the data sheets from the HPC 1200, the HPC HKD-75 handheld decoder, or other reference source be utilized;**
- **The number of tumblers;**
- **The proper key blank;**
- **The position of the highest and lowest depth;**
- **How the depths appear in relation to each other;**
- **How to differentiate each depth;**
- **Relationship of each depth with the keyway wards;**
- **If for a motor vehicle, determine which cylinder contains all wafers in order to enable cutting a key to fit all locks.**

31_3.2.3 Theory of Decoding Wafer Locks

Specific depths for particular locks can be found in "depth and spacing" manuals or by taking measurements on keys from other locks of the same type. Generally, all wafers rest at the same vertical position when not at shear line. Their bitting surfaces will be in perfect alignment and will mirror the depth coding of the key. If the entire wafer pack could somehow be lifted to shear line without disturbing the relationship between each component, the lock would open. It is this interrelationship between active locking elements that must be decoded and will yield depth information, which can be translated to a cut key. The relative depth of each bitting position on the key corresponds to the internal area of the wafer that forms the

keyway and thereby allows the lock to be visually decoded.

It will be remembered that the design of a wafer is such that the key passes through its center, allowing the vertical surface (which is spring biased) to reside on the key bitting area. There is in essence a programmable slot in the center of every wafer tumbler. The vertical position of this slot will be adjusted either upward or downward, depending upon the corresponding depth of each cut on the key. If the cut for a particular wafer position on the key is deep for example, then there will be more material at the top of the wafer slot and less on the bottom. The slot will appear to be lower in its overall position.

A comparison of each wafer with respect to the others, and their position relative to a side ward in the keyway (used as a constant value), allows an estimate of the depth of each wafer. Usually, the bitting difference between differs ranges between .015" and .025", with .020" being common. For example, a lock may have the following five depths:

Cut	***Depth***
1	***.240"***
2	***.220"***
3	***.200"***
3	***.180″***
4	***.160″***

The depth coding for each individual wafer can thus be extrapolated by assessing the relative position of each slot, in comparison to a known standard such as a keyway ward or other wafers. Once the slot position of the highest and lowest differ is ascertained, the intermediate depths can be determined.

31_3.2.4 Tools for Decoding Wafer Locks

Several tools can be employed in the decoding process for viewing, moving, and measuring wafer positions. These include a borescope or magnifying otoscope, wafer depressor (reading tool), spring door tool, code cutter, slip coder, and depth and spacing keys. Patents have also been granted for specialized tools, such as that developed by Hansen in 1935 (**1991151(303)**).

A **wafer depressor or reading tool** is utilized to move all but the selected wafer out of the field of view.

A **slip coder** provides a means to read individual differs on a key and translate them to direct codes and measurements.

A **borescope** or **otoscope** allows the magnified viewing of wafers.

A **straight pick** can be used to lift all wafers.

31_3.2.5 Guidelines for Decoding Wafer Locks

- **Wafer design is standardized for conventional mechanisms: they are either square cut or under cut (rounded edges);**

Motor vehicle wafer locks can feature different wafer configurations. For example, Datsun introduced a wafer with a notch in the top to prevent removal when rotated 180°. The design was not popular due to wear, jamming, and collapse. A half or split wafer is used in Mercedes cars to provide twice the number of permutations. Each side of one tumbler can operate at a different depth while using the same space in the lock. Thus, an eight-wafer lock will have sixteen permutations;

- **A lock will generally have only one shear line;**
- **Locks that have been master keyed will have two shear lines;**
- **Master pins have two contact surfaces for left and right bitting. The key blade is either oriented right or left in order to raise the appropriate portion of the wafer. A two-digit code will indicate which side of the wafer is acted upon by the key.**

It is important to know which side of the key to use when a lock has master pins and which side of the wafer is being decoded. Decoding is particularly applicable to these locks and is preferable to impressioning because of the likelihood that the wafer will slip when torque is applied;

- **A lock that has been master keyed will have two keyway profiles;**
- **All wafers within a single-bitted lock will extend in one direction;**
- **There is always an area above and below each wafer**

within the shell;
- **Depths are determined from a measurement of the internal dimensions of the open space within the wafer;**
- **The overall length of the wafer will be equivalent to the diameter of the plug;**
- **An uncut key that exceeds the dimensions of the free space within one or more wafers will be blocked from entry into the keyway;**
- **An undercut wafer will not prevent reading the lock;**
- **Half and split wafers (utilized in Mercedes, BMW, and other cars) can be visually decoded;**
- **Do not apply turning pressure to the lock while decoding. To do so will "hang" the wafers and cause false readings.**

31_3.2.6 Difficulties and Cautions

A number of conditions can cause difficulties in decoding certain locks or producing properly operating keys for them. The following problems should be identified and analyzed prior to attempting to open a wafer lock:

- **Worn wards within the keyway;**
- **Worn wafers;**
- **Keyway wear;**
- **Bent wafers (from excessive torque during picking);**
- **Small difference between differs;**
- **Many differs;**
- **Inability to observe a specific wafer;**
- **Inaccurate extrapolation, causing too deep or shallow cuts to be made, resulting in binding or the necessity to "wiggle" the key to make it work;**
- **If cutting a key for a vehicle ignition, try using it in the door lock first. If the key has been cut improperly, the ignition may turn due to wear but the key may not be able to be withdrawn (resulting from depths which are too low or too high).**

31_3.2.7 Procedures for Decoding Single-Bitted Wafer Mechanisms

The following decoding procedures apply to single-bitted wafer locks. Decoding may be accomplished in either direction (front to back or back to front) without the necessity of disassembling the lock. Knowledge as to the appearance of wafers prior to viewing them will facilitate accurate estimates as to their depth.

31_3.2.7.1 Decoding with a Reader Tool

- **Lubricate, then run a blank key through the keyway, insuring that wafers do not "hang" in the shell or at shear line;**
- **Insert blank key and cause marks to be made by each wafer, denoting their position. The blank may be "smoked" with carbon for this purpose. File each wafer to the first depth-cut;**
- **Move the keyway cover out of the way (if applicable);**
- **Illuminate the keyway so that the bitting material above the wafers is visible;**
- **View the keyway directly dead center, without creating any angles or perspective. If viewed at an angle, wafers closest to the front will appear higher;**
- **Insert a reader tool and raise all tumblers to shear line. A straight pick may be employed to lift each tumbler;**
- **Read each wafer in succession, and estimate depth. Remember, there are generally 5 depths, with "1" being a "no cut", and "5" being the deepest cut. Also, there may not be 5 differs, but only 3 or 4, causing the improper interpolation of each differ;**
- **If unsure of a particular depth, make the cut more shallow than deep;**
- **Use a gauge or micrometer when cutting the key after each depth has been determined.**

Reading a Chrysler lock with an EZ Reader tool, by Harry Sher

31_3.2.7.2 Decoding by Observation of Bitting

Decoding may be easier with a borescope or ophthalmoscope. In

such case, a depressor is utilized to move all but the active wafer from view. Once a landmark is determined from which to estimate each depth, the tumblers are viewed in sequence and a notation made of the information. A key is then produced to the direct code.

31_3.2.8 Decoding Double-Sided, Double-Bitted Locks

There is a difference in the decoding procedure for single and double-bitted locks. The following guidelines apply for wafers having bitting surfaces on two sides.

- **If the lock is used in a motor vehicle, the following information should be known:**
    - **Make, model, body, and year of the vehicle;**
    - **Code data and code location on the lock body;**
    - **Key blank types;**
    - **Root depths and spacing;**
    - **How keys will operate;**
    - **Which bitting is active on both sides of the key;**
- **Be certain that the lock is double-bitted, with active wafers oriented in opposite directions. A key with bitting on both surfaces may merely be mirrored for convenience;**
- **Locks for motor vehicles may contain up to eleven tumblers. On certain models, there may be an added cut at the tip of the key that does not correspond to a wafer position. In such cases, cut both sides of the key to allow entry through the keyway;**
- **Some locks will have active wafers in all positions on both sides; others in only certain positions. For example, a key may be coded 13545 on one side and 35 on the other;**
- **If there are active wafers on both sides of the plug, then alternating cuts must be made on either side of the key;**
- **The order of reading must be determined, beginning with the first wafer. It may be on the top or bottom of the plug;**
- **If producing a key for a motor vehicle, it must be determined if there is a valet function. Knowledge of the lock is required;**

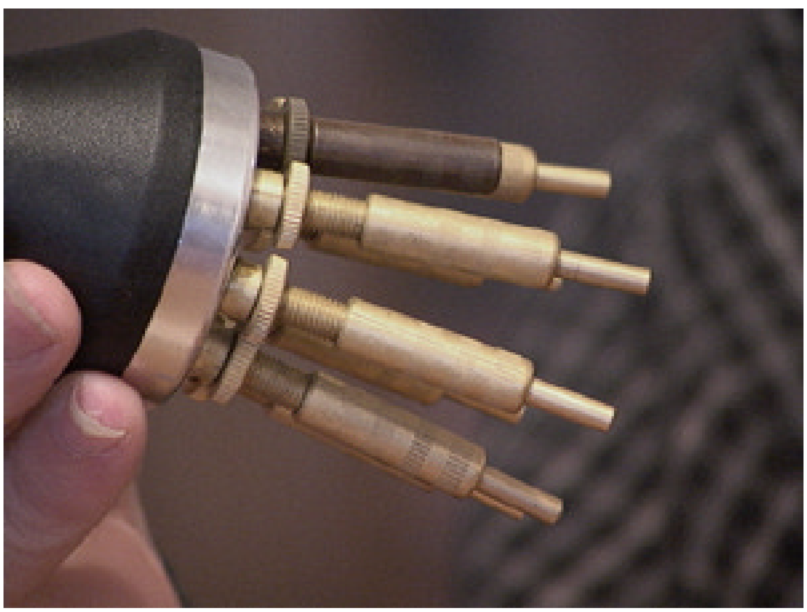
- **It is preferable to read all bottom cuts or all top cuts in sequence;**
- **When illuminating the keyway, shine the light at the bottom to read top wafers, and at the top to read the lower set.**

31_3.3 Decoding Axial Pin Tumbler Locks

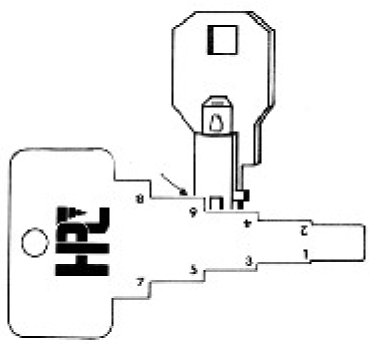
When a tubular lock is picked, it must also be decoded. Code depths may be read from a decoder tool or from the key that opens the lock. Keys that have been produced during the impressioning process may be damaged or chipped. The HPC TKPD-1 can be utilized to determine the depth of each cut, measured in 1/64" segments. In order to use the tool, the key is rotated in a clockwise direction with the blank facing the technician. These locks may also be disassembled using the HPC APF tool. The **Peterson PRO-1 tool** may also be used to pick and decode an axial pin tumbler lock.

The Peterson PRO-1 tool, courtesy of Harry Sher.

LSS204: Harry Sher on picking axial pin tumbler locks







31_3.4 Decoding G.M. Sidebar Locks by Direct Measurement

Sidebar locks can be directly read using the HPC GMTD-5 decoder gauge. This process requires that pressure be applied directly to the sidebar by drilling a very small hole through the lock cover. A stiff wire or pick is then used to depress the sidebar while the wafers are raked to alignment. Each of the five depth gauges is then inserted to read the height of each tumbler.

31_3.4.1 Sidebar Code Reader

A patent (**2070228(304)**) was granted in 1937 to FitzGerald and assigned to Briggs and Stratton for a simple code-reading device

for their lock. The tool allowed the direct measurement of the four depths associated with each of six wafer positions.

31_4.0 Indirect Measurement of Internal Components

Active components may be measured indirectly, using various procedures involving observation, touch, and special tools. Decoding devices produced by HPC, Falle, and others are available to provide precise extrapolation of depth and spacing data during the decoding process. **Indirect** measurement refers to a process whereby components are evaluated and decoded through other than direct means. The analysis is generally accomplished by comparison of data from a known standard, without actually being able to physically examine the component. Dimensions are either estimated or precisely determined through extrapolation. The primary means for deriving code data by indirect measurement include:

- **Visually reading the lock;**
- **Set of tryout keys;**
- **Impressioning the lock;**
- **Examining tumblers or levers through a viewing hole or keyway;**
- **Silicone impression of the inside of the lock after picking;**
- **Use of pressure-responsive materials;**
- **Utilizing a special pick/decode tool;**
- **Utilizing a shim decoding device;**
- **Tactually decoding the tumbler positions;**
- **Picking, then decoding the picked lock;**
- **Other means of reading tumbler combination.**

31_4.1 Tryout Keys

Tryout keys are designed to exploit the tolerance errors of active locking components. They utilize a matrix of specially cut blanks that encompass all possible permutations that will open the lock, based upon depths that are between standard levels. Once a tryout key has been found to open a target lock, a matrix of codes can be determined that will produce a properly working key. In a simple example, let us assume that a three-

wafer lock has been opened using a **tryout key** with the code of 2.5 4.5 1.5. In our example, a 1.5 cut will simulate a 1 or 2 code; a 2.5 will simulate a 2 or 3 code; and a 4.5 will simulate a 4 or 5 code. The matrix of combinations must include:

CUT #1	CUT #2	CUT #3
2	4	1
3	5	2

Based upon this knowledge, all of the keys that theoretically must be cut in order to find the correct one would be: **252, 251, 241, 242, 352, 351, 341, 342.**

31_4.2 Examining Active Locking Components Using a Viewing Hole or Keyway

Active locking components can be observed and measured externally. They can be viewed by using optical instruments and their measurements derived through the use of decoders. Ophthalmoscopes, otoscopes, and magnifying loops may be utilized to peer into the lock and calculate the depth of each wafer, disc, lever, or tumbler. Depth gauges and feelers can likewise be employed to extrapolate individual bitting.

Lever locks generally have a viewing hole that allows observation of the lever pack, gates and fence. Calculations can also be based upon the appearance of the bellies. Certain locks, such as wafer and disc tumbler, are particularly well suited to visual decoding techniques because of the design of the active locking components. The procedure for decoding a standard wafer mechanism by **indirect measurement** is detailed in **Section 4.4.2.**

31_4.3 Impression of the Inside of the Lock

It is possible to obtain an impression of the position of the active locking components after they have been picked or manipulated to the open position. Impressioning material such as silicone can be injected through the keyway, then removed once it sets up. An imprint of the various tumbler depths will be reproduced. Another method, patented by the author (**5355701(305)**), utilizes carbon paper in conjunction with a fine rake wire combined with a protective covering during entry and removal. A precise image of the VingCard key can be produced in seconds using this process. Impression marks, caused by a difference in pressure upon the tumblers, will be indicated on

the surface of the carbon. This can be directly translated for the production of a key. A more sophisticated electronic method for decoding this lock and others was also patented by the author. It is described elsewhere in this text.

31_4.4 Utilizing a Special Pick/Decode Tool

There are many instruments that are designed for picking and decoding lever and pin tumbler locks. Most of these utilize some form of moveable shim to sense the position of each active locking component. The more sophisticated devices use fine wire and are detailed later in this section. The best engineered, most accurate, and versatile of these tools are examined in the following discussion. Detailed instructions, including video presentations, may be found in **LSS+/x CD/ROM**, and at **www.security.org**.

31_4.4.1 Lever Lock Decoders

Because of the popularity of lever locks throughout the world, many decoders have been devised that range from simple to very complex. The first lever lock decoder could be said to have been a fine wire with a mirror attached to it. A lighted taper was placed in the lock in order to smoke the levers. Then, a blank was inserted and rotated until it made contact with each belly. The bellies were then examined to determine points of contact.

The crude decoding device was used to read the marks left in the carbon. A finely focused lamp was employed to see where the key bit had touched each lever. This information told the lock picker where the key would make contact with the levers and where it began the lifting action for each belly. With patience, he could figure out a key that would not trip the internal detectors that had been developed to frustrate this practice. Ultimately, Chubb solved the problem: they implemented the curtain as a shroud. Since the use of this primitive procedure, many decoders have been developed as a response to the introduction of improvements in lever mechanisms. See Lee (**3735496(306)**) for a method of decoding certain high-security lever locks by measuring the distance between the lever and other components within the lock by utilizing a special set of keys with predetermined bitting depths.

Based upon a study of the famous Bramah lock that was successfully bypassed by Hobbs, the author has concluded that a form of decoder was developed by him to measure the length of

each slider. It is possible that this was the first rudimentary pin and cam system, perfected two hundred years later by John Falle.

There are various forensic implications that will often result from the bypass of lever locks. In other cases, essentially no trace will be found. Each lock must be studied, and a thorough knowledge is required of the latest bypass techniques, in order to assess whether in fact a lock has been compromised.

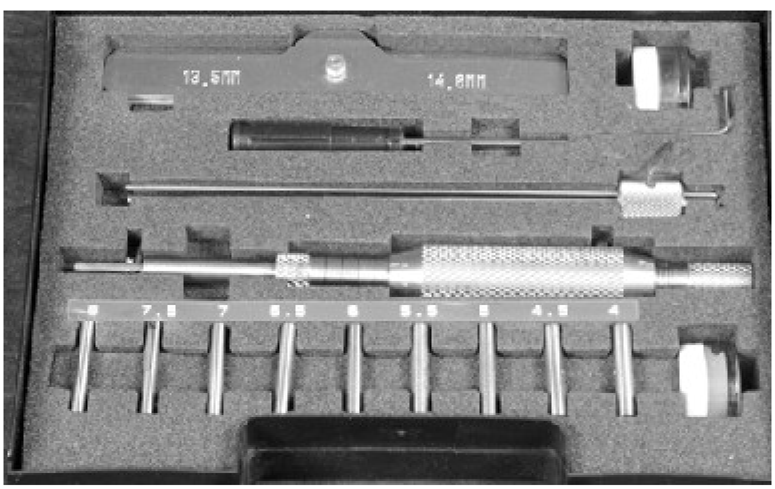
Forensic implications of the bypass of lever locks. Courtesy of Hans Mejlshede.

31_4.4.1.1 Universal Lever Lock Belly Reader

A discussion of reading the belly of a lever. Courtesy of Hans Mejlshede.

LSS304: Universal belly reader system, by John Falle

This decoder, manufactured by Falle, is sold exclusively to government agencies. It is designed for use with medium security five and six-lever locks with barrel and curtain, such as the Chubb 114, the Union five-lever Red, and many other models.





The system is an improvement over the use of plasticine, discussed in **Chapter 30**. It will be remembered that such a system relies upon the insertion of a plasticine key that is turned under the levers, so that they make an impression mark in direct correlation to the height of each belly. There are three disadvantages to using plasticine:

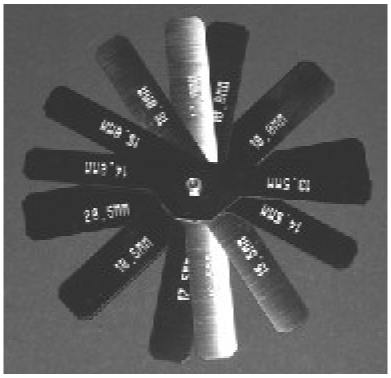
- **In many instances, the skirt rotates counterclockwise, which may result in breaking or fracturing the metal in order to take readings;**
- **Markings that are left on the plasticine can be very difficult to interpret;**
- **Often, the plasticine can be deposited onto the belly of the levers and then onto the users key, thus providing an alert to the process.**

The Falle kit is supplied with a series of data sheets for each lock for which the tool is designed. Information includes lever spacing to properly position the plunger pin under any specific lever. Belly height for each type of lever is also provided. The tool is calibrated in 1-mm increments.

31_4.4.1.2 Basic Lever Lock Decoder

This Falle kit is supplied with tools that are designed to identify the make of a target lock to be opened. The system utilizes a set of feeler gauges to measure the length of the keyway. The operator inserts the gauges (from end to end) to find the largest size that will fit.

There is also a pinhole-measuring tool to ascertain the diameter of the pin or post size of the key. This gauge is inserted into the keyway; the bow is then slid down to hit the face of the lock. The user can then read from the gauge to determine the required dimensions.



The decoder consists of two separate gauges; the one at the front of the tool controls the depth for which the plunger pin is inserted into the lock. The decoder gauge at the rear adjusts the height to which the plunger pin is inserted underneath the levers.

31_4.4.1.3 Pin and Cam System (Universal Lever Lock Decoder)

The John Falle lever decoder system. Courtesy of Hans Mejlshede.

LSS303: Universal pin and cam system, by John Falle

The term “**Pin and Cam**” refers to the original design which used a small cam to apply lift to the pins in the key tip. The basic design has since been modified and updated, but the underlying theory remains constant. There are several different versions of the Pin and Cam system, customized for specific lever locks. The **European** lever Pin and Cam will open certain of the locks that are found in Europe. The **Universal Pin and Cam** system can be utilized for many different **lever locks.** One example (shown in the linked photograph) is the Mottura lock. Shown in the hyperlinked photograph are different versions of these systems produced by John Falle.

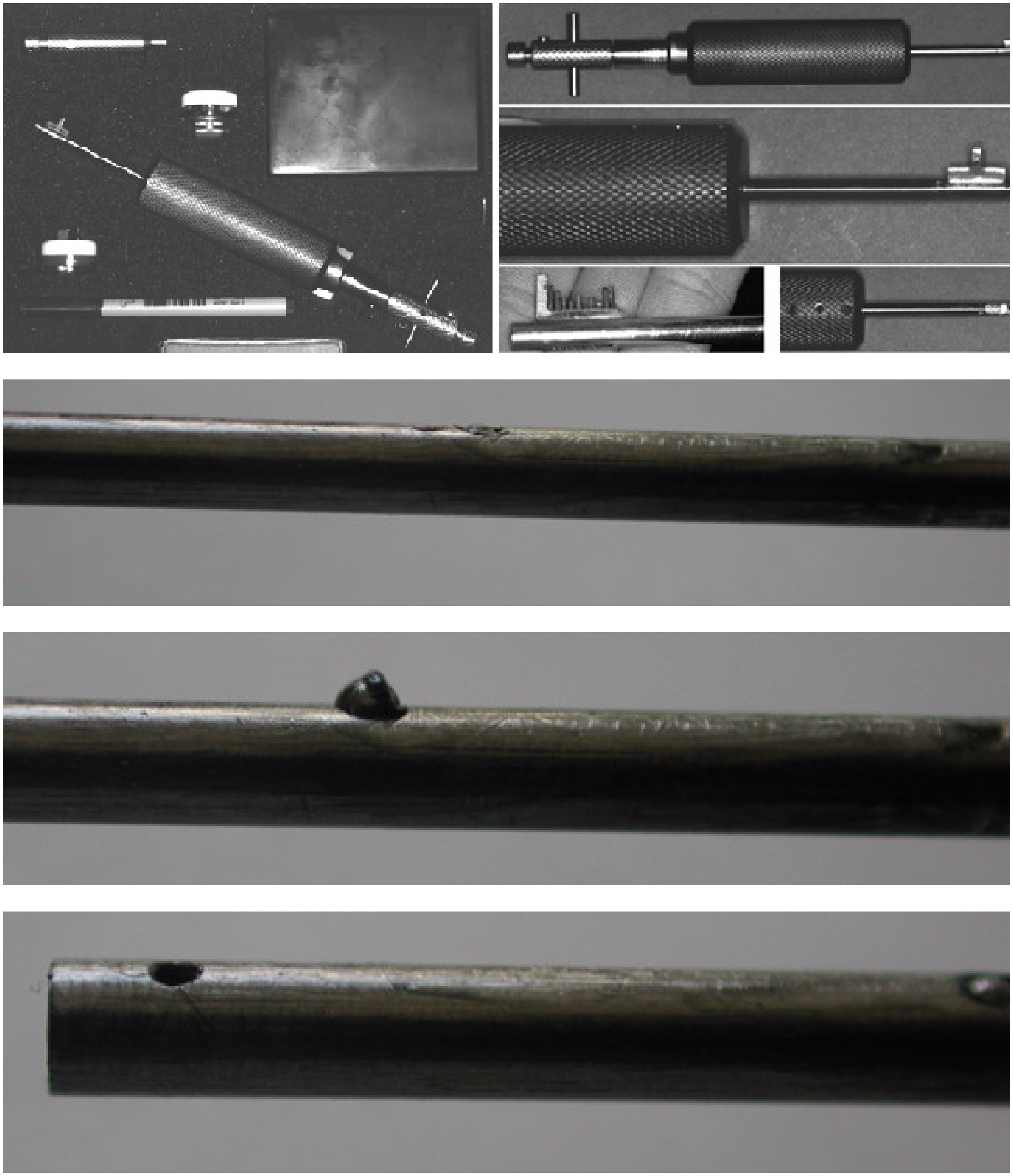
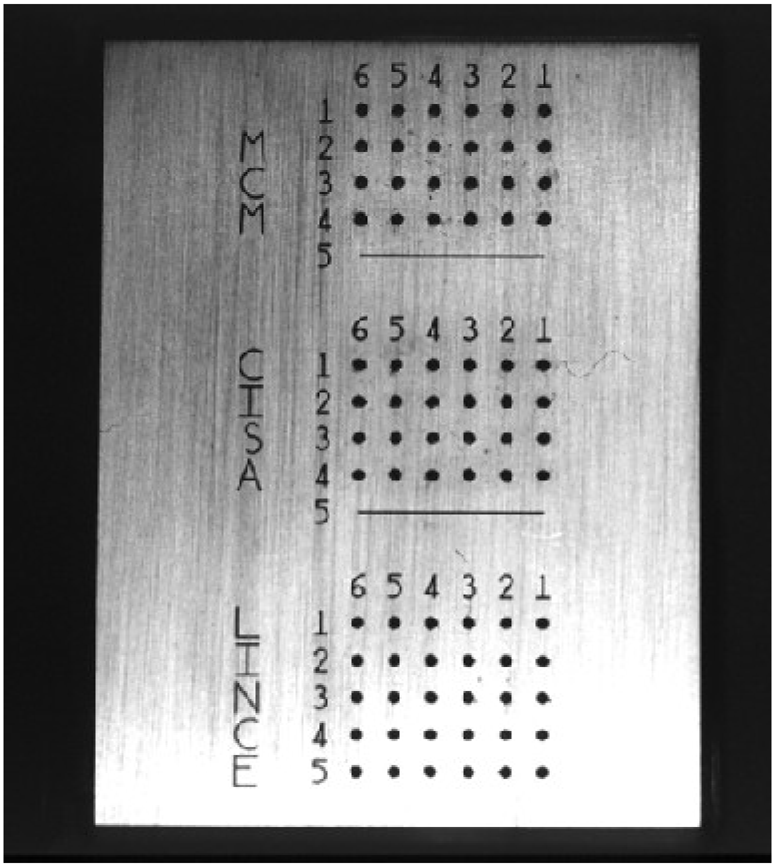


Figure LSS+3101 The John Falle Pin and Cam system relies upon the movement of a bearing under each moving pin that is inserted into the die corresponding to

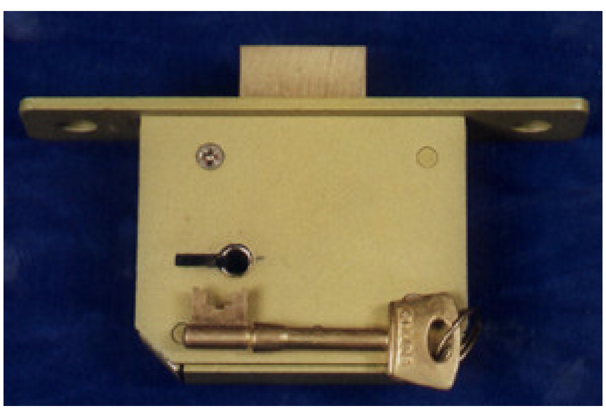
the location of each lever. Extremely precise sensing of movement in each individual pin is achieved by forcing the bearing to move vertically against each lever. The tolerance error is determined for each of the levers through the movement of the individually adjustable pins within the tool.

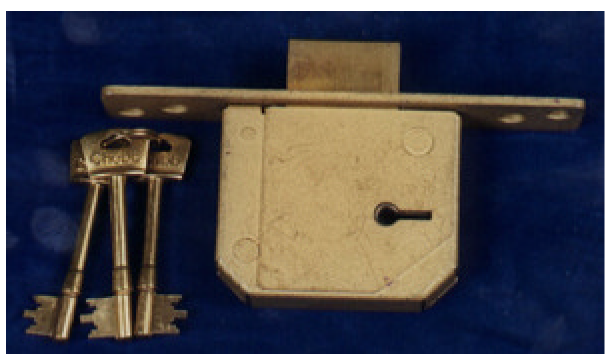
This system was initially designed to defeat the Chubb 110 lever lock. The original process required the insertion of a probe into the keyway so that it would rest to the left side of each lever in order to take readings. The space that was vacated enabled the operator to probe for the gate in the adjacent lever, thus allowing the decoding of all levers. A modified system has been introduced for **British** lever locks.

In response, Chubb introduced a spring steel clip that was placed underneath the bellies of the levers at exactly the point that the probe was trying to reach, thus preventing the system from working. As a result, Falle introduced a modified and upgraded approach. The system consists of a simulated key-bitting surface that allows the placement of different length pins into each lever position. These pins are precisely controlled through a plunger located at the end of the tool and can be individually lifted to calibrated positions.



The **pin and cam system** is supplied for use on any one of five high-security locks. Currently, this includes the Chubb 110 (seven lever heights), 3G 114 (eight lever heights), and seven-lever safe lock, the Leg five-lever black insurance lock, and the CR European double-bitted lever locks.





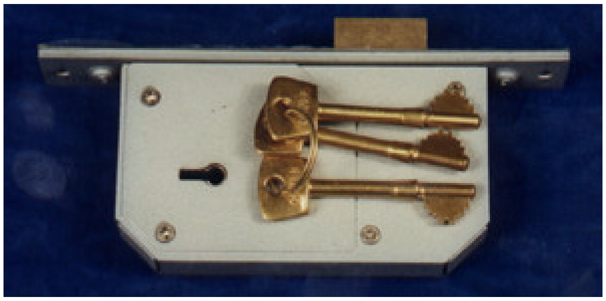


Figure LSS+3102 examples of different British locks that can be opened with the specialized pin and cam system. Courtesy of John Falle.

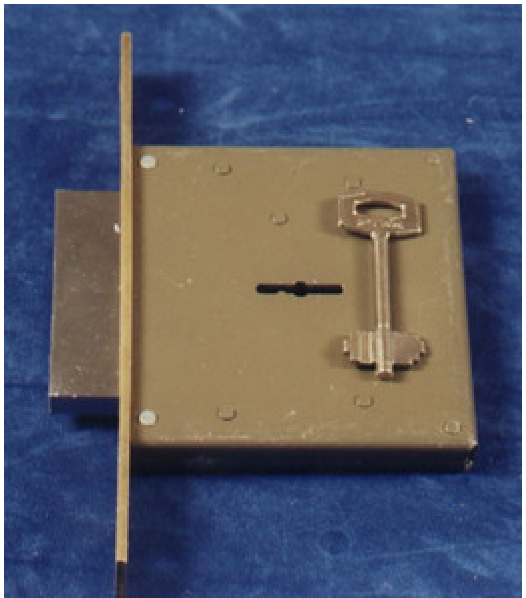
All of these high-security locks have one of the following design features in common for which the Pin and Cam system is primarily designed:

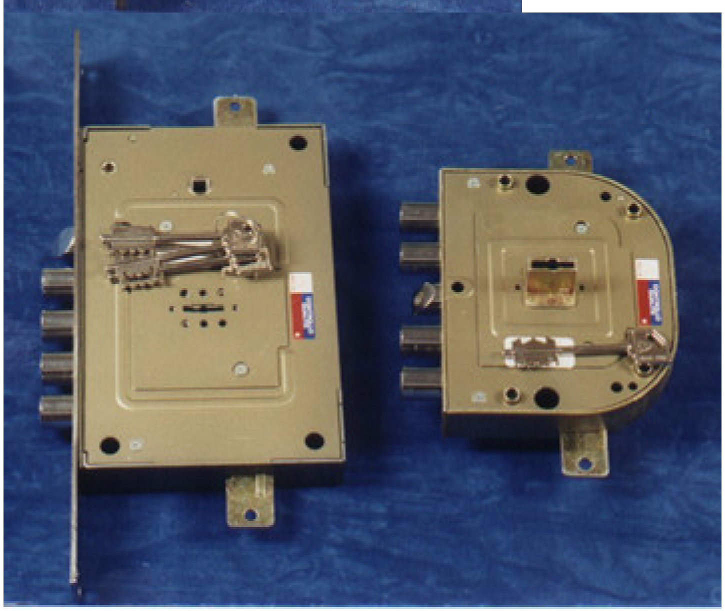
- **They may have very large belly groupings as in the case of the Chubb 114. Thus, even if the groupings are known, a large number of keys would have to be tested in order to determine the correct combination;**
- **They may have (as in the case of the Leg five-lever black insurance lock), belly groupings that are very difficult to distinguish, even with the universal belly reader tool;**
- **The locks may have no belly groupings whatsoever. This is the case with the Chubb 110, seven-lever safe lock, and the CR lock.**

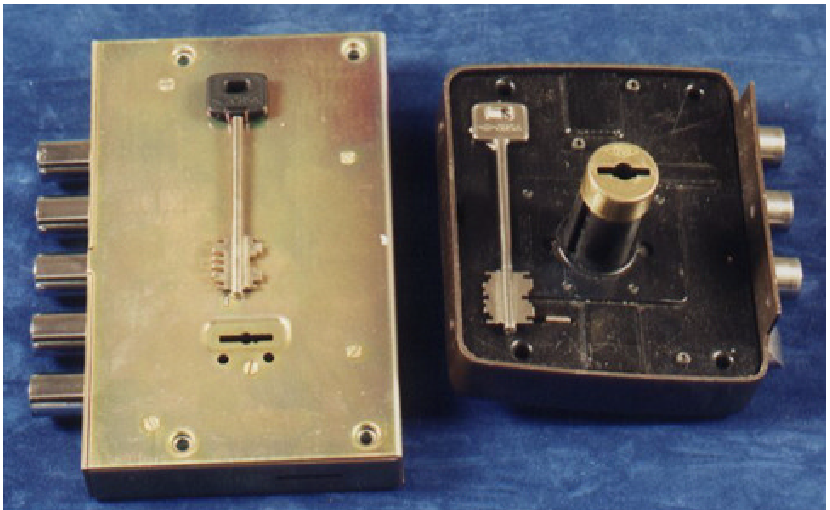
The system is effective against most high-security locks, regardless of:

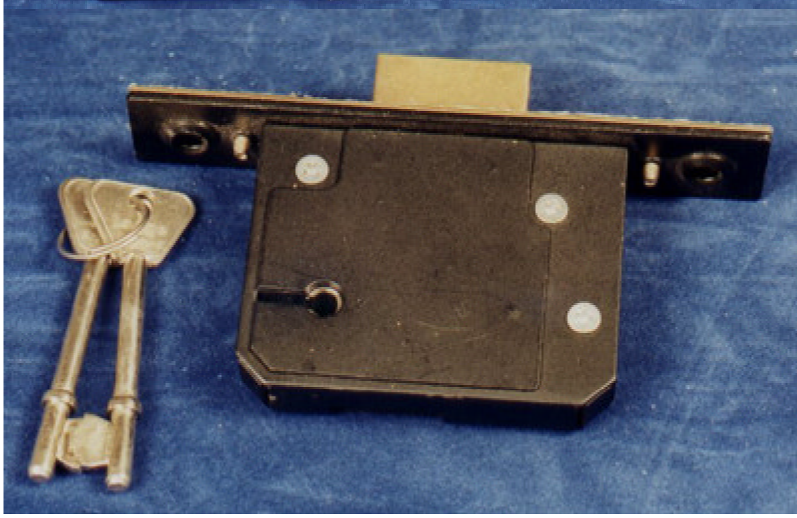
- **The number of levers;**
- **Barrel and curtain or pick-protection mechanisms;**
- **False notching on the levers that are designed to frustrate picking.**

Different versions of the **Pin and Cam system** are effective on many locks listed below, including those shown in the photographs:









- **Antonioli**
- **Beta**
- **Boda 428, 2925, 2926 (unlocked) (locked)**
- **Cerutti**
- **Chubb 6K174 (locked) (unlocked) (Bankers Safe)**
- **Chubb 6K75 (Leamington and Conqueror Safe, 7 and 8 lever)**
- **Chubb 3G110, 3G114, 3G117**
- **Cisa**
- **Esety**
- **FAS 309, 389 (S&G 68/80) (locked) (unlocked)**

- **FAS 6880 (locked) (unlocked)**
- **Ferr**
- **Fiam**
- **ISM**
- **Jewel**
- **Kassel**
- **Legge Black**
- **Moia**
- **Mottura Serrablocca**
- **Potent (7-lever lock)**
- **Potent**
- **Power Titan**
- **Preffer**
- **Ross 600 (6-lever lock)**
- **S&G 68-80 (Fas)**
- **Sab**
- **Securemme**
- **SLS (multistump lock)**
- **SMP (dual-stump lock)**
- **Teseo**
- **Viro**
- **Yale**

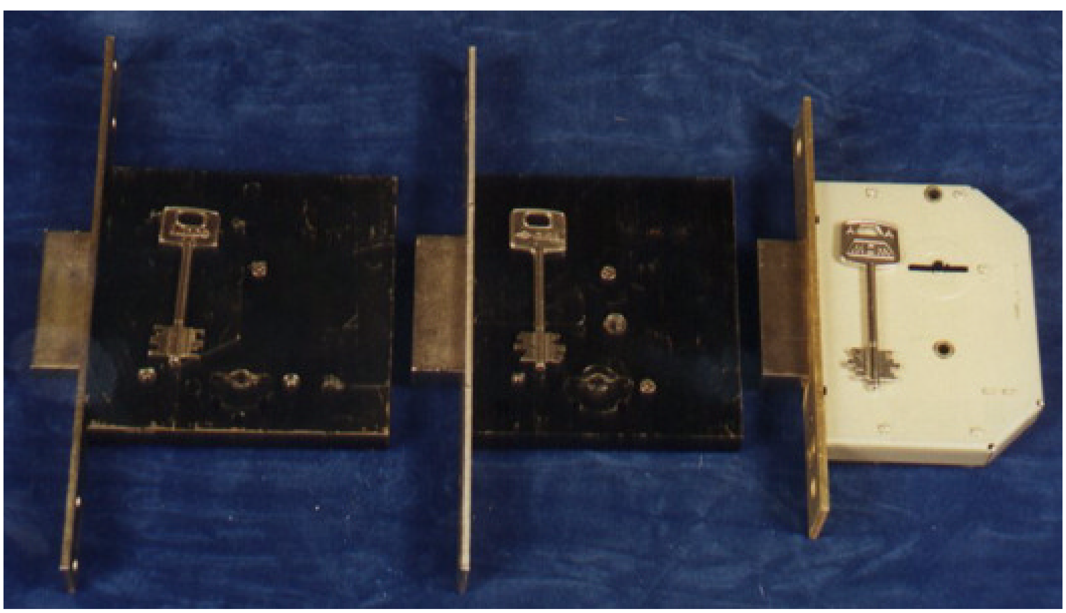


Figure LSS+3103 A variety of European lever locks can be opened by

the John Falle Pin and Cam systems. Some examples are shown within section 31_4.4.1.3. Courtesy of John Falle.

31_4.4.1.3.1 Pin and Cam System Operation

The system is a high-tech improvement over traditional impressioning techniques. It will be recalled that to impression a lever lock, a blank is inserted, torque applied, and the bitting surface is moved against the levers. This will cause marking, correlating to the position of each lever with respect to its gate and the fence. In the Pin and Cam system, the tip of the decoder tool simulates the function of the blank, as a series of interchangeable steel pins are inserted to reproduce bitting positions within a key. In the case of the 110, for example, there are nine possible cut depths, and the decoder tip itself measures a #9 height.

Positioned within the tip and directly below the pin is a hardened steel cam. It is free to slide forwards and backwards in relation to the pins. When the cam is rotated, the pin that is positioned directly above it would be raised exactly .5 mm. With practice, the user would place five pins of equal length into the holes directly below the levers. The decoder is inserted into the lock and rotated to the unlocking direction, and torque is applied. The cam is positioned below each pin and then turned and twisted to see how easily it will rotate. Each lever is tested to determine whether there is movement (when the gate and fence are properly aligned) or whether there is no movement (when the lever is blocked against the racking stump). This procedure is repeated with all the pins in the decoder. Eventually, the shape of the key will be formed with the combination of pins within the cam and the lock will open.

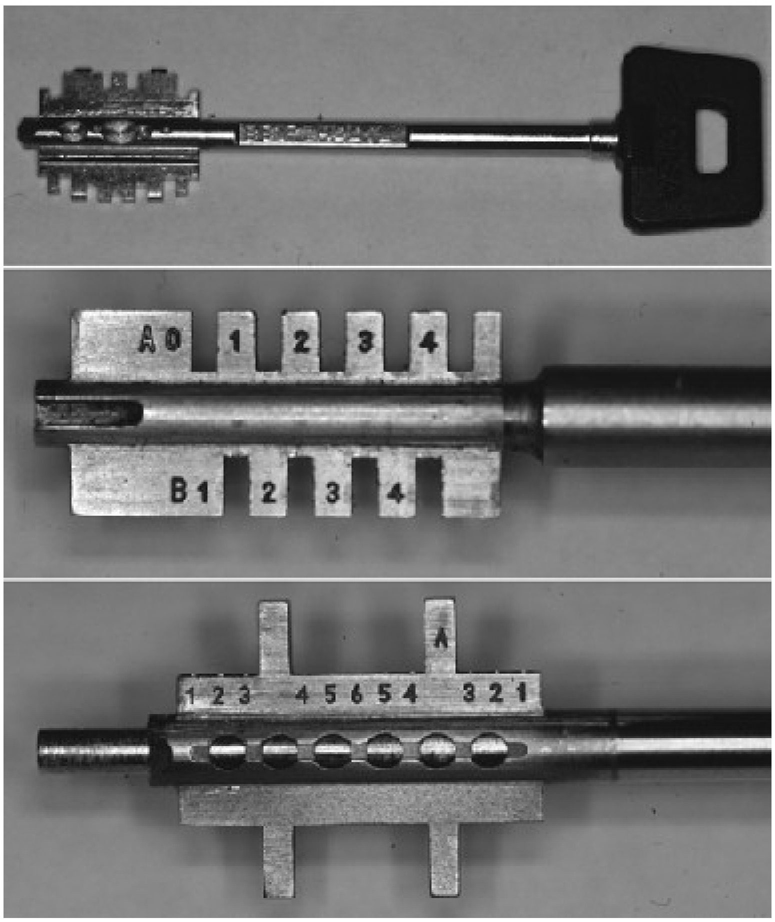
Actually, the system is quite simple in concept and operation. If the cam is stiff and unable to rotate, the pin should be changed to the next shorter length. When the cam becomes loose and is free to move, the pin should remain because the lever either is in the correct position or is not binding at that time. This system will work on any tensionable lever lock without regard to the number of levers. False notches are not relevant.

31_4.4.1.3.2 CISA Lever and Pin, Pin and Cam System

LSS303: Pin and cam system for CISA and other European locks, by John

Falle

This highly specialized decoder is for use on the latest development by CISA. The cylinder lock is designed for attachment to an existing CISA six-lever mechanism. The new lock has eleven pins which seat within cuts on the shaft of a normal lever lock blank (six pins on one side and five pins on other).



The user then has his original key duplicated onto the new blank; the result is a key which contains both lever cuts and pin cuts. To open the door, the user must first insert his key into the outer pin lock and turn it 90°. Once this has been accomplished, the key is free to enter the original lock and operate it in the normal manner. This is a clever improvement and is designed to protect the lock against picking, impressioning and many other forms of attack.

The modified Falle system defeats this lock with considerable

ease and consists of two decoders. The first will identify the code of the pins in the external pin lock. This information is then transferred to the tip of the modified Pin and Cam System, then used to defeat the internal lever lock.

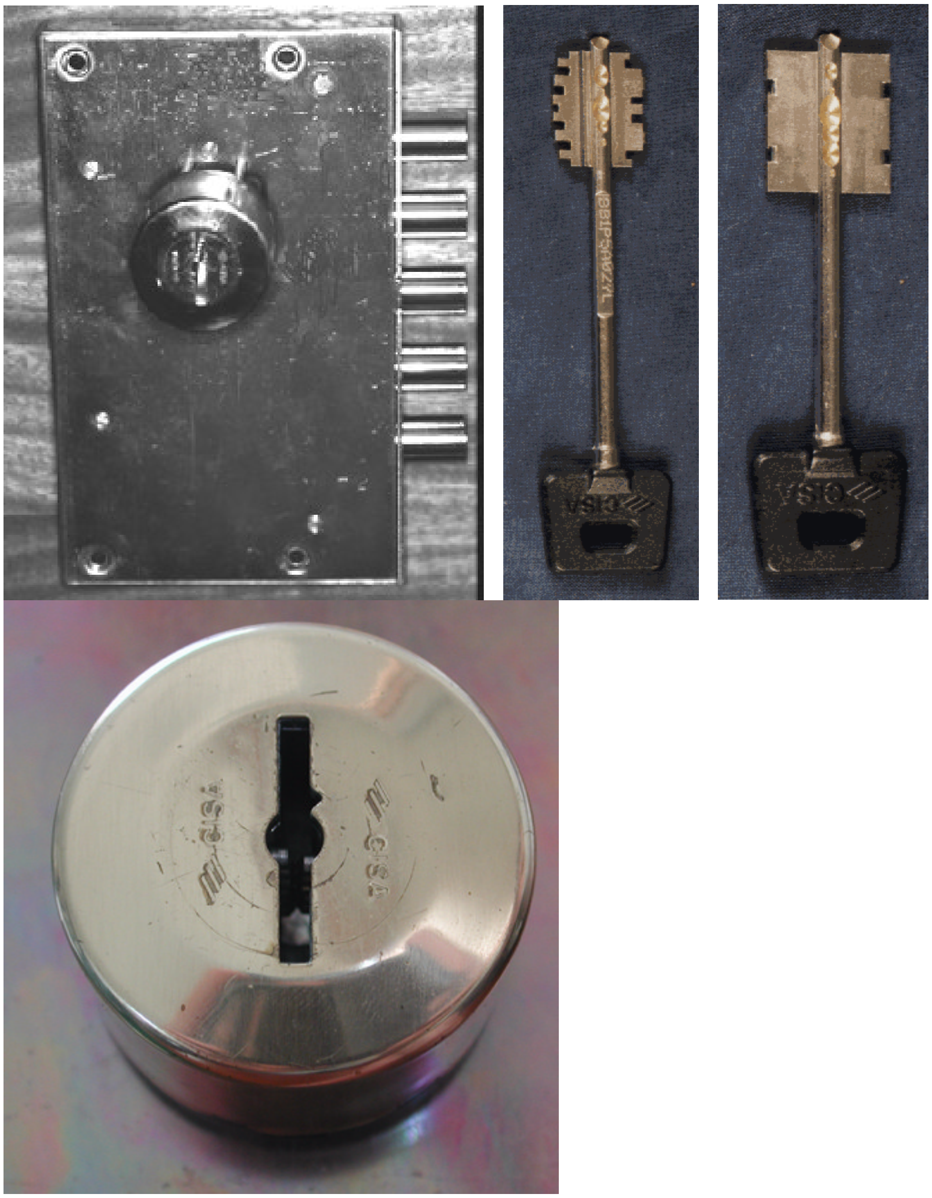


Figure LSS+3104 The secondary locking system introduced by Cisa. Note the bitting for a pin tumbler lock on the middle of the lever keys.

31_4.4.1.3.3 Chubb Battleship Pin and Cam

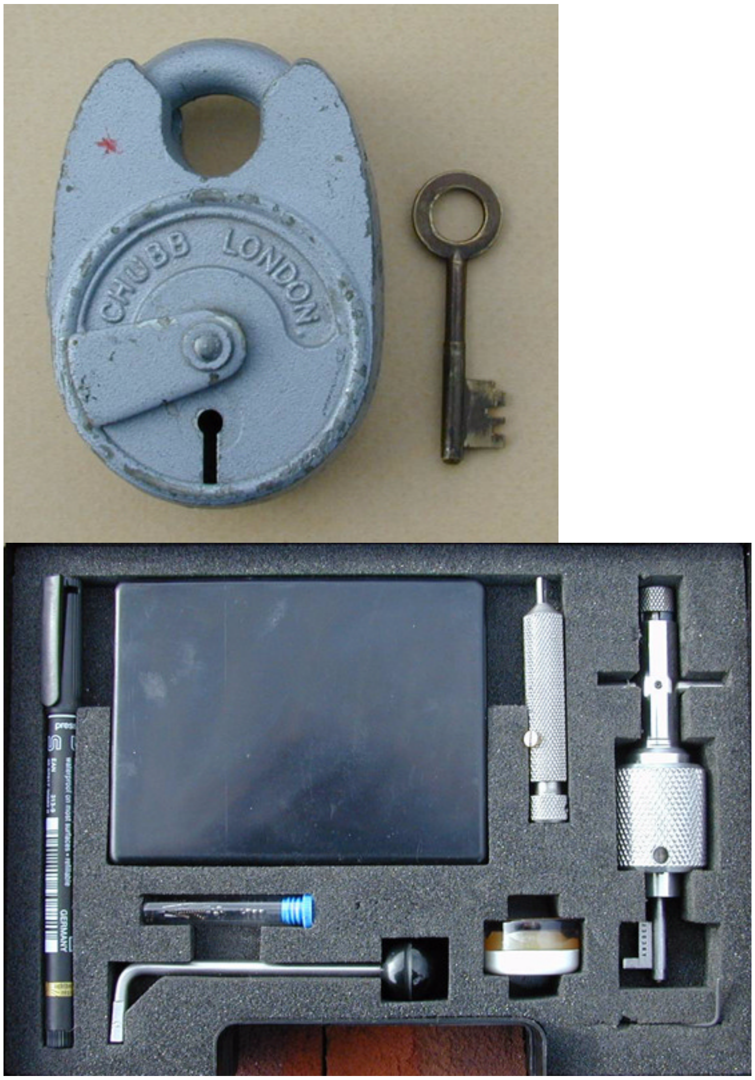


Figure LSS+3132 Chubb Battleship Pin and Cam system by John Falle.

This Pin and Cam System is for use on the Chubb Battleship six Lever padlock. The system is slightly modified and is much smaller than other systems for normal lever locks. The decoder will both open the lock and also allow the code to be derived. The system is easy to learn and use within a relatively short period of time. A lock can usually be bypassed within a period of three minutes of less. No additional training is required if the operative is familiar with other pin and cam systems.

31_4.4.1.4 European Lever Lock Decoder

This device, also produced by Falle, is only sold to law enforcement and government agencies. In order to function

properly, the lever lock first must be picked before decoding. It is effective on all **double-bitted lever mechanisms** that require the key to be turned at least two complete revolutions to open. Cisa has also introduced a secondary locking system that must be bypassed before the lever pack can be accessed. Note the **triple bitting** on the keys shown above. The **new Euro Lever Lock decoder** is also shown. See **LSS+/x** for detailed operating instructions.

LSS301: European lever lock decoder, by John Falle

LSS302: European lever lock pick, by John Falle



This tool is designed to open **lever locks** with certain characteristics. Specifically:

- **The levers have several gate areas; the first and the third, and the second and the fourth always have the same coding;**

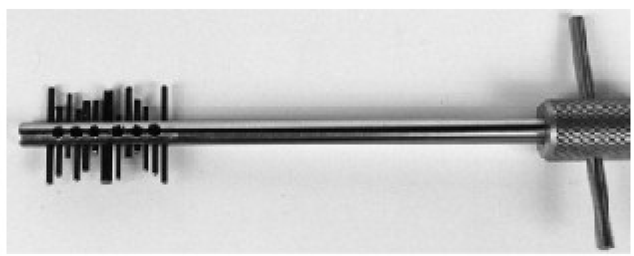
- **In most cases the opposite sides of the bitting are symmetrical and reversed, allowing the key to work when inserted from either side of the door;**
- **There are two packs of three levers each, one on either side of the bow. This effectively prevents the design of a two-in-one pick (wheel pick) for this mechanism; a three-in-one pick would be too weak to manipulate the levers.**



Figure LSS+3105 The MCM lock is one that can be decoded and opened with the Euro Lever Lock system. Courtesy of John Falle.

Consequently, Falle has designed a **two-in-two** system, incorporating a series of three tension tools and two different picks. Each of the tension tools and picks have adjustable and interchangeable lever lifters. The tool allows the picking and decoding of a multiple-turn device. This requires the resetting of tension to different bolt sections and repicking the lever pack.

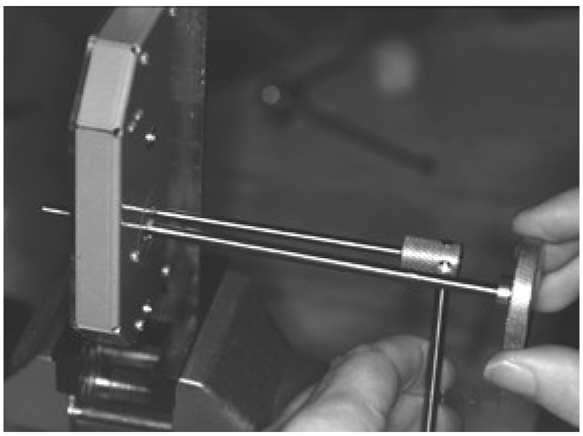




In practice, the lock is picked to a partially rotated position (bolt not entirely thrown) so that decoding may proceed. On the pick body, there are a series of 1 mm markings as well as fractional indicators. A separate depth gauge is also provided.

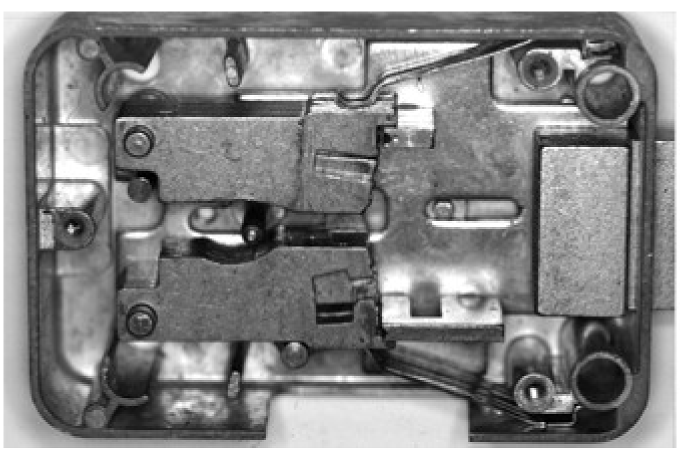
The tool is placed under each lever and moved into position to lift that lever to the correct height. Once all levers are decoded, a key is produced.

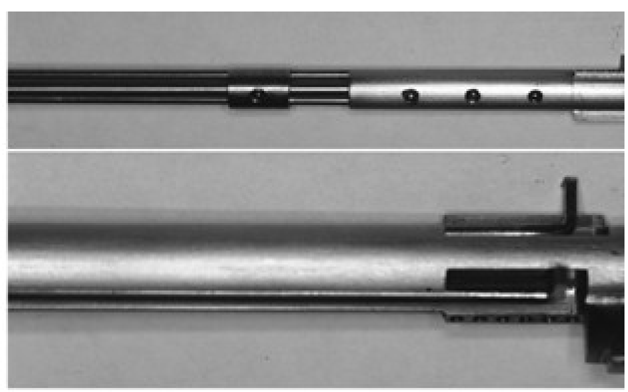
A recent innovation has been developed for many of the double-sided lever locks in Europe. The decoder will effectively identify the codes of one half of the key very quickly and silently. This enables the user to construct a variable key and rotate the lock into its second position before using the Pin and Cam system to identify the second side of the key.



The system has been designed for several popular locks in Europe, including Cisa, Lince, MCM, CR, Esety, Fiam, Mottura, S.I.A.S, and Cerutti.

31_4.4.1.4.1 Chubb/Lips Decoder





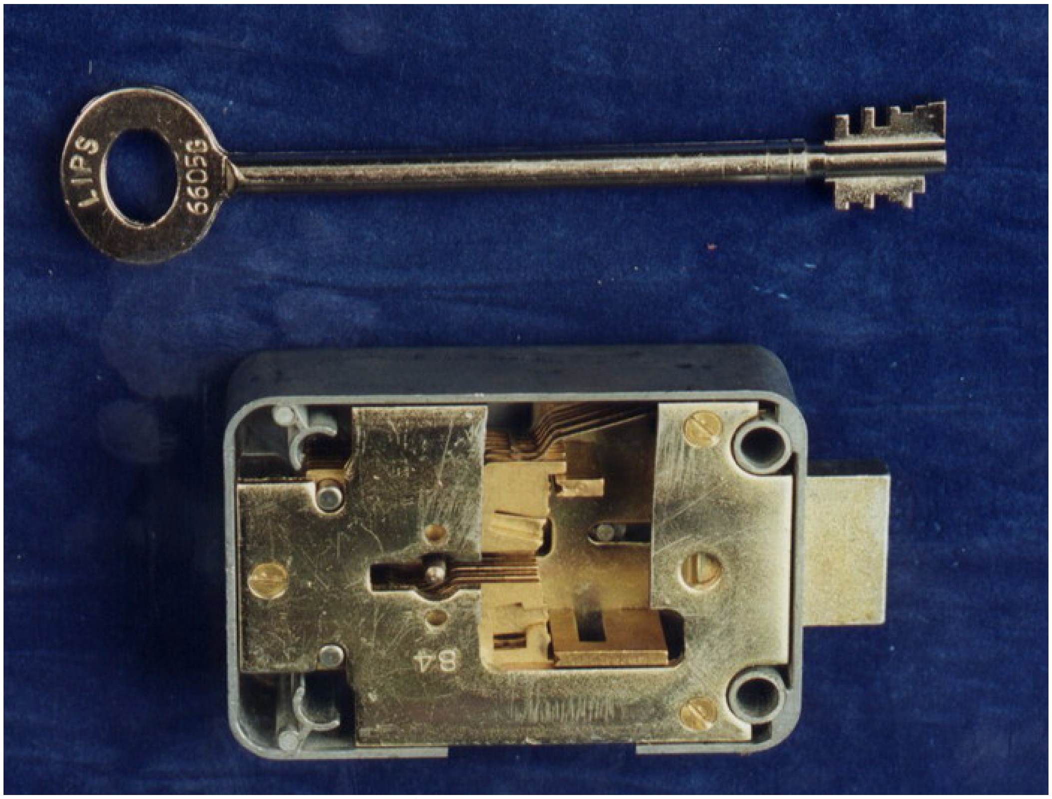
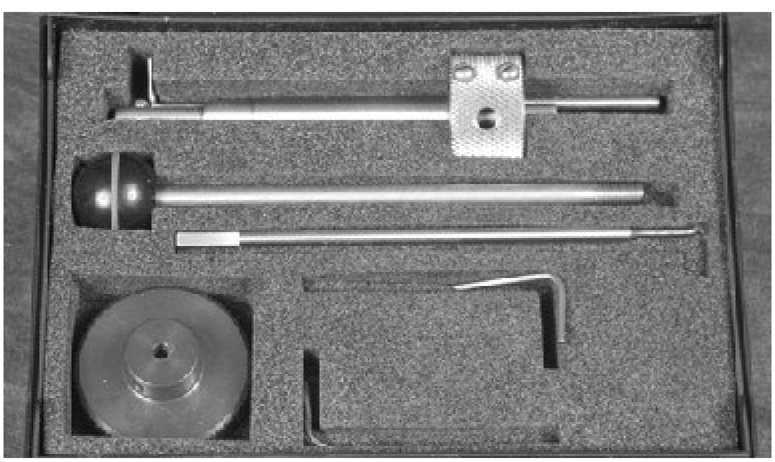
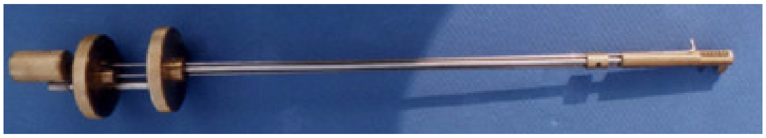


Figure LSS+3106 The Chubb/Lips lever lock can be opened with the John Falle system. Courtesy of John Falle.

The Chubb/Lips lock decoder system is designed for use on the fourteen-lever Lips Lock which is now being fitted to top-grade Chubb Safes and various other European safes. The system is a modified three-in-one wheel pick combined with a variable key in one tool. It is relatively simple to use and will allow the lock to be opened and a code generated for the key.

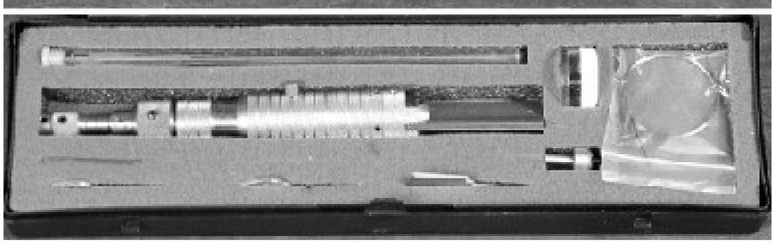




31_4.4.1.5 Ingersoll Decoder

The **Ingersoll Impregnable** lock is produced in a ten-lever high-security padlock or cylinder and six standard lever systems. Although Ingersoll is a relatively small company, their locks are extremely difficult to covertly bypass. They are available in several countries, and the tool is thus briefly mentioned here.





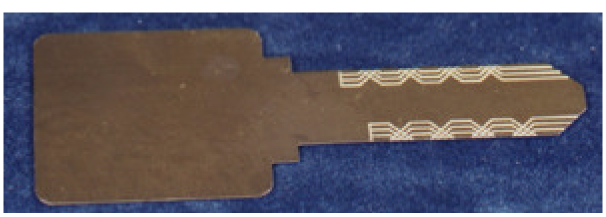


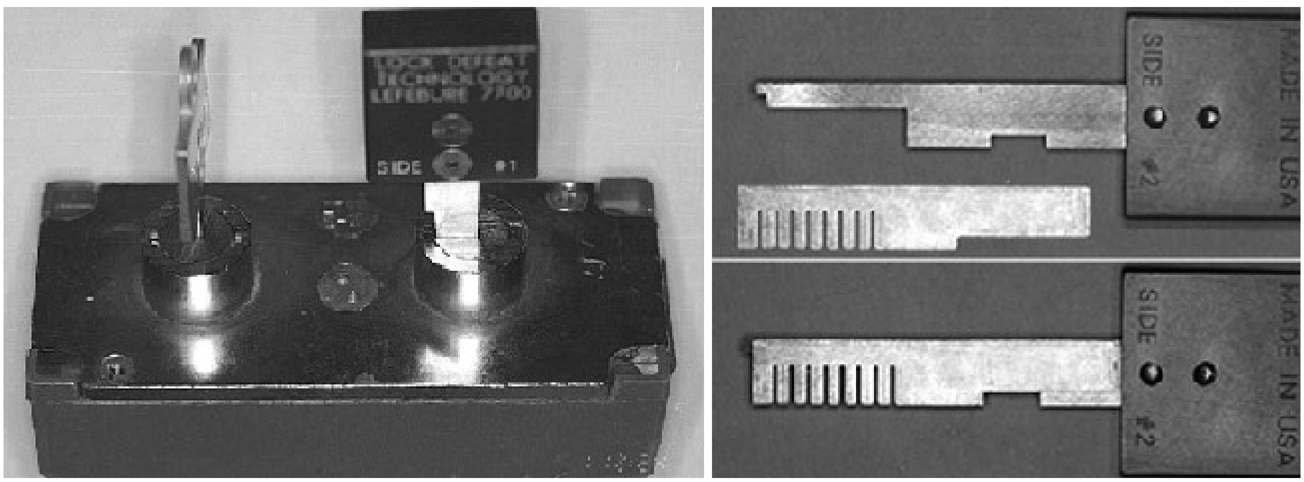
Figure LSS+3107 A key is produced as the result of decoding the Ingersoll, using the variable key generation systems. Courtesy of John Falle.

The decoder is a modified **pin lock decoder** as described above. It incorporates a specially engineered key tip, and a custom gauge on the body that controls the position and angle of the

needle and shim delivery system.

31_4.4.1.6 LeFebure Lever Lock Decoder

The LeFebure seven-lever dual-control lock is utilized in safe-deposit vaults throughout the United States. The bitting combination for both the renter's key and guard key can be changed without disassembling the mechanism. See **Chapter 22** for a detailed description. A decoding/impressioning tool for the 7700 series was introduced in 1997 by **Lock Defeat Technology.** The system allows almost instant bypass of the renter's lever pack and will produce an impression on a brass blank that can be decoded through extrapolation.

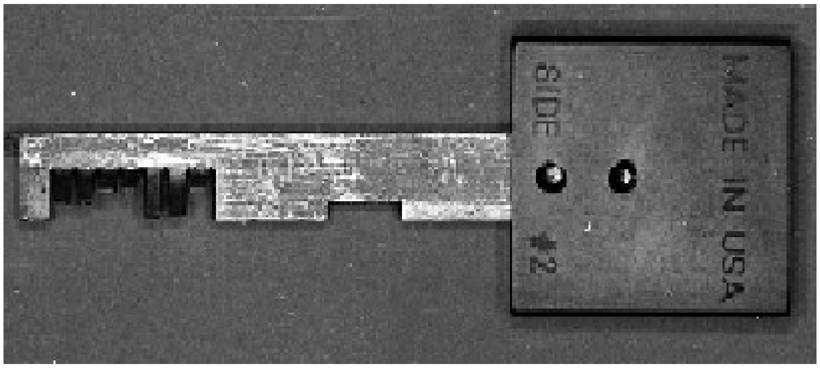


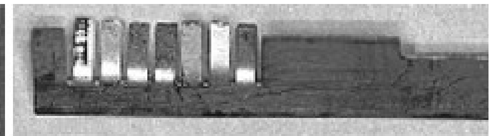
Exploded view 1, 2, 3, 4, 5.

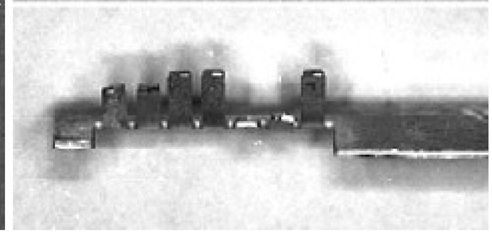
Individual levers in each lever pack are identical in design with regard to the spatial relationship between gate and belly. Differs are created by physically placing a lever in a different position within the lock.

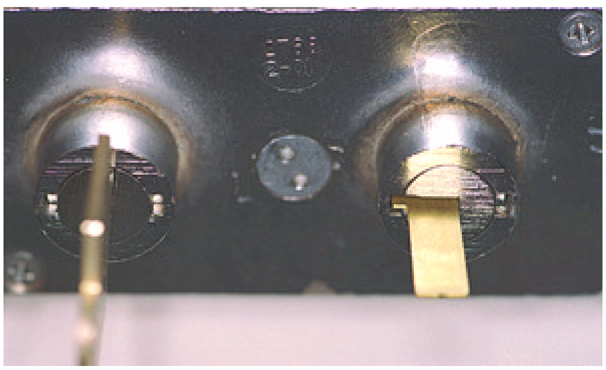
Decoding and impressioning this lock is extremely simple because the location of each gate directly correlates with the position of the lever and its belly. In many respects, the design of this lock is identical to a conventional wafer mechanism. In both instances, the active locking components are offset by the precise distance to the gate or shear line. The impressioning and decoding process resembles the use of plasticine and yields almost identical results. In practice, a special brass strip is inserted into the lock alongside a key guide that is used to actuate the bolt. The strip is then forced against the lever pack until stopped, resulting in a precise impression of the

relative position of each lever.









The guide key, in concert with the impressioned brass strip, is then turned until the levers are raised to the position of the fence. Because the strip mirrors the relative height of each lever at the drop in point, all that is required is that the strip be rotated to the correct position. The impression strip can then be decoded if the amount of rotation required to bring all gates to the fence can be ascertained.

31_4.4.1.7 Falle Floating Pin Decoder

Falle developed what can be described as a floating pin decoder for determining the position of the bellies in a lever lock. This device consisted of a nylon cam that had holes drilled to correspond with the spacing of each lever. Steel pins were inserted into the cam, and the lock was in effect impressioned. As each tumbler was biased, the position of each pin would change, until all of the pins corresponded to the height of each lever.

31_4.4.1.8 Fichet Decoder Systems

There are now at least three different safe locks produced by Fichet in France. The oldest of these locks is now very rare and was produced for safes prior to 1966. Several tools have been introduced that are capable of opening the original mechanism. Consequently, the lock was upgraded and modified to prevent bypass.

31_4.4.1.8.1 Fichet Monopole Decoder

Falle initially designed a tool to decode the original lock. Fichet introduced another modification to increase security. The present decoder will defeat this lock, but it is much more difficult to do. The Monopole system is shown below.

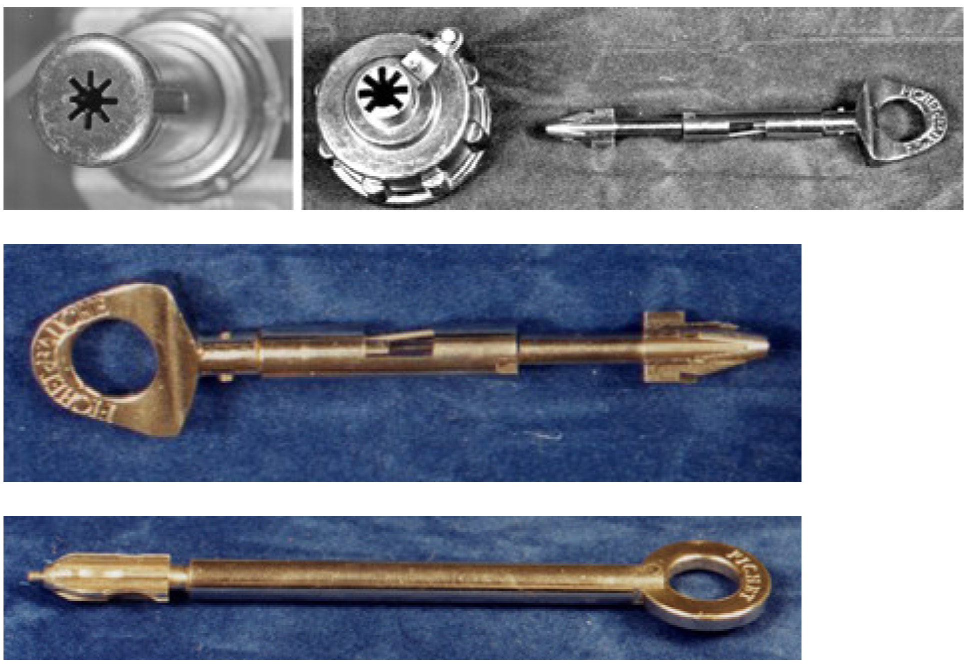


Figure LSS+3108 Note the unusual design of the key for the Fichet Monopole lock. Courtesy of John Falle.

There are two features of the lock that need to be identified in order for it to be opened (**tilt** and **push**). The **tilt** feature is identified by the tilt gauge, which is extremely easy to accomplish. The **push** feature is defeated by way of a specially modified pick and this is easily accomplished if the lock was manufactured prior to 1997. If the lock is third generation, however, both features will have to be defeated with the modified pick; this can be very difficult. In the photographs below, the "H" series lock and decoder is shown.

31_4.4.1.8.1.A Fichet "H" Series

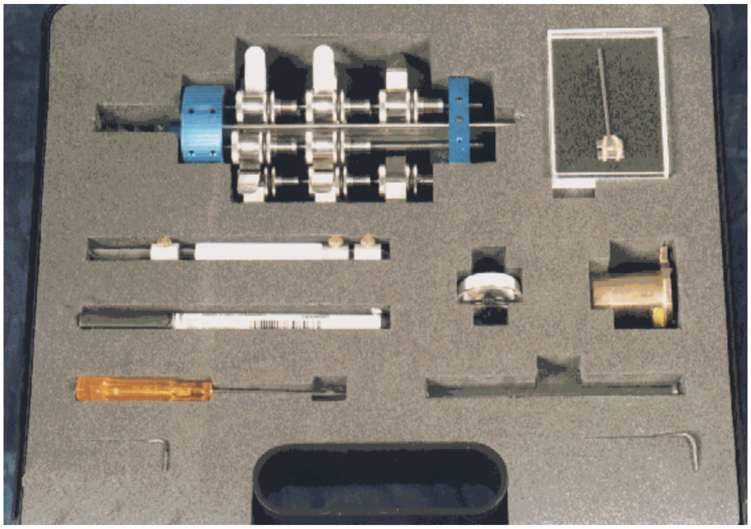
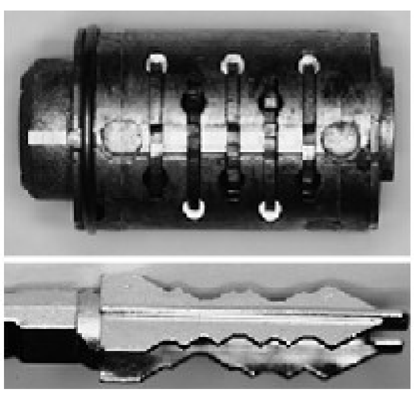
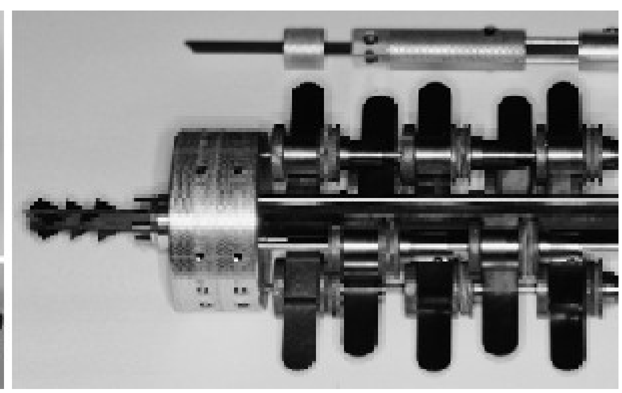


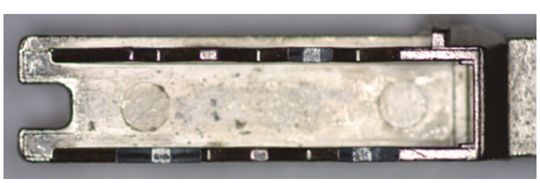
Figure LSS+3109 The decoder system for the Fichet H series lock. Courtesy of John Falle.

This Fichet lock contains ten small levers and two sidebars. The lock has been sold for many years and is extremely popular in many European countries. The decoder system consists of two separate tools which are both used during the opening procedure. The decoder will not only open the lock but will also result in the acquisition of a code.









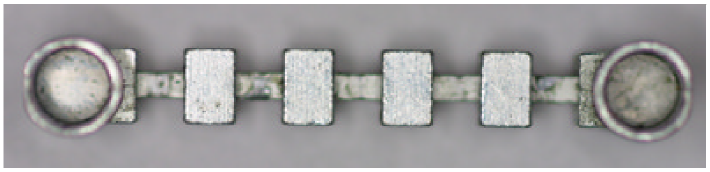
 

Figure LSS+3110 A perpendicular view. In the "H" version, the sidebar mates with the gates on each disc.
of the Fichet key.

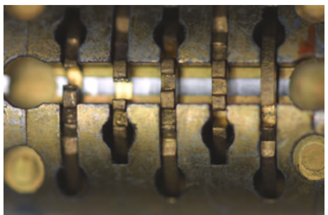
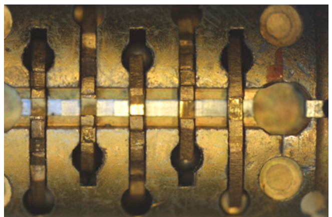
  


Figure LSS+3111 The Fichet lock contains two sidebars, controlled by five pairs of circular discs that pivot around a central pin. The bitting on the key causes each disc to rotate until its true gate is properly aligned with the sidebar. In the above photographs are shown the core which contains a slot on each side which provides a recess into which the sidebar can retract when the gates are properly aligned. From left to right (and in the linked exploded views), the discs are not properly aligned and thus will not permit the sidebar to retract; the gates are aligned; the sidebar is in a retracted position, and the sidebar is protruding, thus preventing the core from turning within the shell.

31_4.4.1.8.2 Fichet Pump (787) Decoder System

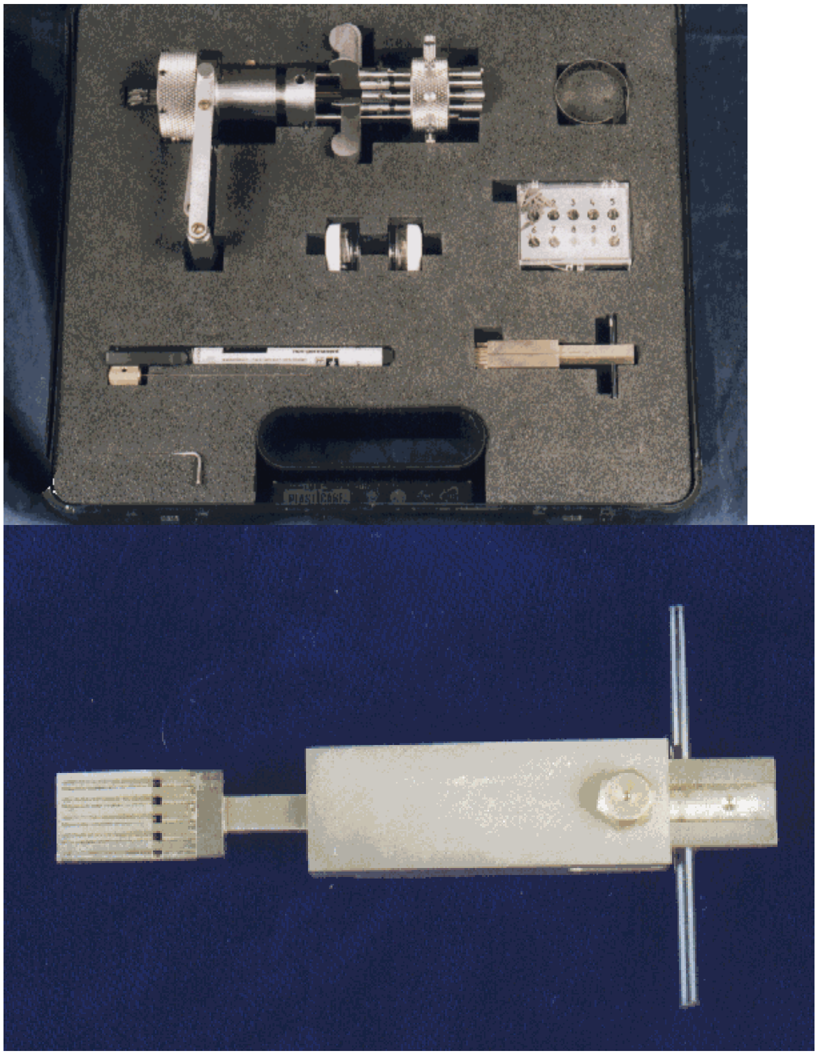
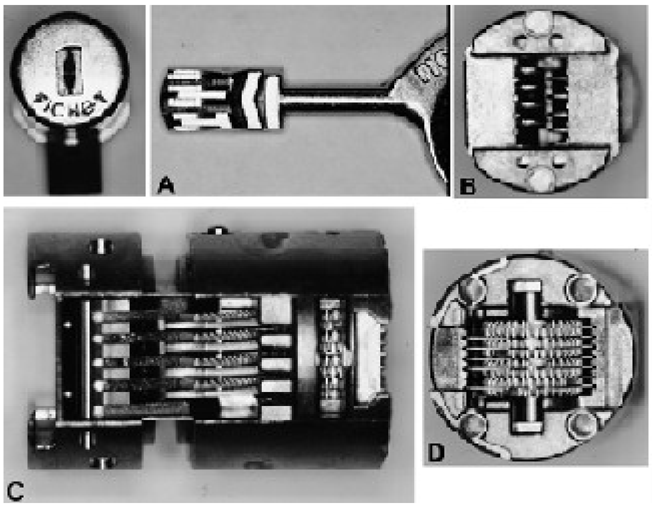
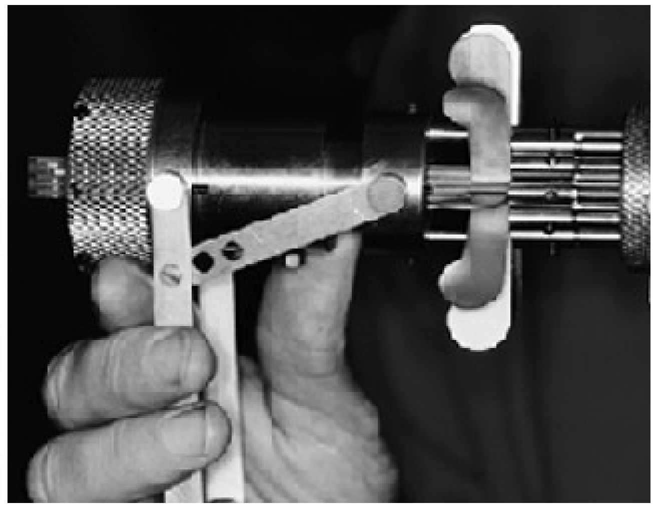


**Figure LSS+3112 The Fichet decoder system and variable Key which can be constructed to the correct
code and used to open the lock, once decoded. Courtesy of John Falle..**

The system is a very specialized decoder that is for use on the French made Fichet 787 Pump lock. This rather complicated mechanism contains ten small levers that are activated by the unusually shaped cuts on the key. The lock is only found in high-security applications. The decoder system consists of a specially designed picking tool which fits onto the body of the lock; the design of the pick allows the lock to be manipulated quite easily. By using the decoder gauges, the code of the lock can be easily determined. A variable key system allows the construction of the correct bitting pattern in order to open the lock.

The main limitation of the system is that of speed during extraction. The decoder is clamped onto the lock with eight locking screws. The clamping system is designed in such a way as to cause no damage to the lock, but if the user has to remove the decoder in a hurry, it will take at least thirty seconds to do so.

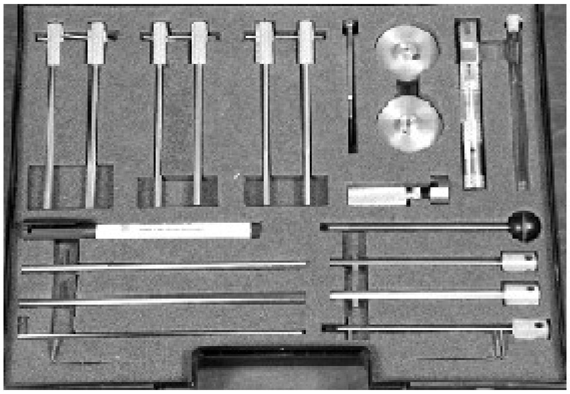


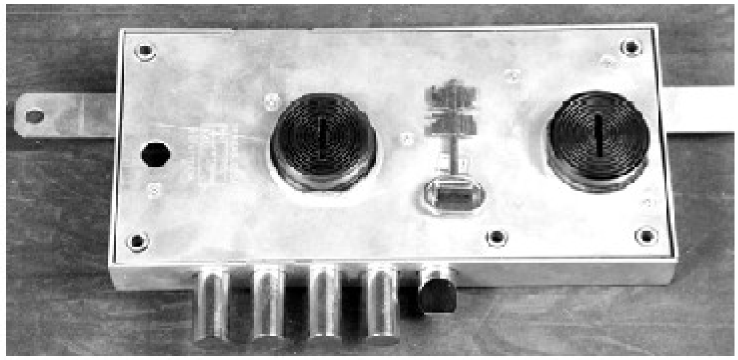


With only minimal training, the user should be able to pick and decode the mechanism in less than three minutes. There is also an eight-lever version of the lock, which can be bypassed with the same decoder in even less time. Up to five minutes will be required to construct the variable key, but this can be done in another location.

31_4.4.1.9 Mottura Serrablocca Pump Lock

This Falle system is designed for use on the Pump mechanism contained as part of the Mottura Serrablocca lock. This unusual design is a combination of two separate locks in the same body. The key has features of both a pump key and a lever lock key and has to be inserted into both keyways in sequence.





The lever portion of the mechanism has to be operated before the pump section can be turned. This can be accomplished with either a Pin and Cam system or the Euro lever lock Decoder described earlier. The Pump decoder is a quick and easy way of defeating this mechanism, and it will open the lock and produce a key code for future entries. This system will usually result in an opening in less than ninety seconds.

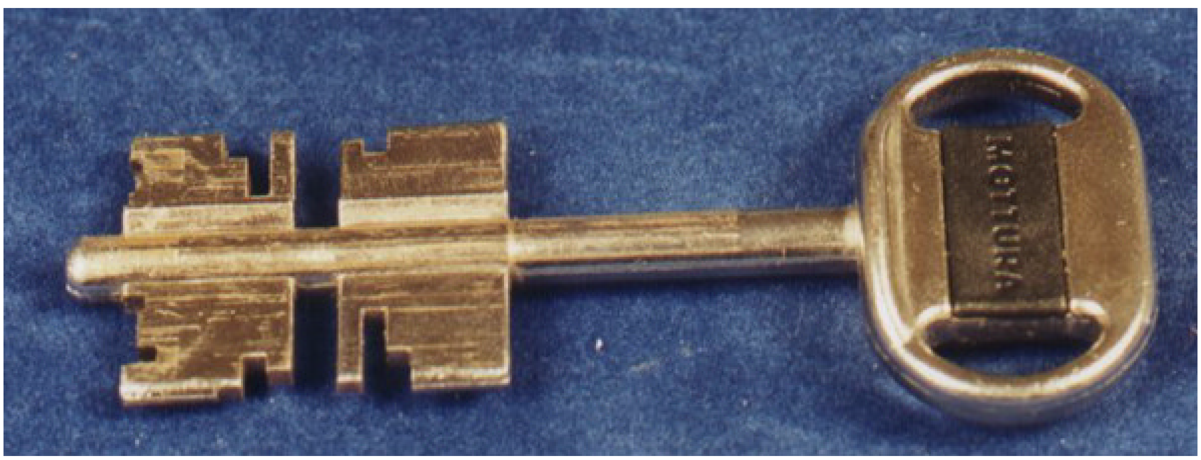
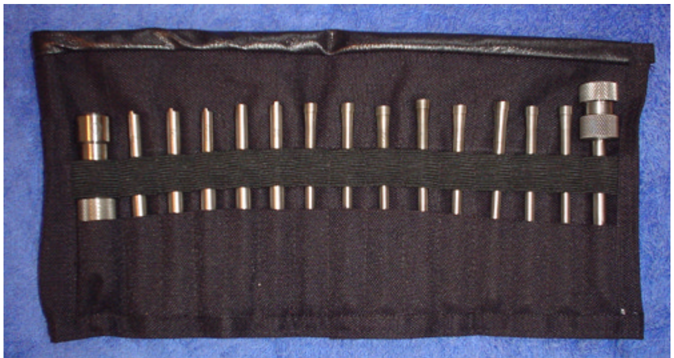


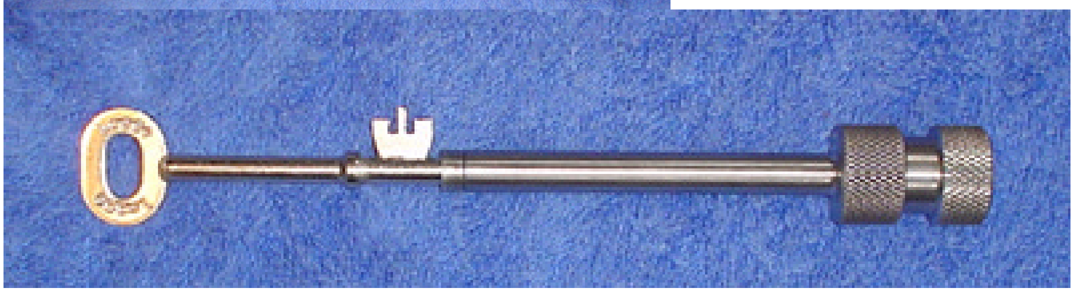
Figure LSS+3113 The Mottura double-bitted lever key. Courtesy of John Falle.

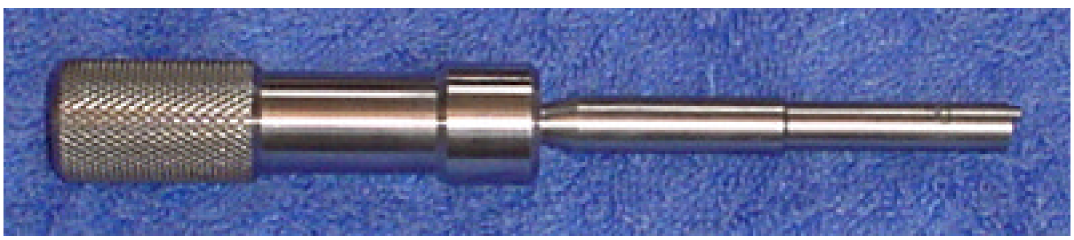
31_4.4.1.9A Key Turning System

LSS304: Key turning system for lever locks, by John Falle

A system for turning European lever keys from the other side of the lock is available from John Falle. In certain instances, the owner will have left the key inside the lock on the other side of the door. The kit is designed to grip the end of the key that is available through the keyhole. The system is neither a decoding nor picking tool.







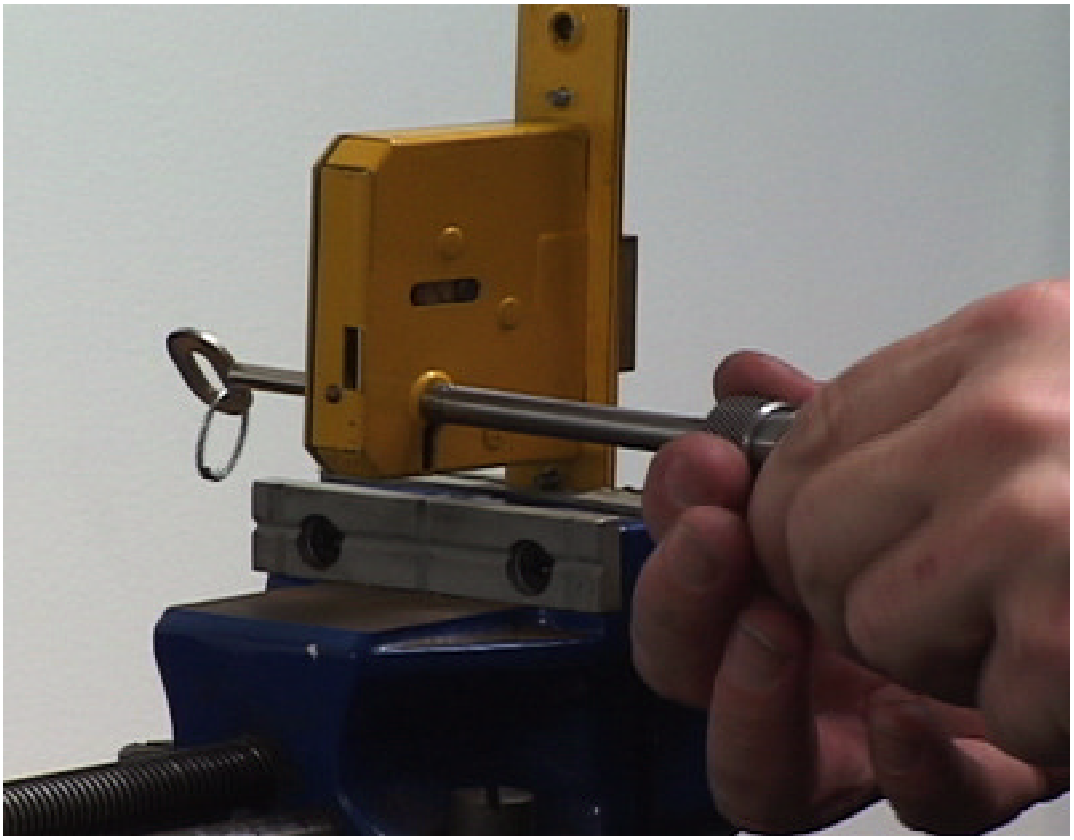


Figure LSS+3131. A key turning system for lever locks.

31_4.4.2 Wafer and Disc Lock Decoders

In **Section 3.2**, decoding and reading of wafer locks by the direct observation of active locking components was discussed. Those procedures were based upon the ability to actually see or measure the bitting for each wafer. In this section, we will concentrate on indirect measurement of the bitting surfaces, requiring an extrapolation of data in order to arrive at the proper code. Many United States patents have been granted for decoders of wafer and disc locks. Five primary patents have been issued since 1934 and are summarized here. In addition, sophisticated systems developed by John Falle are described.

31_4.4.2.1 Code Finding Devices

Several "code-finding keys" have been patented. Generally, the function of these devices is to determine the height of each wafer when raised to shear line. Simon developed a "code-finding key", in 1934 (**2015322(307)**) for determining the depth of each

wafer. The design utilized a key, with each depth-cut having several longitudinal segments. This allowed the device to be moved within the lock in an attempt to determine which tumbler was at shear line.

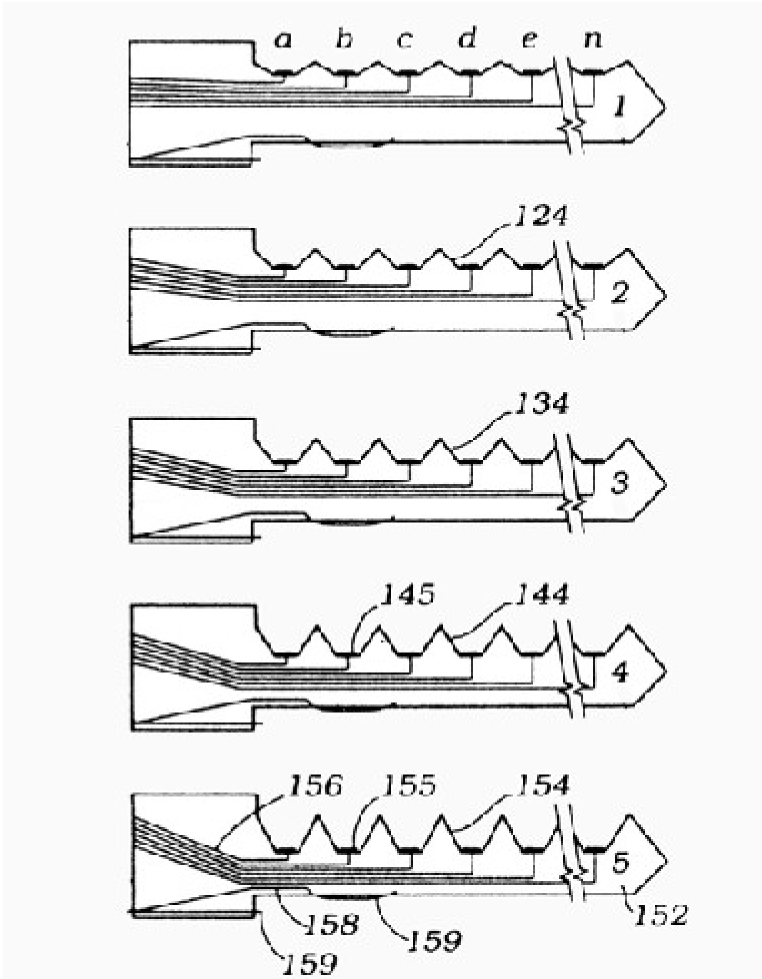
The following year, Hansen (**1991151(308)**) developed a decoding and reading device for wafer locks that utilized a sliding pick attached to a gauge. The feeler pick could be moved both horizontally and vertically to manipulate each wafer and read it. In 1937, a patent (**2066645(309)**) was granted to Rial for a more sophisticated wafer decoder. This instrument was comprised of a moveable pick that was attached to a gauge. The pick could be moved laterally to cooperate with each tumbler. As the wafer was raised to shear line, a reading would be taken to determine its depth.

In 1941, Hoffman (**2257054(310)**) invented a device for decoding a pin tumbler lock with a mechanical feeler that also allowed manipulation of the tumblers.

Tampke received a patent (**2727312(311)**) in 1955 for a device that was capable of decoding both wafer and pin tumbler locks. The tool would sense the position of the active locking component when it reached shear line and provide a display of the position of the tumbler that could then be correlated with a depth chart. Easley patented a decoder for a Schlage wafer lock in 1985 (**4517746(312)**). The lock was discussed in detail in the first edition of this text and remains in use in millions of homes and apartment complexes in the United States. It can be master keyed and utilizes three types of disc wafers: **combination**, **series**, and **master**. The decoding tool allows manual sensing of the shape of each type of tumbler so that a key can be generated.

In 1987, McConnell received a patent (**4680870(313)**) for a wafer lock decoding system using a feeler key and shim to determine tumbler positions.

In 1992, a patent was issued to Grant (**5133202(314)**) for a decoder that would sense the position of each wafer through the completion of an electrical circuit. A specially designed set of depth keys would have an electrical contact at the base of each tumbler position. Each key would be inserted and the conductivity of each wafer detected. Any tumblers at shear line would show a different resistance than those not properly aligned.



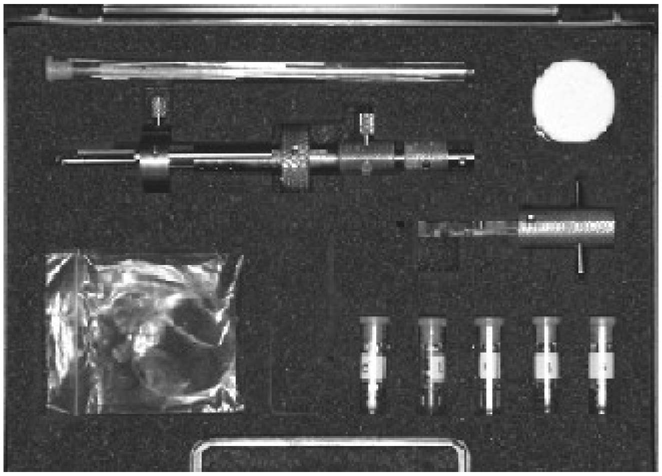
In 2000, a device was patented by Kang for a lock picking tool that utilized a clever reading tool that allowed recording of tumbler position (**6134928(315)**).

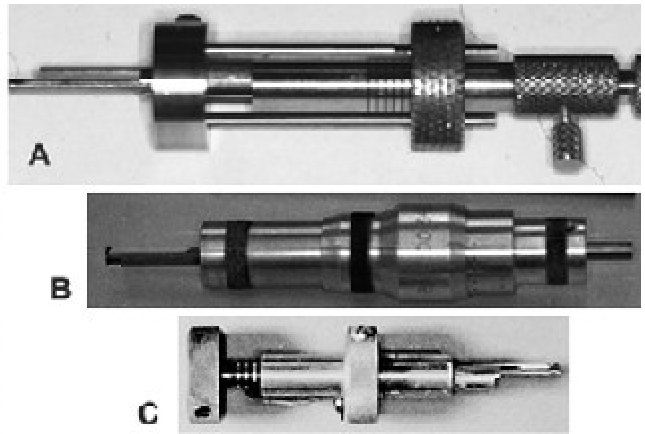
31_4.4.2.2 Abloy Disklock and Granit Decoder Systems

Forensic implications of picking or decoding the Abloy lock. Courtesy of Hans Mejlshede.

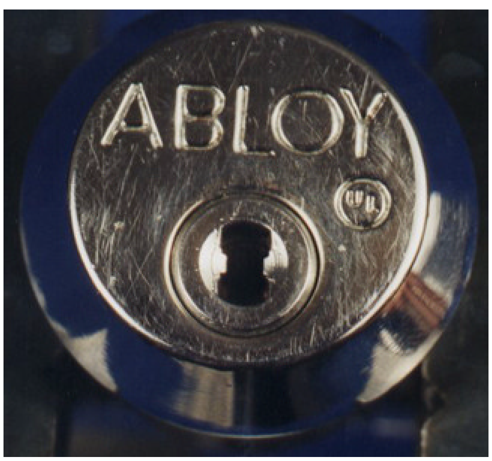
According to Falle, the Abloy and **Granit** disc lock decoding tool was perhaps the most challenging to conceive. This was due to the multiplicity of lock designs that incorporate slightly different disc patterns by both Abloy and **Abus**. It was almost impossible to develop one tool to open all of the Abloy locks.

The resulting tool opens all but two of the systems and decodes all but one of them. The Abloy lock is fully described in **Chapter 17.**





The system will decode and open all variations of the 6 mm diameter Semicircular keyway locks, with small, medium, or large discs having reversible and non-reversible design. It will decode and open all of the newer 7.5 mm diameter keyways, small and medium discs, irrespective of the format.







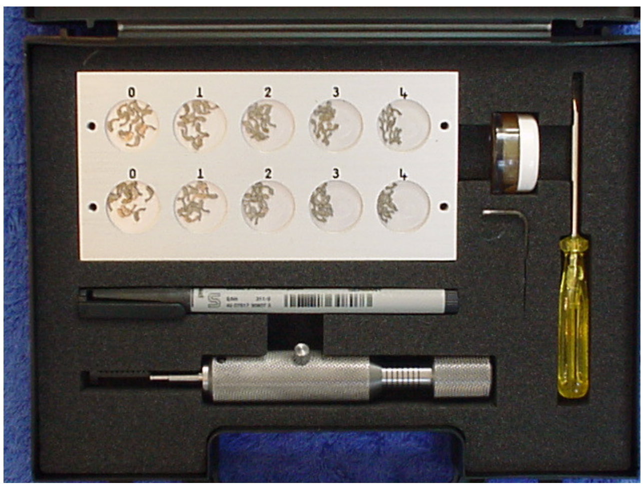
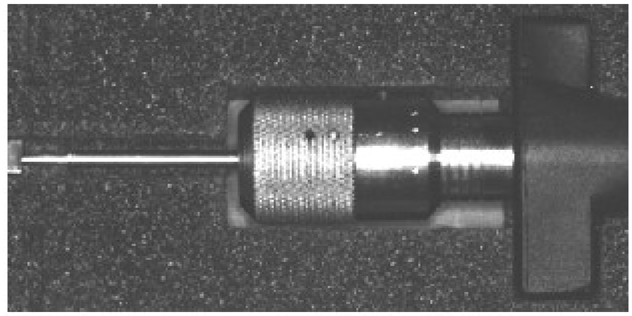


Figure LSS+3114 The different Abloy DiskLock models, and the Abloy pin and cam system.

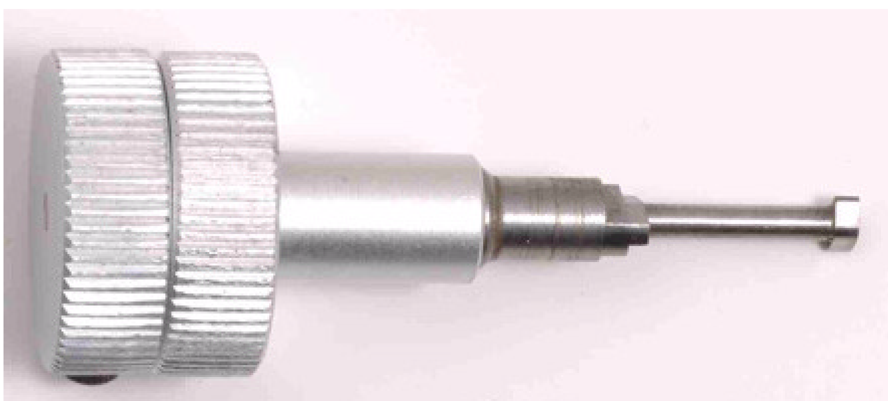
It will decode but **not** open the Abloy Disklock, but it will not decode or open the Abloy Disklock Pro. The fundamental differences between the **Disklock** and the **Disklock Pro** is that the **Disklock Pro** contains spacers of two different thicknesses. These hardened steel black spacers have a different thickness than the brass spacers. If a locksmith has inserted a combination of the brass and the steel spacers, the lock cannot be decoded. The tool will not work on copies of the Abloy system, such as the reproduction from the Orient.





The device is provided with an attachment enabling it to decode and open the Abus Granit lock that has gained such popularity worldwide. Abus produces the lock in four different configurations.

LSS301: Abus decoder, by John Falle

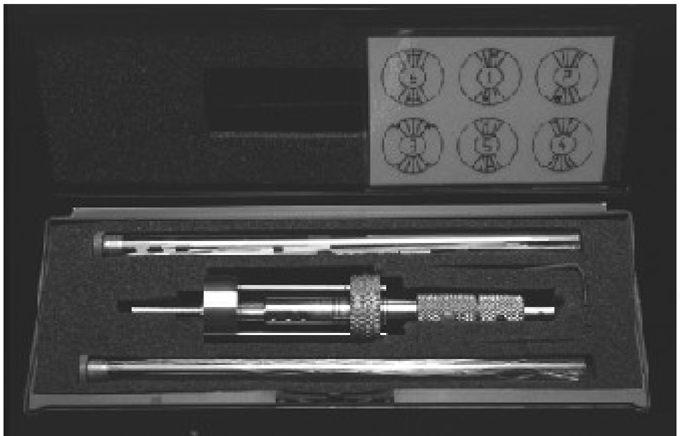


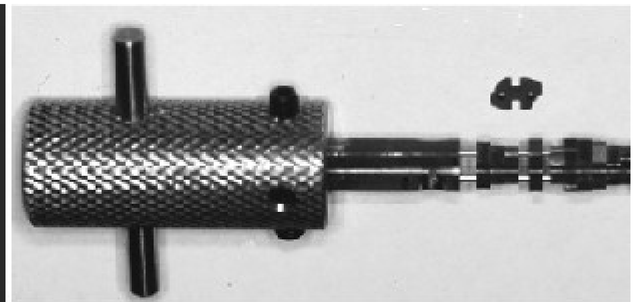
This Abus pick will open both the new and old Abus Plus. The tool was originally invented by Andreas Pabst.

31_4.4.2.2.1 Abloy Disklock Pro Decoder System

LSS303: Abloy decoder system, by John Falle

This system will decode the Disklock Pro. The system has been primarily designed for use on the standard profile keyway, although it may be effective on locks that have modified profiles, which vary in different countries.







The system is designed to decode but not open the lock. Decoding can occur within two minutes with practice.

31_4.4.2.2.2 Abloy Variable Key Generation System

The Variable key generation system is designed to be used in conjunction with the Abloy decoders described above. It enables the user to construct a working key to the code that is derived from the decoder system. The finished key is very precise and conforms perfectly to the specifications of the factory original.

The code must be correct for the key to function. The variable key is quite expensive. This is due to the maintenance of high tolerances during production, using a manufacturing procedure called wire erosion. Construction of the key is very easy and only takes a couple of minutes to complete.

31_4.4.2.3 Tibbe Lock Decoder





Figure LSS+3133 Ford Tibbe decoder and lock. This tool is produced by John Falle.

Falle has devised a combination pick and decoder for the **Tibbe** disc lock that was introduced in Ford and Jaguar automobiles in Europe about 1987. This lock, as described in an earlier chapter, functions in similar fashion to the Abloy disc mechanism. It is a modified sidebar mechanism that relies upon the rotation of discs rather than depth cuts.

The lock is currently produced in two versions: one with six discs and four differs (rotations from 0^{o}- 37^{o}) for each tumbler; the other has eight discs, with three differs (used in Jaguar). Each disc has a hole in its center with angular cuts on the side and a sidebar groove. When all discs are rotated and aligned, the sidebar drops into place. The key has two sides and four identical rows of bitting with a left and right row on each surface. This allows the key to be inserted for either orientation.

The decoder pick is primarily designed for use on the six-disc mechanism, although it may also be used with the larger lock.

The tool is really a modified two-in-one wheel pick, utilized for lever locks. Tension is applied by way of the torque bar. This is inserted into the lock, and hooks into the drain hole on the bottom of the plug. Once tension is applied, the pick can be used to manipulate the discs into the correct position for opening. The picking process involves feeling for true and false gates; the tool will constantly provide an indication as to which disc is being manipulated. Once opened, the direct code can be read from the dial markings on the body of the pick. A key can be cut using the HPC BlueSHARK key machine, and certain Framon cutters, with a special attachment.

31_4.4.2.4 Chubb AVA

LSS304: Chubb AVA pick and decoder system, by John Falle

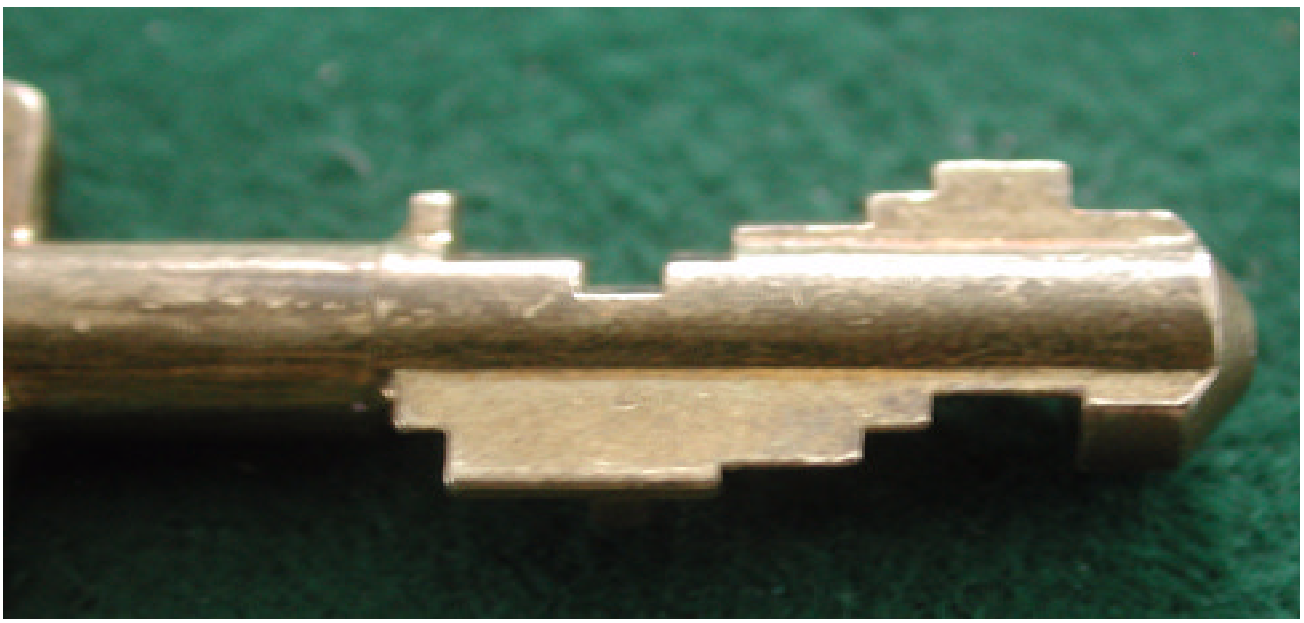


Figure LSS+3134 Chubb AVA key.

The modified wafer mechanism has been described elsewhere in this text. Falle has developed a **decoding system** that works on the ten-detainer Hercules padlock and other standard designs. The system is most effective on the smaller nine-detainer mechanisms, the Ford AVA, and the Chubb Guardian systems.

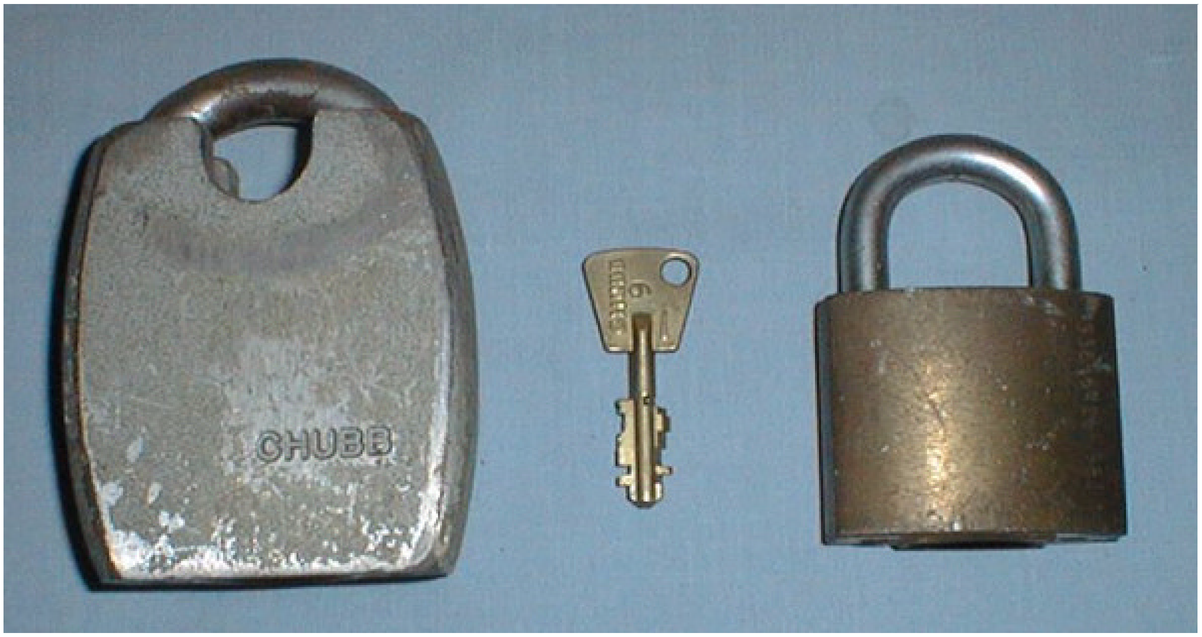
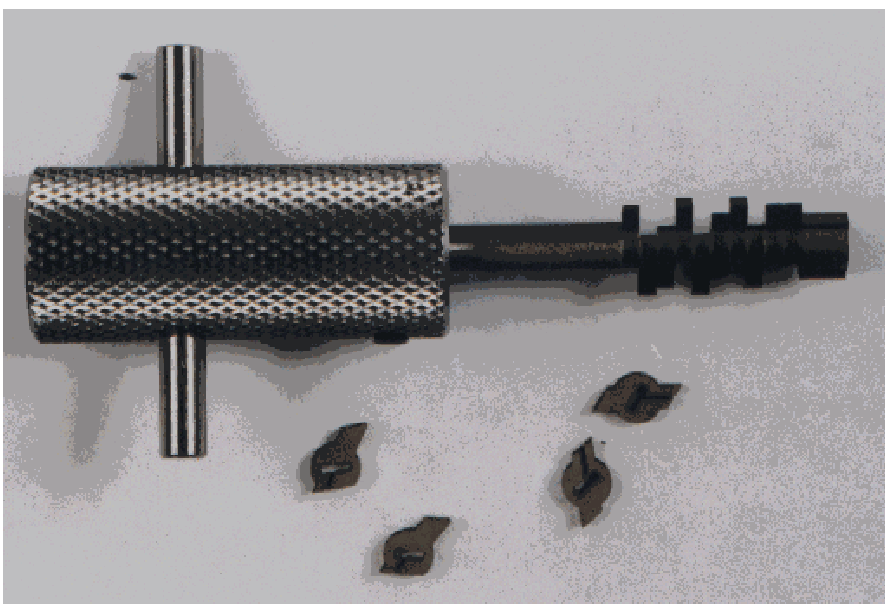


Figure LSS+3115 The Chubb Ava padlock. Courtesy of John Falle.





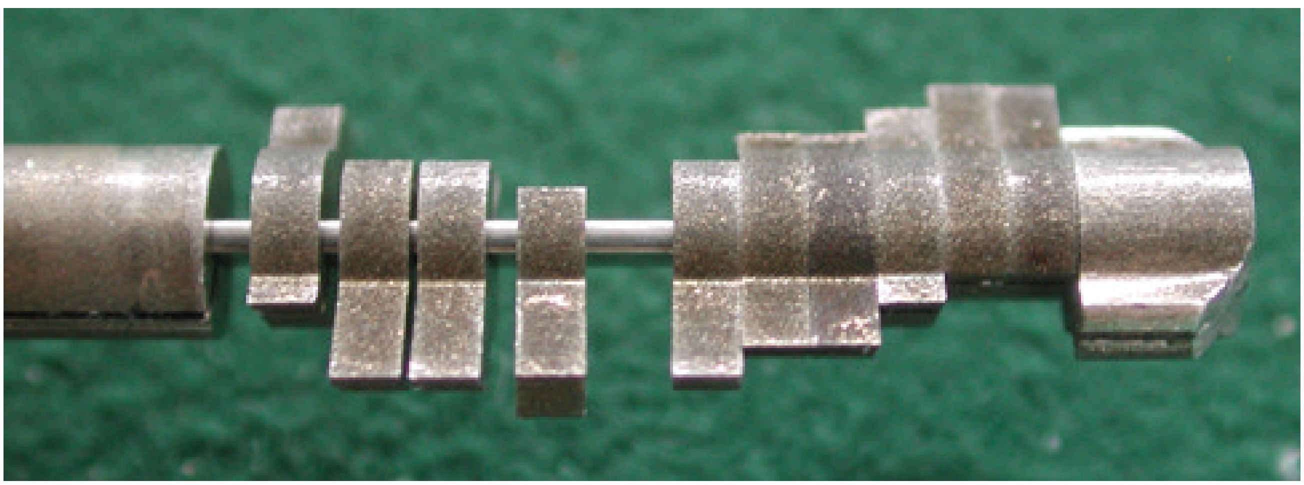


Figure LSS+3116 The variable key generation system for the Chubb Ava wafer lock. Once the lock is decoded, a simulated key can be produced with the same codes. Courtesy of John Falle.

31_4.4.2.5 Evva 3KS Laser Track System

LSS305: EVVA 3KS pick and decoder system, by John Falle



Figure LSS+3117 The Evva 3KS system can decode and simulate a key. Courtesy of John Falle.

The 3KS has been described in **Chapter 17.** It is a sophisticated mechanism that incorporates twelve sliding detainers and two sidebars. The lock is produced to high tolerance and is considered to be highly secure against bypass. The decoder system will open this lock and also provide the user with a code, which can then be utilized to construct a working for later use. It is expected that a variable key system will be available for the 3KS.

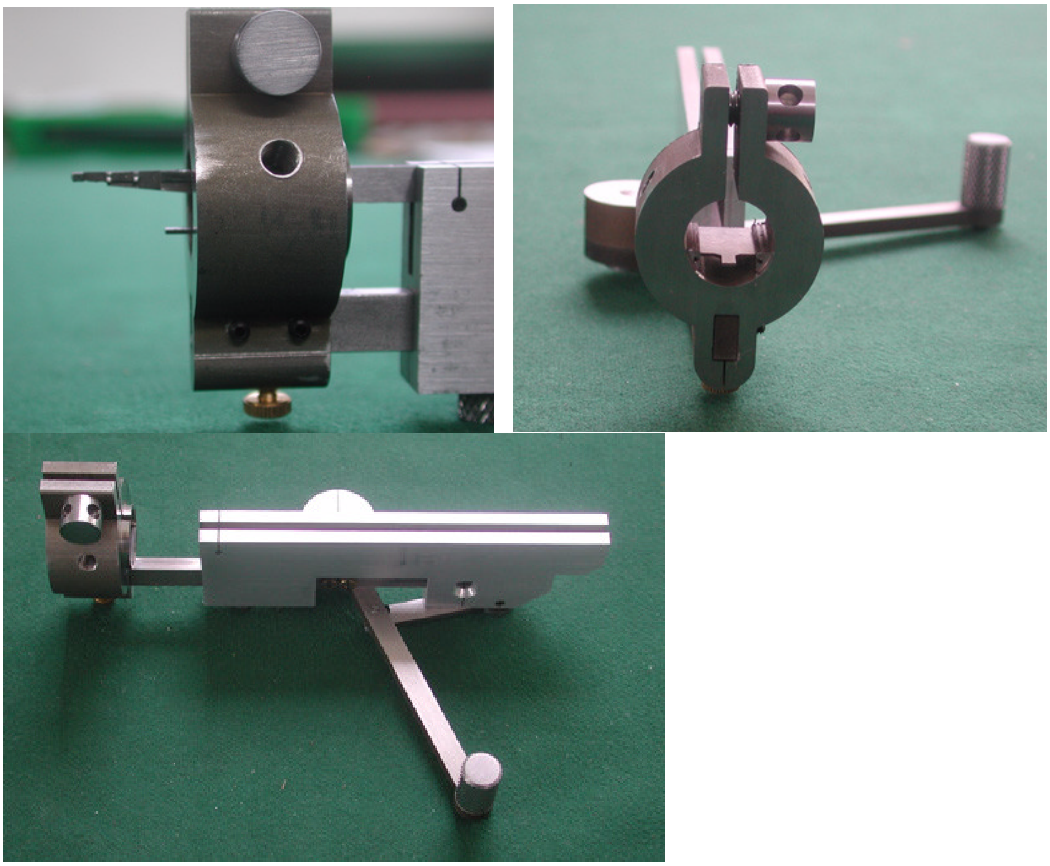
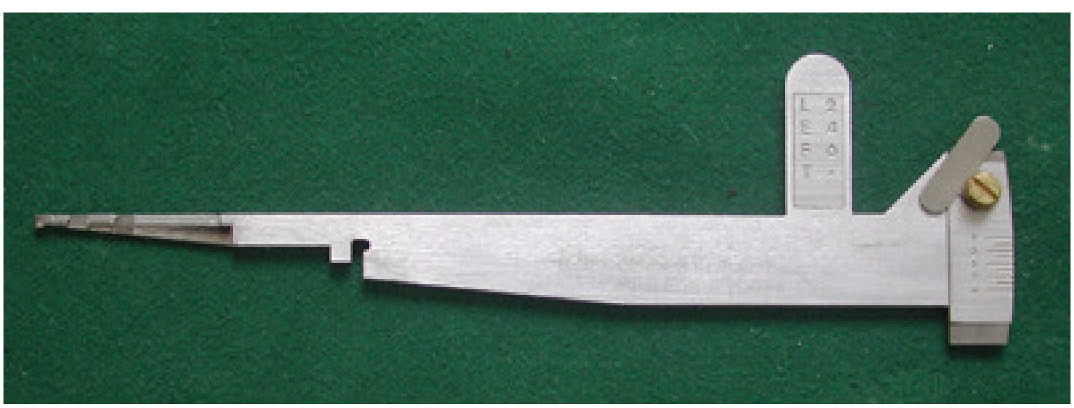
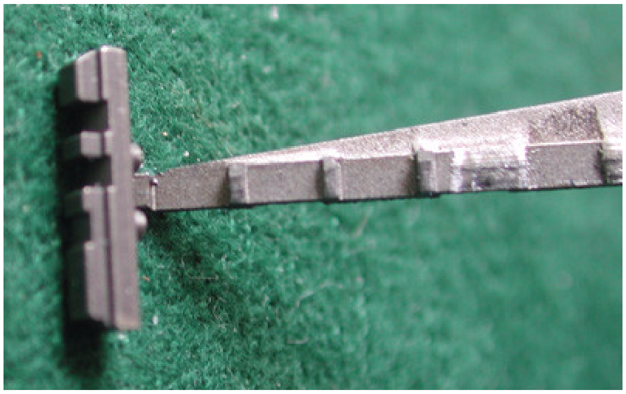


Figure LSS+3135 The 3KS pick and decode system allows the manipulation and decoding of each slider as they are moved into contact with the dual sidebars.

There are system limitations inherent in the decoder tool, which concern its fragility. Some of the decoder components are very weak and will not stand rough usage. The decoder must be used by a skilled operator who has been trained on this specific system. The system requires a minimum level of light during use. The process can require several minutes to complete.





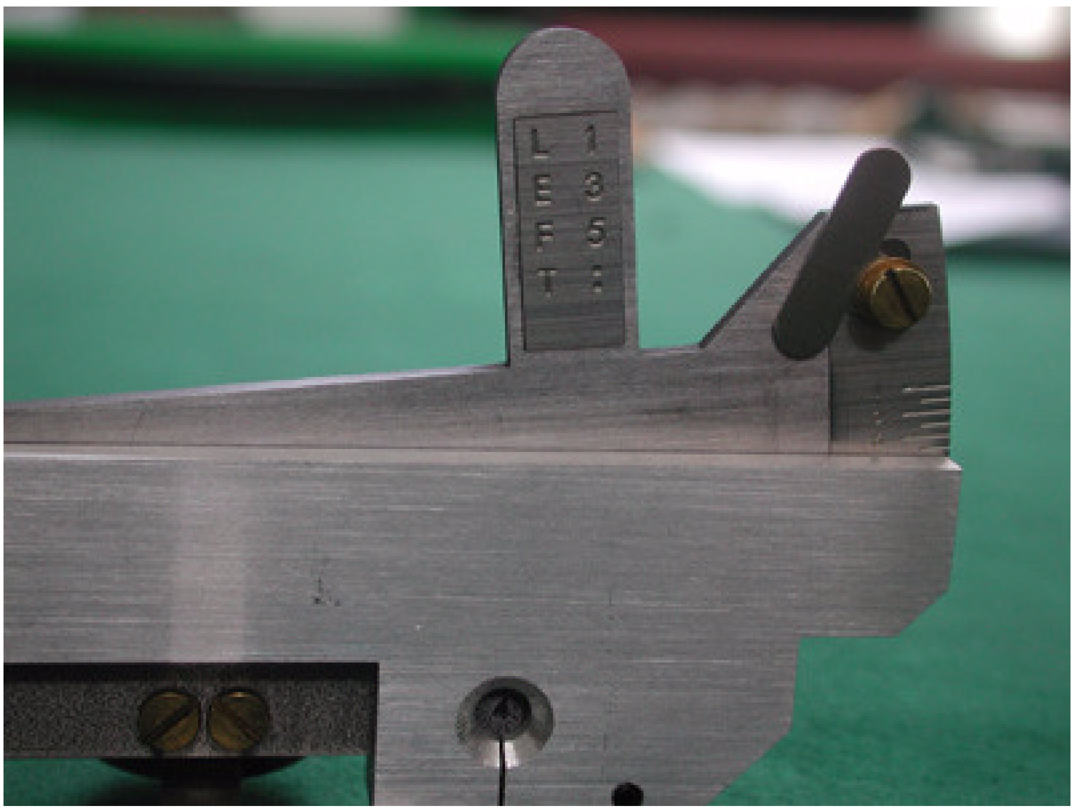
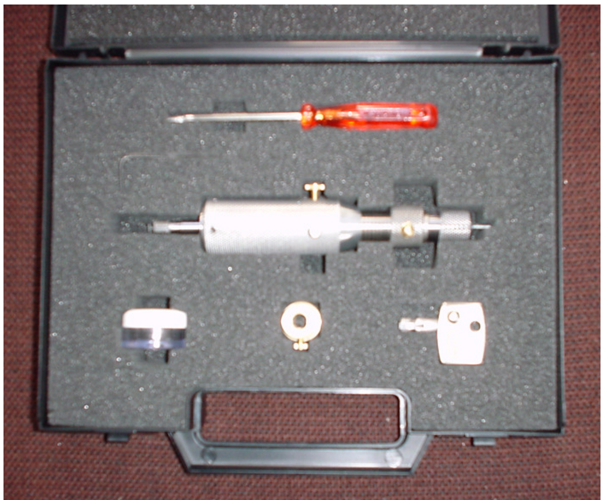


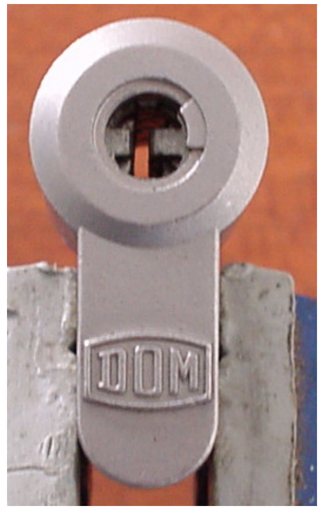
Figure LSS+3136 The slider probe has two distinct designs that allow movement of each wafer. The tool allows a direct reading of each wafer position.

A skilled operator can usually open the a lock in under ten minutes. This period can be interrupted and the user can continue from the point of tool extraction. The process allows the lock to be decoded while it is being opened. This is a very specialized tool that requires proper training in its use.

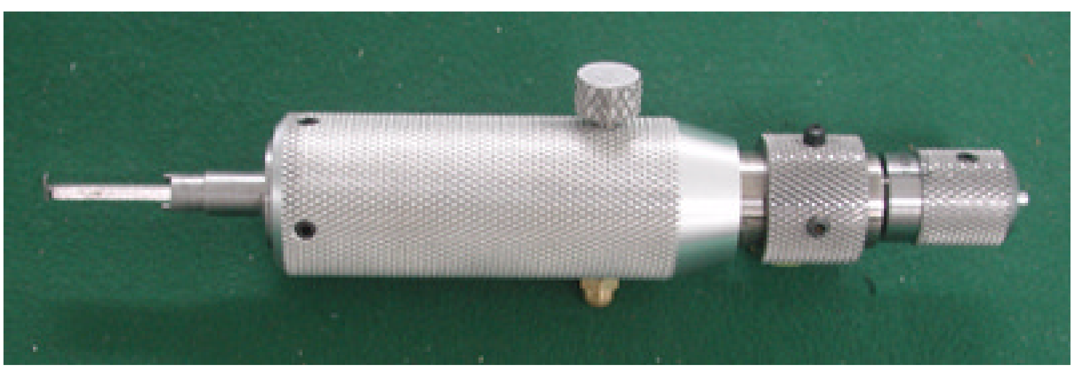
31_4.4.2.6 DOM Diamond Decoder

LSS304: DOM Diamond decoder and pick system, by John Falle.









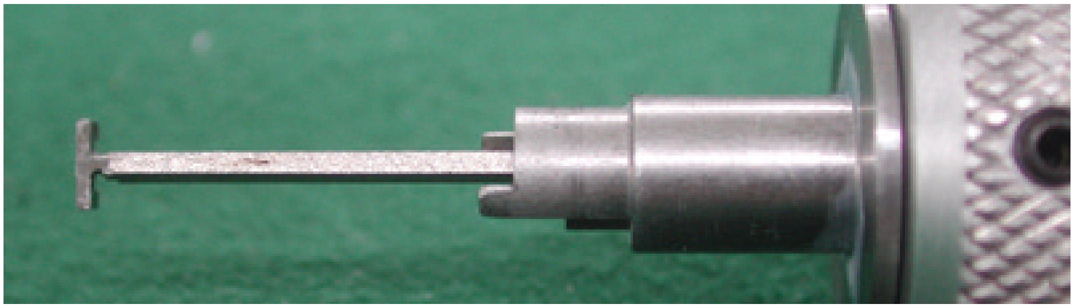




**Figure LSS+3118 The Dom Diamond decoder system by John Falle. The lock in some respects
resembles an Abloy because of the use of wafers.**

This John Falle decoder system is for use on the German DOM DIAMOND mechanism. The lock is very accurately engineered with high tolerances and contains ten rotary discs of an ABLOY type design. The lock is an engineering masterpiece but is very expensive and quite rare. The tool can easily open this lock and also provides the user with a code for future use.



Figure LSS+3119 The Dom Diamond key is very distinctive and unique with its surface of complex angles.

The main limitation of the system is speed. As with all decoder

picks, the time required will depend on the skill of the user. This tool is much easier to use than the Abus Granit decoder, and a skilled operative should be able to open the lock in less than three minutes. Once the lock has been opened, a further ninety seconds will be required in order to determine the code. There are no other machines available that can cut these keys to code. The only way to open the lock a second time with this system is to use the system as an auto-dialer. It is therefore recommended that the user always determine the code if a future entry is required.

This is a highly specialized decoder for use on a top security lock. The system would only be taught as part of an Advanced Entry Course where a full day would be dedicated to its use. The skilled user should be able to open the lock in less than three minutes.

31_4.4.2.7 Ford Galaxy Decoder

The John Falle decoder system is an extremely effective tool for use on the two-track wafer mechanism fitted to Ford Galaxy vehicles. The lock is also fitted to other automobiles including various models of Volkswagen and Audi. This decoder is extremely easy to use and not only opens the lock but also determines the code for future openings. The method employs a variable key that is an integral part of the decoder, and this can be used to open the car on future entries if required. The technique employed in this decoder is a variation of the Pick and Form technique used in other systems such as the Bi-Lock Decoder.

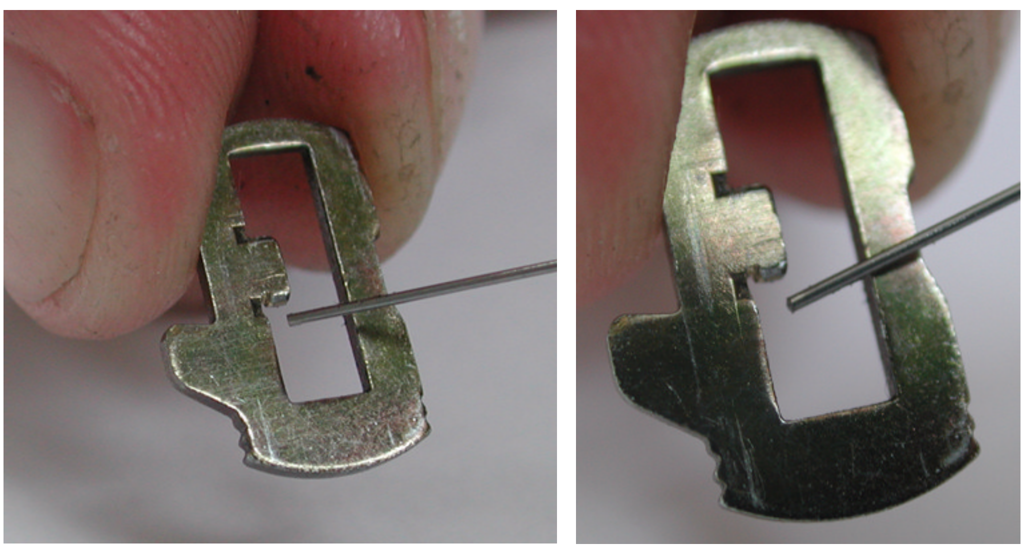


Figure LSS+3141 Ford Galaxy wafers, showing indication of picking

and decoding, indicated by pointer. Note slight indent during forensic examination.

The only limitation of this system is that it utilizes variable key shims of the cut-out variety. This means that each time the user decodes a lock, two shims are required and these cannot be reused. The operative will therefore need to purchase replacement shims from time to time and that will incur additional cost.

This system is very quick; the user should be able to open the lock and achieve the code within a period of two to three minutes. The technique is quite easy to learn and only requires about an hour of instruction.

LSS301: Ford Galaxy decoding system, by John Falle

31_4.4.3 Sidebar Decoders for GM and Ford Automobiles

Four principal U.S. patents have been granted for automobile lock sidebar decoders: (**4185482(316)**) 1980; (**4667494(317)**) 1987; (**5325691(318)**) 1994; and (**5224365(319)**) 1993. There are several methods to pick, decode, and open these sidebar locks as described in the patents. The locks can be bypassed in the following manner:

- **Obtain the code from the lock body or glove compartment cylinder. If this procedure is used, then the last two cuts must be determined through trial and error. Remember, in GM cars since 1974, the ignition cylinder is keyed differently than all other locks;**
- **Remove the sidebar and examine the wafers and position of the "V" cuts, then insert a blank and read the position of each tumbler;**
- **Place pressure on the sidebar, pick the lock, and read the depths using a decoder;**
- **Utilize a patented decoder to pick the lock and derive the code.**

In the case of the Briggs and Stratton lock, there are certain rules that will aid in the decoding process:

- **The original lock had four bitting depths;**

- **In 1966, an additional depth was added, bringing the total to five;**
- **The maximum difference between adjacent depths can be two;**
- **The maximum number of equal depths on a key can be no more than four;**
- **There are never more than three equal depth cuts adjacent to each other;**
- **The R&D decoding tool can be used to read the lock after picking.**

A-1 Security Manufacturing Company makes a set of picks for GM-10 cut locks that does not require drilling. The system allows pressure to be exerted on the sidebar; it is then a simple matter to move the gate of each wafer under the sidebar to allow the plug to turn.

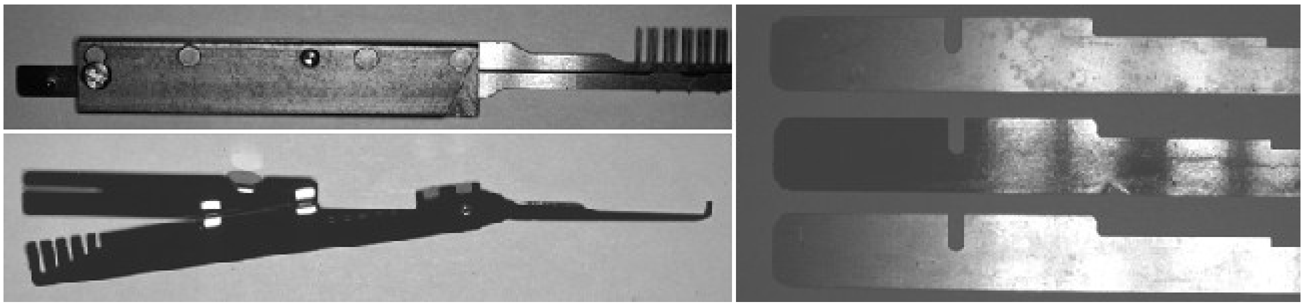


The A-1 GM 10 cut pick system, courtesy of Harry Sher.

31_4.4.3.1 Joosten Pick/Decode Tool for GM and Ford Locks

A Patent was granted to Doug Joosten, R&D Tool Company (**4667494(320)**), for two unique sidebar pick and decode devices. These instruments are for use with GM and Ford locks and provide

an easy method to open them. Because of their popularity, detailed information is presented in the Infobase and on **www.security.org**.



Exploded view 1, 2.

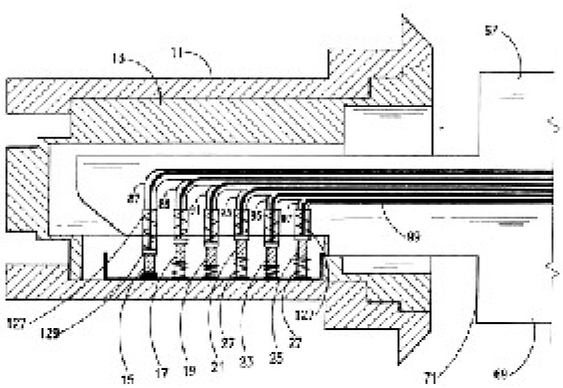
Pick tools for the sidebar lock, courtesy of Harry Sher.

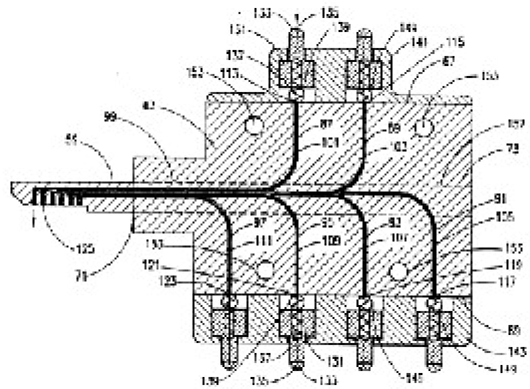
The Joosten tool actually consists of six individual devices: Spring compressors (3), shutter retainer, spring retainer with slide, and decoder. A spring compressor is configured for insertion into the keyway. It raises all the tumblers to a radially outward position and compresses the springs that normally bias the tumblers inwardly. A spring retainer tool is inserted into the keyway in concert with the spring compressor tool. It engages the wafer springs to retain them in a compressed position, thereby freeing the tumblers for movement.

A tumbler-adjusting tool is inserted to grasp the wafers and move them to a position where the lock mechanism can be opened. A decoding tool is then inserted to measure the radial position of each tumbler. It provides a code number that can be used to make a new key. A dust cover holding tool is provided to hold open the spring-actuated dust cover.

31_4.4.3.2 Dobbs Sidebar Decoder

A patent (**5224365(321)**) was granted in 1993 for another type of sidebar lock decoder. This device utilizes individually controlled pins that decode the position of each wafer after manipulating the tumblers simultaneously into alignment with the sidebar.





Narrow passages within the decoder provide channels for plunger wires to control each wafer, and to rest at a reference point that corresponds to the location of each gate. Individual windows allow viewing of the depth of each plunger in its chamber. At least one graduated scale on each housing corresponds to the wafer depths of the lock. It indicates the position of each plunger in relation to its threshold reference position, when the wafers are manipulated into the "open lock" condition. A similar device is produced by MSC in Germany. The "Sputnik" allows the manipulation of individual tumblers through the use of fine wires. It is described elsewhere in this text.

31_4.4.3.3   Embry Sidebar Decoder

A patent was granted in 1994 (**5325691(322)**) for a sidebar picking and decoding method that differs from that of Joosten and Dobbs. The device is comprised of a tool to apply torque, a picking tool, and a decoding tool. Torque is used to bias the sidebar out of its notch in the inner wall of the cylinder housing, and the wafers are then manipulated with the pick. The plug is turned slightly and the torque wrench is removed. The position of each wafer is then decoded. This system is unique in that it purports to afford a quick means to both pick and decode a General Motors sidebar lock.

31_4.4.3.4   Nail Sidebar Decoder

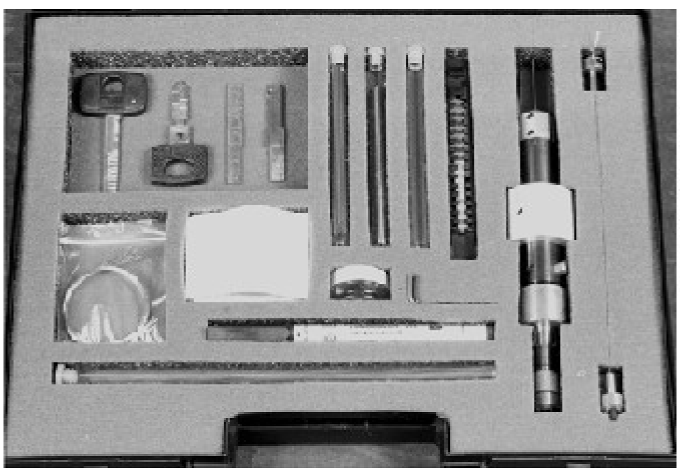
In 1980, Nail was granted a patent (**4185482(323)**) to pick and decode Briggs and Stratton sidebar locks. The tool used sliding shims with tooth-like projections.   Each would mate with an individual wafer for raising them and feeling movement. In operation, each of the wafers is raised so that their V gates would be positioned above the intersecting point of the sidebar.

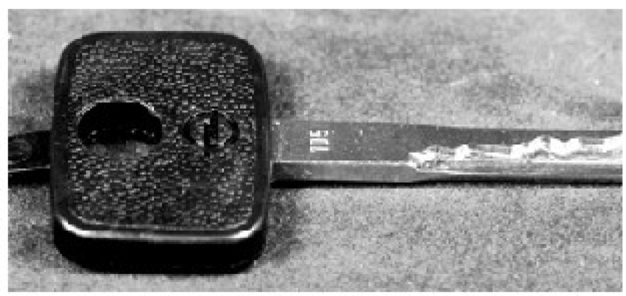
As each wafer was released when the decoding tool was withdrawn, a change in resistance would be felt when the gate passed the sidebar. This information would be displayed on the tool and noted, thereby disclosing the depth code for that bitting position.

31_4.5 Laser Track Decoders

LSS302: BMW lock decoder system, by John Falle

Many foreign automobiles utilize a "laser track" locking system to improve security against picking. These mechanisms are actually modified wafer designs that require the discs to slide across the surface of the blank within tracks. All of these locks are similar in design. A patent was granted in 2000 to Magini for a decoding system for laser track locks (**6148652(324)**). This process allows the probing of all four tracks simultaneously.





The Falle decoder system is a modified Pin Tumbler Lock decoder described elsewhere in this chapter. Presently, the system is effective on the following lock mechanisms, with other attachments for additional locks under development:

Bypass of laser track or sidewinder locks. Courtesy of Hans Mejlshede.

- **BMW HUF (4 track HU 58, 59, and 63 profiles), and 2 track**
- **Ford Galaxy (2 track internal HU66 profile)**
- **Honda Legend (4 track internal)**
- **Lancia Alfa (2 track)**

- **Mercedes HUF (2 track HU41 profile, and 4 track HU39 profile)**
- **Nissan Infinity (4 track NSN9P and NSN10 profiles)**
- **Porsche 928 lock**
- **Saab (2 track)**
- **VW/AUDI**
- **Toyota Lexus (4 track internal)**
- **Vauxhall HUF and YMOS (2 track YM27 and HU43 profiles)**
- **Volvo HUF (2 track HU57 profile and 4 track)**



Figure LSS+3120 The Falle vehicle decoder system will open many laser track locks. Courtesy of John Falle.

The system is only capable of determining a code for the key and will not open the lock. Opening speeds can vary from lock to lock, but most vehicles can be decoded in less than two minutes.



Figure LSS+3140 BMW decoder produced by Silca.

31_4.6 Decoding Devices Using Fine Wires or Shims

A number of sophisticated decoding devices rely upon the insertion of fine wires or shims to obtain information about the active locking components. These instruments typically contain a shim for each tumbler or allow for the introduction of one very fine wire to measure each component in sequence, then tactually determine its position. Devices have been designed to pick and decode lever, wafer, disc, sidebar, and pin tumbler locks. Some are fairly simple in their operation; others are quite complex and sophisticated. Decoding devices introduced by Falle and others allow for the acquisition of a great deal of information, including:

- **Position of rotating discs and their gates in the Tibbe, Abloy, Ingersoll, Abus, and other locks;**
- **Determination of the height of levers;**
- **Height and rotation of pins in standard pin tumbler and Medeco locks;**
- **Determination of the height and position of pins within a dimple pin tumbler lock.**

Perhaps the most sophisticated device is the Falle pin lock decoder. This tool allows the introduction of a fine wire into the cylinder through a sheath in the form of a needle. The wire probe is positioned under each pin tumbler and then moved vertically to the break point between lower pin and driver. Precise indexing marks on the tool provide for the extrapolation

of the length of each pin. Similar and less precision devices were patented for the decoding of Medeco locks in 1976 (**3987654(325)**, **3985010(326)**) by Lock Technology Corporation.

In certain cases, information must be gathered from several locks in order to produce a composite key. Such is the case, for example, in a positional system where the master key is actually a composite of individual change keys. This situation is often encountered in magnetic card systems and dimple pin tumbler locks such as Keso. Information may be obtained from individual change keys or through electronic sensing means, wherein a number of locks are "read" to derive enough data to determine the code for the master key.

31_4.6.1 Pin Tumbler Lock Decoders

There have been many significant patents issued in the United States for various types of decoders for pin tumbler locks.

31_4.6.1.1 Pin Lock Decoders

In 1937, Abrams received a patent (**2087423(327)**) for a calibrated code finding key and pick tool. The device would gauge the height of each pin, and display the results on a dial attached to the tool. In 1944, Johnstone invented a decoding device (**2338768(328)**) that was comprised of a series of keys, each having different bitting patterns that could be interchanged to manipulate and measure the tumblers. Harwell, in 1955, was granted a patent (**2720032(329)**) for a simple device to determine the height of a tumbler, once picked.

In 1957, this same inventor was granted another patent (**2791840(330)**) for a more complicated variation of his original device. Essentially, Harwell succeeded in producing an adjustable caliper system that would work with a large number of depth and spacing combinations. Naill, in 1974, was issued a patent (**3827151(331)**) for a decoder that utilized a series of fine shims, each with a projection at its tip resembling a diamond pick. All of the shims were contained within a frame and could be individually manipulated and contacted with each tumbler. The shims together formed a key that could be inserted into the keyway. The procedure required the lock to be picked; then each tumbler would be measured and a key produced from the derived code.

A patent was granted in 1985 to Smith (**4535546(332)**) for a unique

decoder that computed the length of a pin tumbler by compressing its corresponding spring by a known factor. This instrument was designed upon the premise that all driver pins were of the same length, and that all springs when fully compressed would occupy the same amount of space within a pin chamber. Although some locks may adhere to this rule, it is not true in every case. Many manufacturers employ **balanced drivers** to prevent the use of a comb pick and similar tools.

In locks that are described by the inventor, the length of each of the bottom pins can indeed be computed with this decoder. In practice, an individual plunger attached to a fine wire was forced upward against each lower pin until the spring was fully compressed. The tool contained a calibration mechanism that displayed the distance traveled by the plunger. A table was then consulted for the correlation between actual pin length and vertical travel. From this information, a key could be generated.

In some respects, this technique resembles the Falle Pin Lock Decoder, wherein a fine wire is extended to measure the dimension of the lower pin. In the Smith decoder the tumbler is measured by forcing it toward the spring, whereas the Falle decoder runs the wire up the side of the pin to shear line. In 1992, the Smith decoder, described above, was improved upon by a Greek inventor (**5172578(333)**). Bitzios developed a pin lock decoder based upon the same premise as Smith, but more complicated.

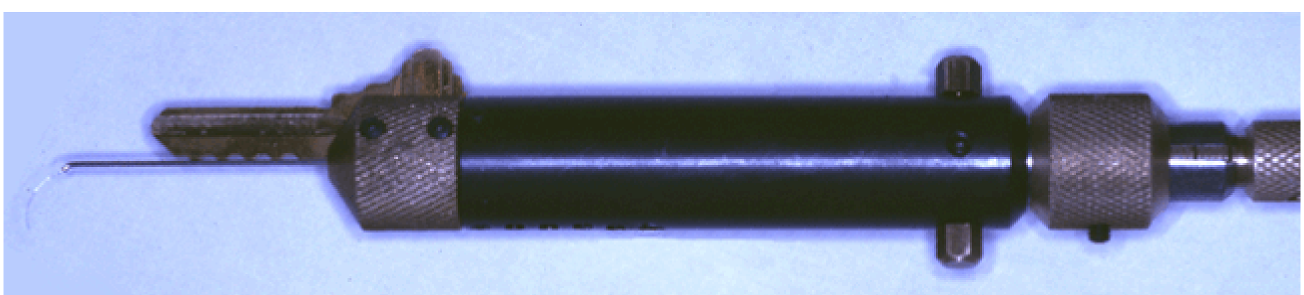
31_4.6.1.2 Universal Pin Tumbler Lock Decoder



Figure LSS+3121 The Falle Universal pin tumbler lock decoder kit. Courtesy of John Falle.

LSS302: Universal pin lock decoder, by John Falle

Falle introduced a revolutionary pin tumbler lock decoder during the early 1980s that achieved wide acceptance by law enforcement and intelligence agencies throughout the world. The device has gone through at least six generations of revisions and will work with many pin tumbler cylinders. The decoder actually measures the lengths of the lower pins without requiring disassembly of the lock. This information can then be used to construct a working key. See **LSS+/ˣ** for detailed operation instructions.



The tool consists of three primary components that provide a calibrated delivery system for a fine shim wire. The **main body**

contains the mechanism for holding a specially prepared blank key and wire tip. The **outer gauge** can slide and rotate, to control the position of the outer skirt needle that acts as a sheath for the shim wire. The **inner gauge** contains a series of 1 mm markings and controls the introduction of a very fine shim wire contained within the skirt needle.

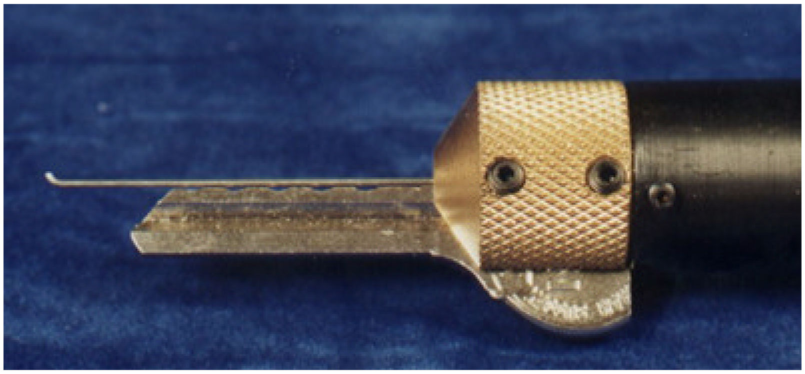
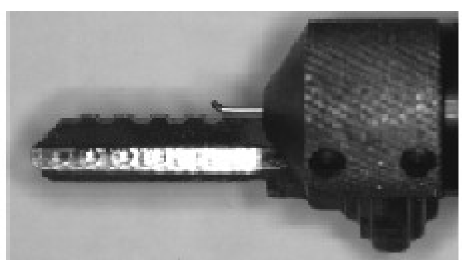
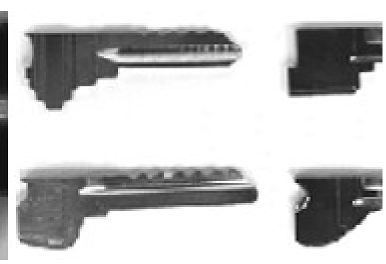


Figure LSS+3122 The pin lock decoder with the needle extended in the probe position. Courtesy of John Falle.

In use, the tip of the needle is positioned upside-down into the forward recess on the key blank. The decoder is then **inserted into the lock** so that the pins and the drivers are situated above the needle. The needle is rotated 180° into its upright position, directly underneath and to one side of the pin to be measured. With the needle in this location, the inner gauge is pushed forward, thereby forcing the fine shim wire up the side of the pin until it engages at the base of the driver.







When the tip of the wire strikes the driver, the inner gauge will be stopped, displaying the distance that it has traveled. This distance corresponds exactly to the length of the lower pin. Once the reading has been taken, the wire is retracted back into the needle, the needle is rotated into its upside-down position, and the tool is withdrawn from the lock. This process is then repeated after repositioning the wire on all the remaining pins, in succession, until decoding has been completed.

The data thus produced can be correlated with a unique set of known measurements provided for each lock manufacturer and model. Because there may be slight variances in the actual readings, some extrapolation is required. The data is translated to produce a working key, using one of the Falle variable key generation systems described later in this chapter.

31_4.6.1.2.2 Pin and Cam Pin Lock Decoder System

LSS305: Pin lock decoder system with pin and cam technology, by John Falle.

John Falle has introduced a significantly more sophisticated design of the original pin lock decoder system, described above. It combines the technology of the shim decoder with the advanced pin and cam system. The resulting technique allows relatively unskilled technicians to be virtually guaranteed of successful bypass of those locks for which the tool is designed.

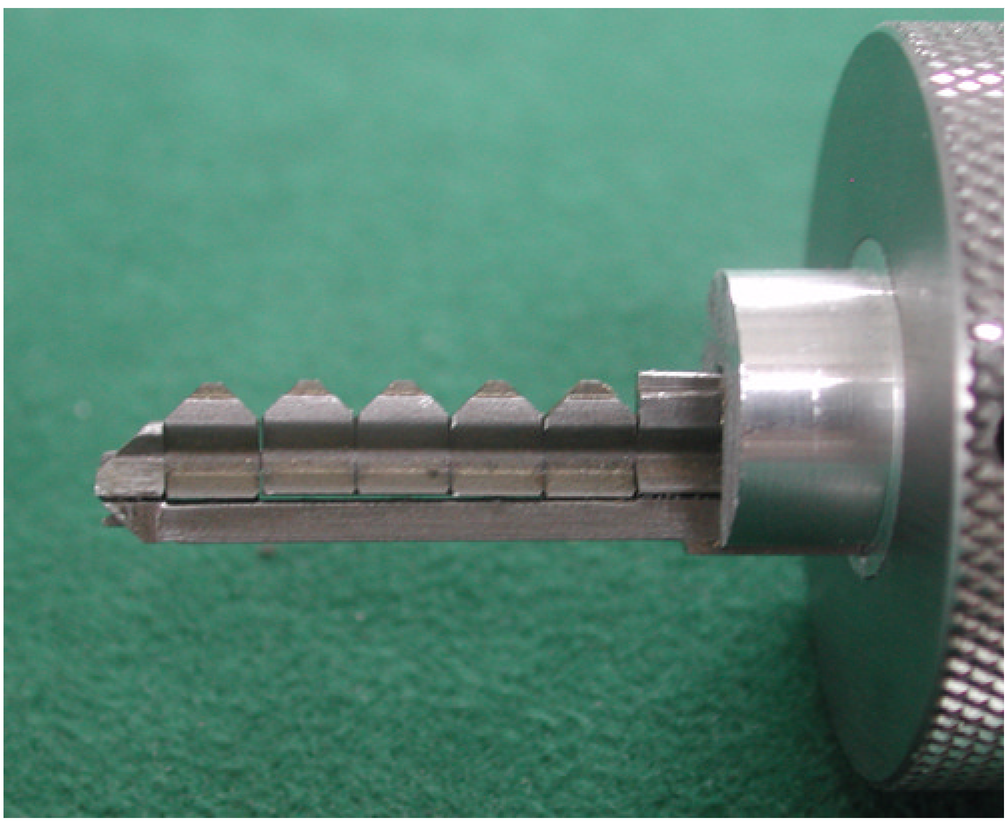
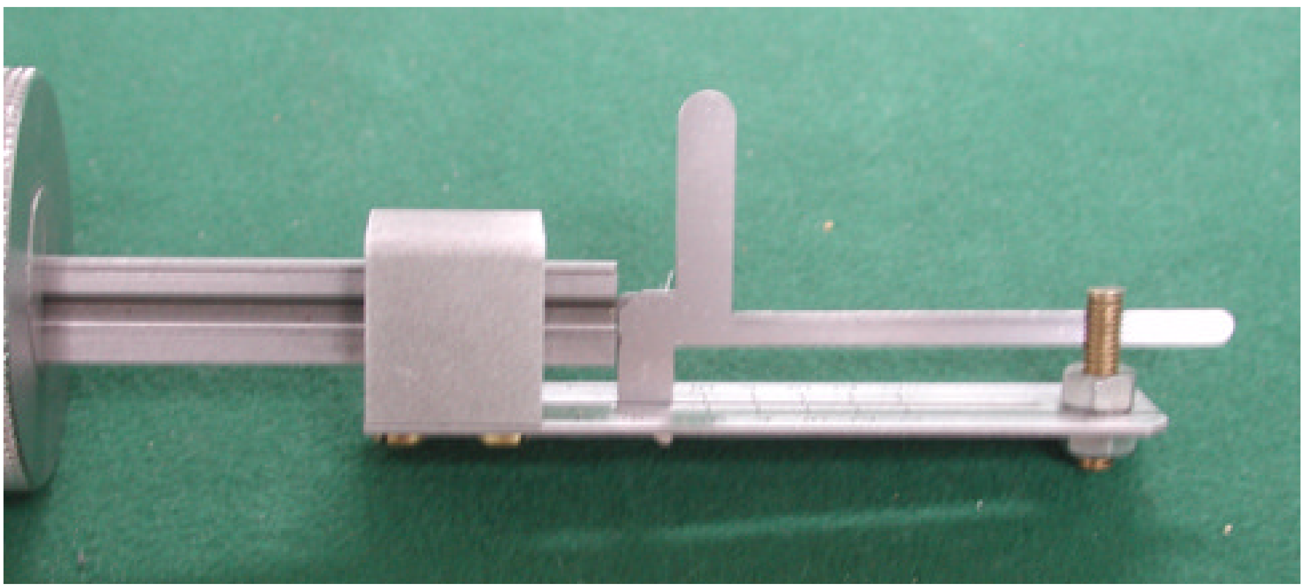
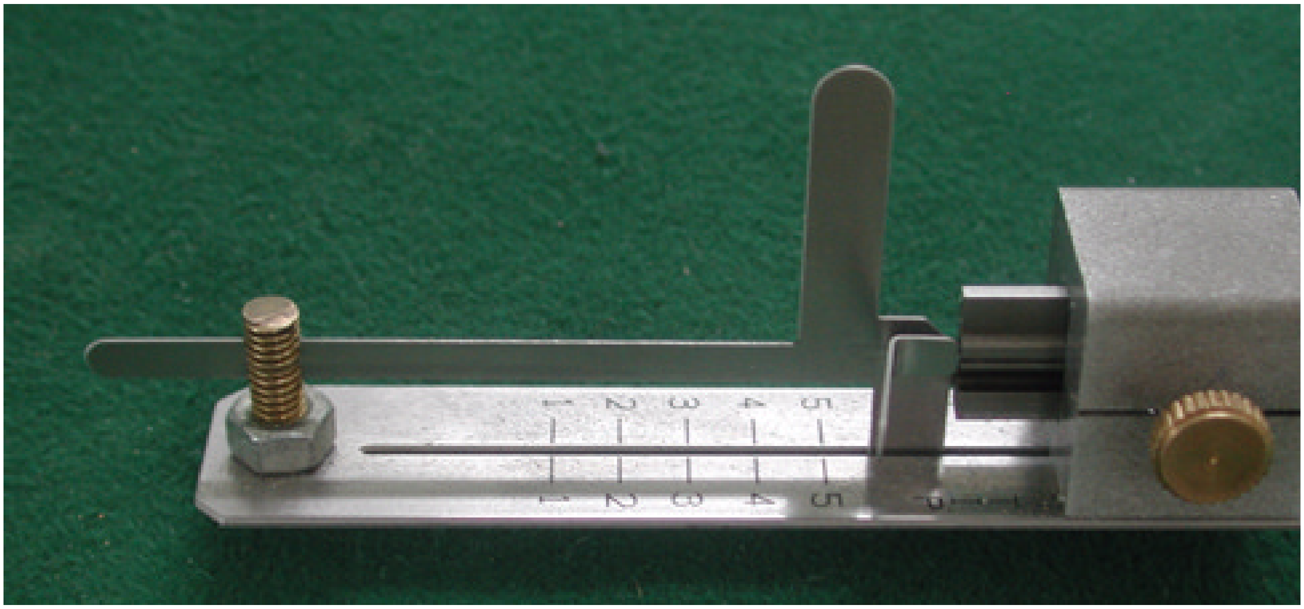


Figure LSS+3137 The decoder carrier allows the interchange of individual keyway differ segments, as shown. The pick-probe is moved under each of the segments to probe shear line.

In practice, the tool with special keyway profile and segment holder is inserted into the lock. A pick-probe is then run under each of the segments, which causes them to be slightly raised. The technician feels the relative movement of each differ segment and corresponding pin. Based upon the detailed description of the theory of impressioning presented in Chapter 30, it is easy to understand that whenever there is slight movement of the keyway segment, such movement indicates that the pin is at shear line. Likewise, whenever movement is blocked, the pin cannot be at shear line. Each tumbler position is sampled until the proper segment has been inserted for each chamber position. When this is accomplished, the lock will open, and has simultaneously been decoded.





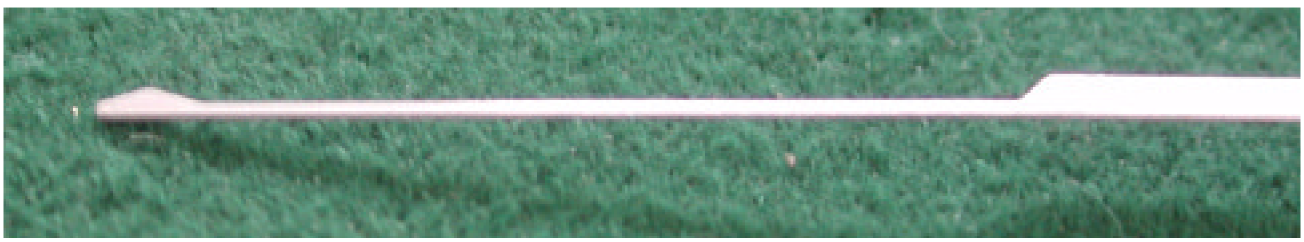


Figure LSS+3138 The calibrated pick-probe holder forms part of the decoding tool.
The pick is moved forward in order to contact each individual differ segment to move
it vertically, in order to probe the shear line.

This system, in the author's opinion, is clearly superior in its ability to defeat common pin tumbler locks in difficult N.D.E. conditions. The system is basically a Pin and Cam system for pin tumbler Locks but each system has been designed to work as easily and as covertly as possible. Instead of utilizing pins, the system uses specially designed Variable Key pieces which assume the shape of perfect key cuts. These Variable key pieces can be individually tested inside the lock to determine whether they are at the correct vertical level for each pin. Incorrect pieces can then be automatically changed by using the specially designed Var-key Container.



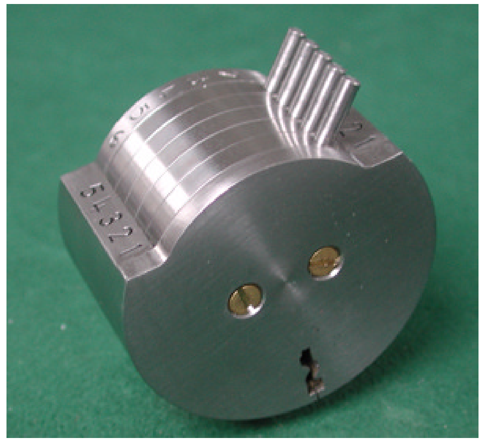


Figure LSS+3139 The tip of the tool is inserted into the Var-Key to select the proper depth segment. All possible differ pieces are contained within this self-contained unit.

In order to select the proper key differ segments, the user simply inserts the decoder tip into the Var-Key holder keyway and flicks the relevant lever to the next position. The device will change the segment to the next size automatically, with no risk of losing any components. The tool is then reinserted into the lock and the process repeated until the lock opens.

The method is quick, silent, easy to learn, and causes no damage to the lock whatsoever. It will not only open the target lock but it will also produce a perfect code for future use. There is no risk of compromise, nor any components that require calibration, or that can become damaged within the lock. The system can be used in conjunction with any other decoding and picking method, and when employed with the Basic Decoder, it can allow extremely rapid openings.

John Falle has managed to translate the difficult process of picking, impressioning and decoding of a pin tumbler lock into one seamless operation. The tool actually impressions the lock with interchangeable segments that simultaneously provide the correct code for each tumbler. The advantage over conventional impressioning is obvious to any skilled technician. Any decoding errors can be quickly corrected without the requirement of starting over in making a key. The system creates a key as the lock is picked and decoded. At the end of the process, a correct key is generated, the lock is decoded, and the lock can be opened and locked at will. Most locks can be defeated in less than three minutes, and more importantly in covert operations, this period can be interrupted without effecting the result. These systems are extremely easy to learn, and only take a few minutes to

master. Once the user has employed one system, he can use all other systems immediately without further training.

As with the original pin lock decoder, each system is designed for use on one specific lock with one particular keyway profile. The systems will work on locks which have five or six pins, and some systems will also work on reverse profiles.

Systems will be limited to popular keyways, although special keyways may be requested.
The following systems are available for locks from the following territories.

UNION 5 PIN Standard Profile (United Kingdom).
YALE 5 & 6 PIN Standard Profile (United Kingdom).
SCHLAGE 5 & 6 PIN Standard Profile (USA).
LOCKWOOD 5 & 6 PIN Standard and Reverse Profile (Australia).
TESA / GAINSBOROUGH 5 pin Standard Profile (Spain).

The following systems may be developed in the future if there is sufficient demand:

ITALY.	**VIRO, CISA, CISA SP.**
SPAIN.	**LINCE, AZBE, UCEM, MCM.**
USA.	**CORBIN, KWIKSET, SARGENT.**
UK.	**MILA, GEGE, CHUBB, EVVA.**

31_4.6.2 High-Security Pin Tumbler Cylinders

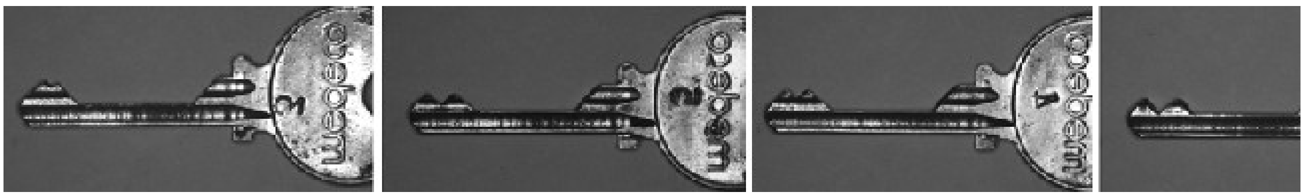
31_4.6.2.1 Medeco Lock Decoder Systems

The original decoder for the Medeco lock was patented and introduced in 1976 by Idoni and Iaccino of Lock Technology Corporation (**3985010(334)** and **3987654(335)**). Since that time, a number of modifications have been made to the lock, making decoding in many respects more difficult. In all of the decoder schemes that are available for the Medeco, fine shim wires or blades are utilized to sense the length and rotation of each tumbler.

31_4.6.2.1.1 Medeco Cam Lock

A patent (**3985010(336)**) describes a means for decoding the Medeco cam lock. It will be recalled that this mechanism is based upon a single rotating pin contained within each chamber that has a

precisely indexed radial aperture. A sidebar, with corresponding complimentary protrusions, must be in perfect registration with all pins in order that it can retract into the plug. The decoder for this lock is comprised of three devices, each with a blade that is inserted into the keyway. The blades have one of three sloping front surfaces, defined as one of three angles to which the tumblers must be twisted for horizontal registration of their apertures.



Each blade will provide specific information relating to a tumbler, and an indication will be given that its front surface is located at a particular position. It will also determine the amount of elevation of the tumbler. This is caused by the camming action between the chisel-shaped tumbler bottom and the blade front surface (when the blade is advanced from its initial engagement with the tumbler to elevate it). Decoding of this lock requires that torque be applied to the blade during its advancement in order to bias the sidebar toward the tumblers. This will force the protrusion into the associated tumbler aperture when the aperture is able to register with the protrusion. This movement causes small but detectable resistance to further advancement and can thus yield a positive indication of registration.

When the angle of the front surface and the required tumbler elevation is known, the tumbler is decoded. The process is repeated for all tumblers. A composite segmented key can then be constructed to simulate depth and rotation. A similar scheme, developed by the author, utilizes a set of twelve precut keys, each having one depth-cut and rotation at the tip. The keys are inserted into the lock in sequence for each tumbler position, with torque applied. An attempt is made to move the key within the plug in an effort to engage the protruding pin of the sidebar. Generally, if the correct height and rotation has been attained, the sidebar pin will catch in the aperture, thereby providing an indication of depth and rotation information.

31_4.6.2.1.2 Medeco Pin Tumbler Lock

A second patent was granted to the same inventors in 1976

(**3987654(337)**) to decode the higher security Medeco pin tumbler lock and to defeat certain improvements implemented by Medeco in an effort to make decoding more difficult. It will be recalled that the high-security pin tumbler mechanism requires that pins be aligned at shear line, as with a conventional cylinder. In addition, each pin must be rotated to one of three angles by the key bitting, so that the vertical channels within each pin are aligned 90° to the sidebar protrusions in order that registration may occur.

The operating theory of the decoder is based upon the presence of the sidebar channel in each tumbler and its accessibility to the wire probe from the base of the pin. This decoder will determine the depth of cut for each tumbler and the rotation of the pin. The device utilizes a wire probe that is manipulated along the channel to sense the position of the tumbler and chisel-point. It requires that a blade be inserted into the keyway in order to place a wire probe beneath the tumbler that is to be decoded. The wire probe is then advanced upwardly along the sidebar channel until it engages the stop at the top of the pin.

The depth of cut of the key bitting is a function of the length of the lower tumbler. The device can be calibrated to provide a direct readout of the dimension of each pin. The angle or rotation can be measured by hooking a wire probe within each channel and then twisting the tumbler until the stop engages the plug. The allowable amount of pin rotation is a function of the angular position required to register the tumbler groove with the sidebar. The device can be calibrated to provide a direct reading of the angle. Medeco has made significant modifications to the lock since the introduction of this tool, but it will still function on many of their cylinders.

31_4.6.2.1.3 Falle Decoder for Medeco Pin Tumbler Lock

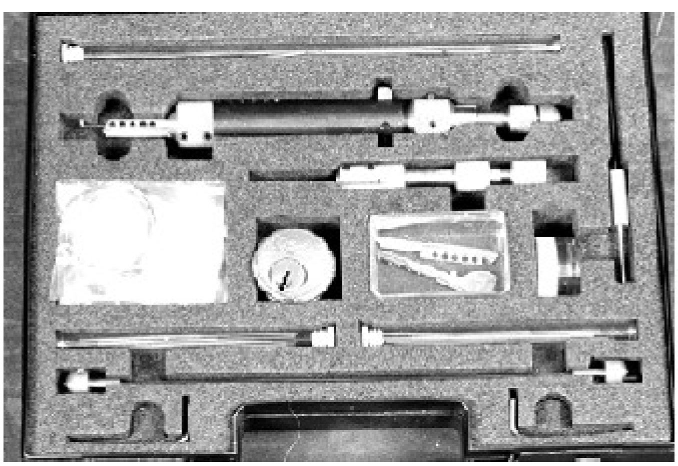
LSS302: Medeco lock decoding system, by John Falle

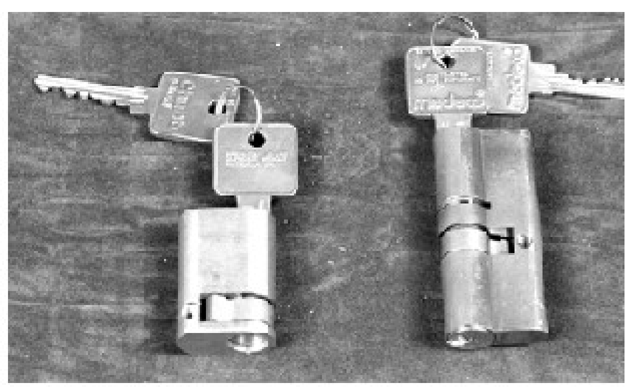
Originally, channels for the sidebar pins ran the full length of the top pin, making decoding a relatively simple process. Medeco changed the design of the pin and introduced a high-security ARX pin, once the decoding scheme became known. The Falle system will decode the original and **Biaxial(338)** cylinder lock, where the channels run the full pin length. There is no decoder available for the cam lock.



Figure LSS+3123 The Medeco ARX security pin. Note the multiple false notches and channels.

The Falle system is a modified pin lock decoder with an added slot probe used to identify the pin rotation angle. As with the Ingersoll decoder, both the slot probe and the shim decoder require a specially engineered key tip.





Because the decoder is supplied with one key tip for each tool, the kit is only effective on one particular keyway which is the common commercial section. There are many different keyways in the Medeco system, some of which are highly restricted. Each key

tip requires very accurate machining in order to work properly. Falle requires five different blanks for a particular keyway in order to produce a custom tip.

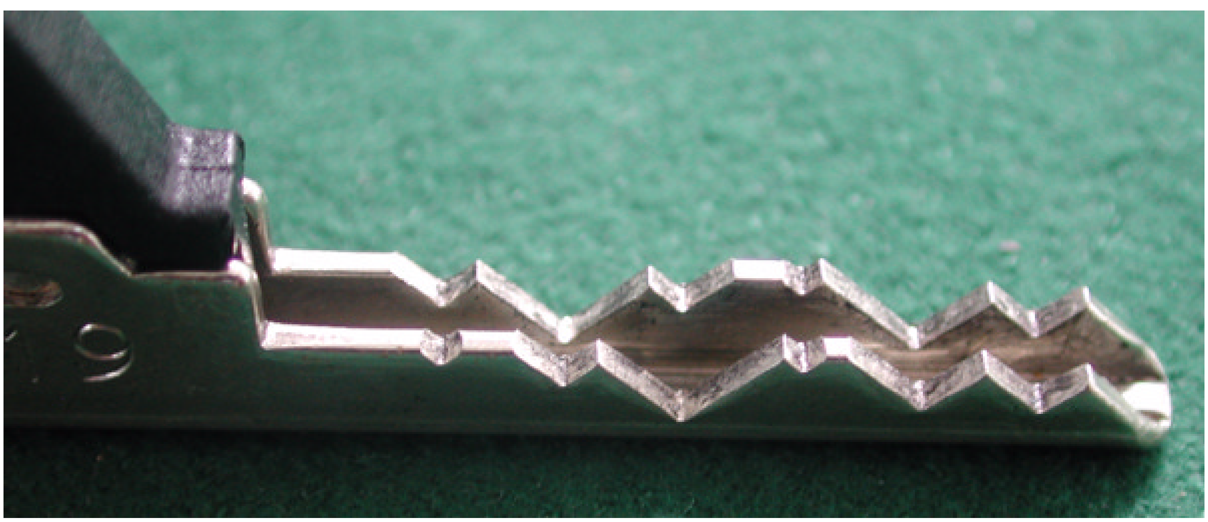


Figure LSS+3124 Key tips for the Medeco decoder. Courtesy of John Falle.

Both the Falle and Idoni decoders require that a probe be inserted and moved around the base of each lower tumbler in an effort to determine the rotation angle of the pin. Falle has also developed a decoder for the **Medeco Biaxial** system, using a slot probe. The length of each pin can be deduced and the rotation angle determined. The system is not effective on those locks that contain ARX pins. Because there are many different keyways, the operative will require specially prepared blanks.

31_4.6.2.2 BiLock Decoder

LSS303: BiLock decoder system, by John Falle



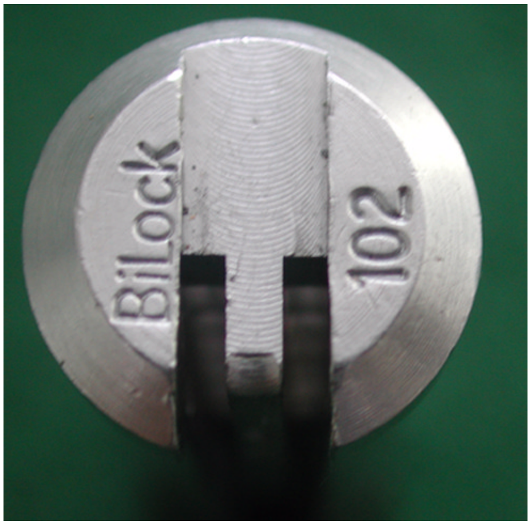


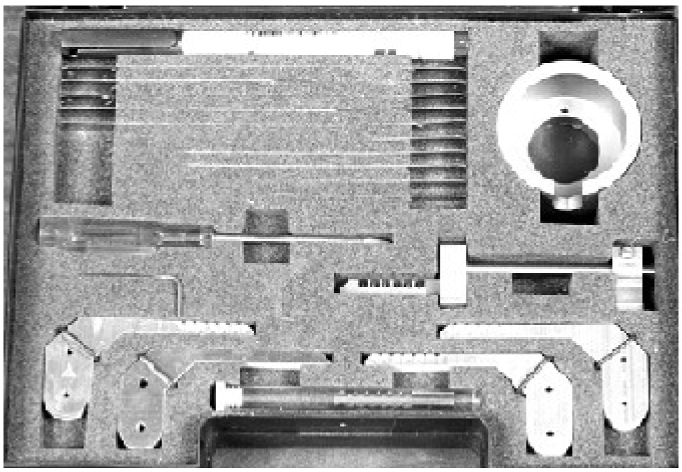
Figure LSS+3125 The BiLock key and cylinder are unique. The system is comprised of dual sidebars, as shown below.

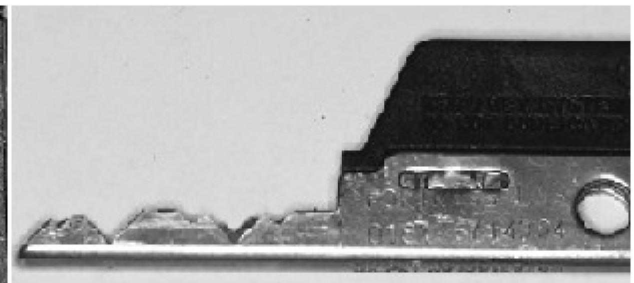


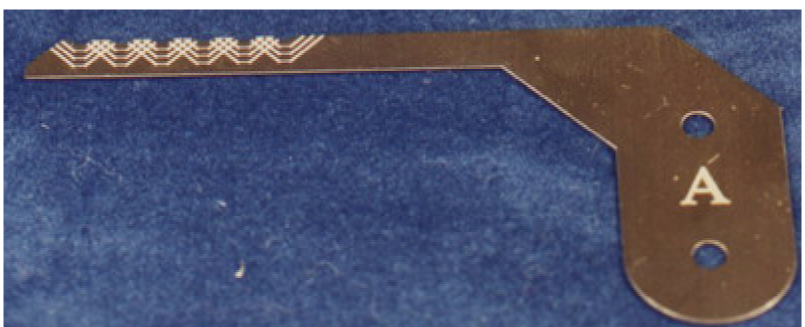
Figure LSS+3126 The BiLock plug contains two sidebars that must retract in order for the plug

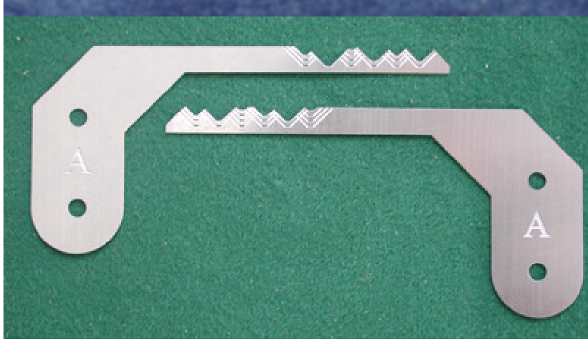
to rotate. The individual pin has a detent to receive the protruding peg from the sidebar,
resembling the design of the Medeco cam lock.

The decoder is designed for use on the Australian BiLock that is now available in Europe and America. The system is very effective against both the staggered and parallel pin versions of the mechanism. The Falle tools will open the lock and produce the precise bitting code for use on future entries.









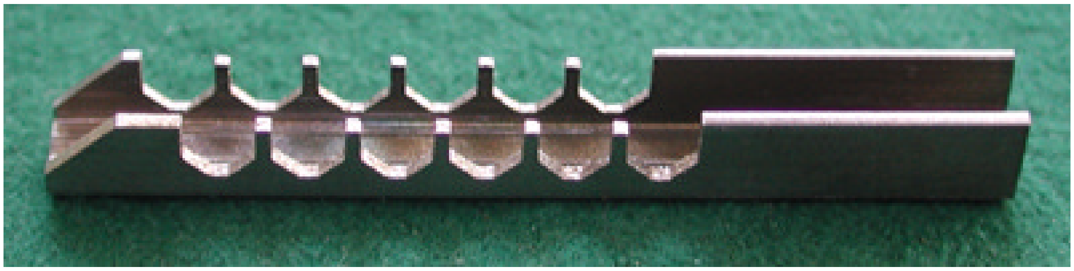
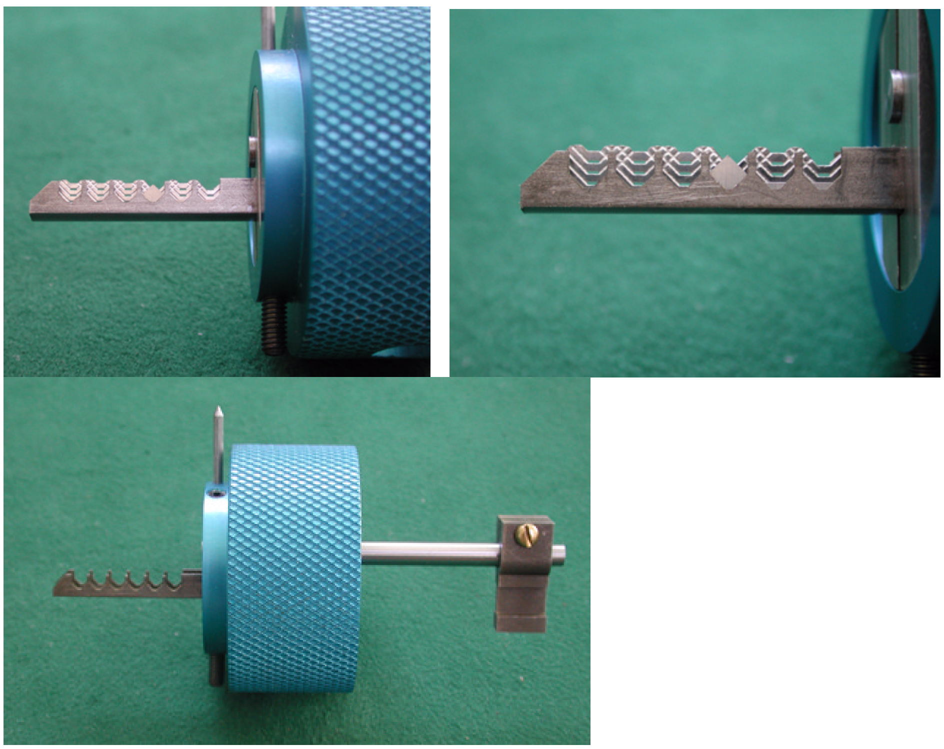


Figure LSS+3127 Individual probes are utilized based upon the variable key generation system. Shown is a blank key, and two that have been cut by code. The carrier is also shown.



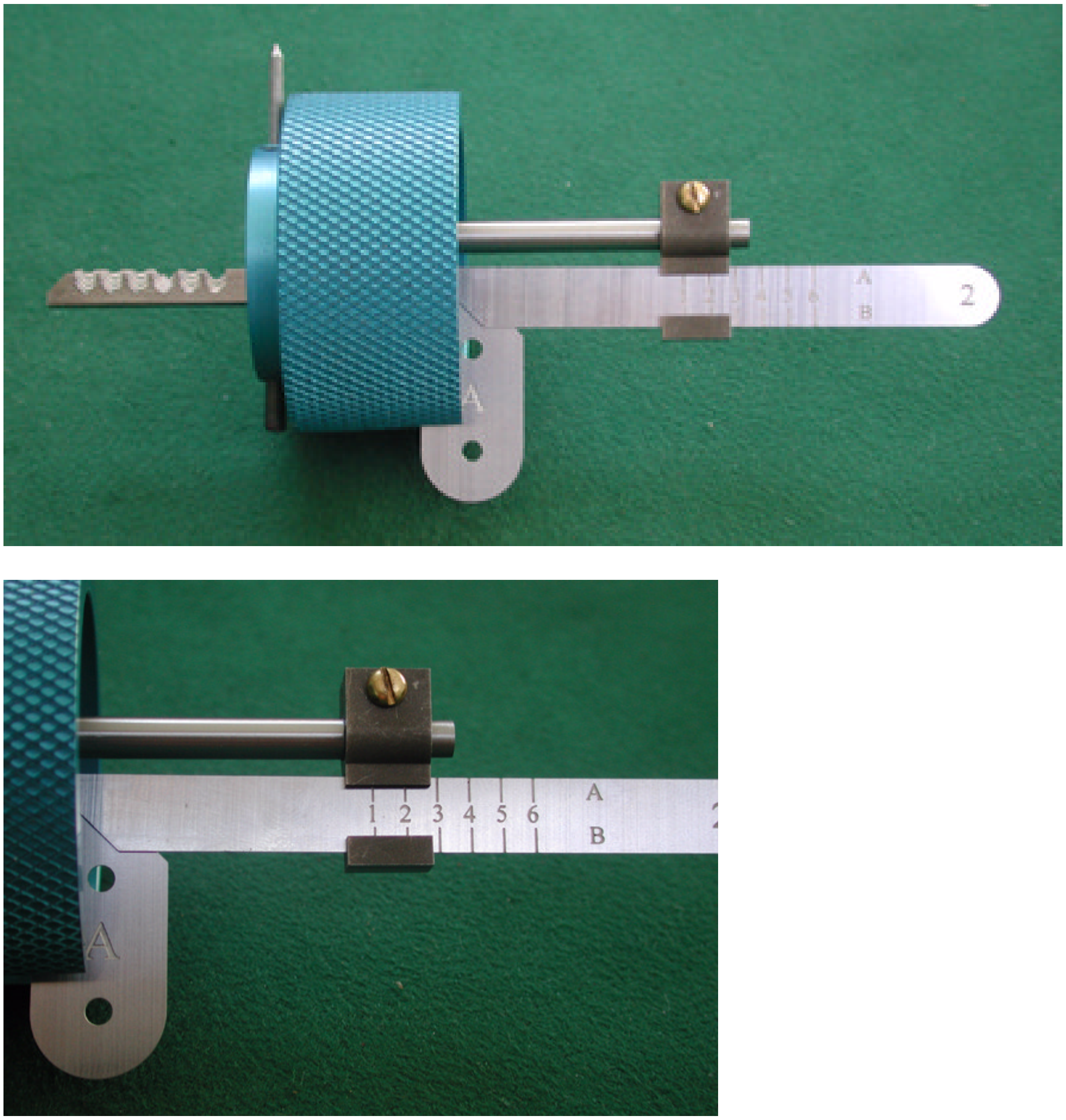


Figure LSS+3128 The John Falle BiLock decoder and pick system will open the lock and produce a key that can be reproduced.

31_4.6.3 Axial Pin Tumbler Lock Decoders

Axial or tubular pin tumbler locks such as Chicago Ace are produced in many configurations and can be easily identified: all have their pins located around the circumference of the keyway. Their design is based upon function and security issues, including the number of active and dead pins, security tumblers, and the interface between pin and key. These devices are extremely popular in vending, access control, alarm, telecommunications, and related industries.

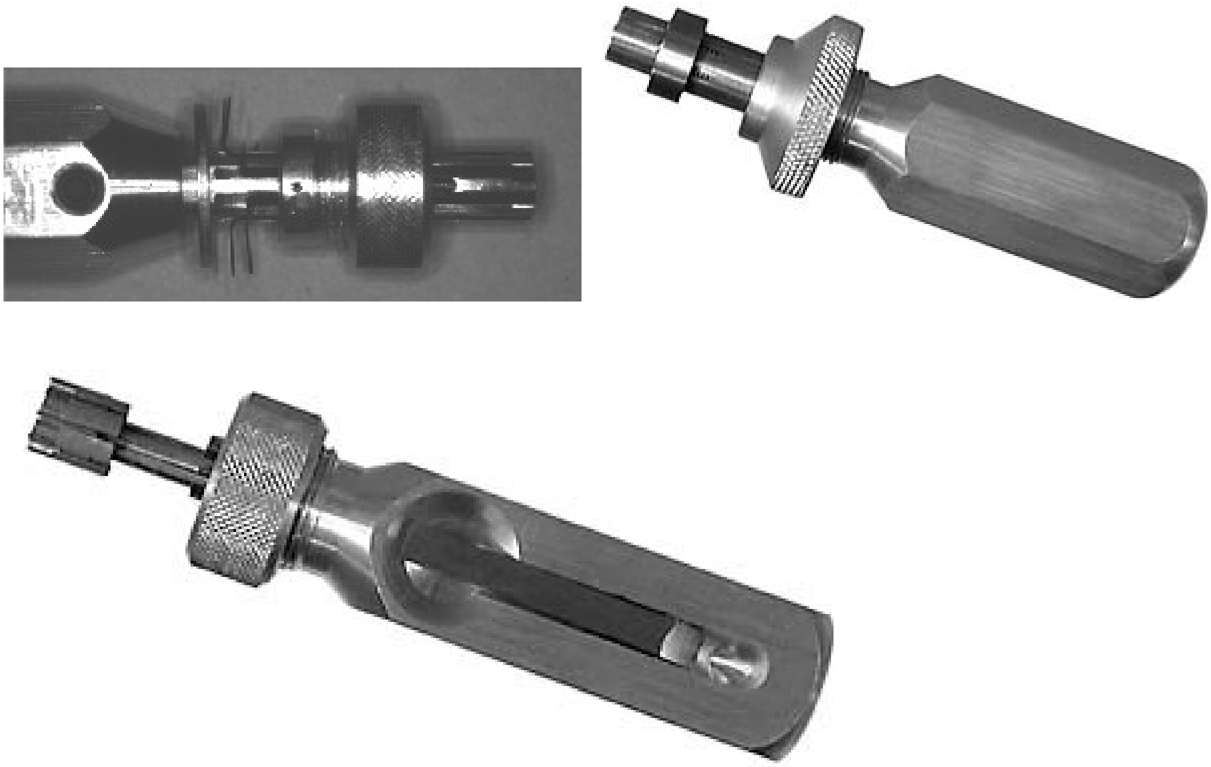
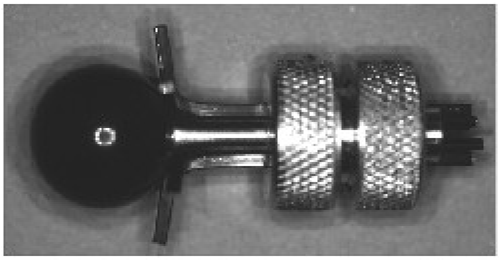
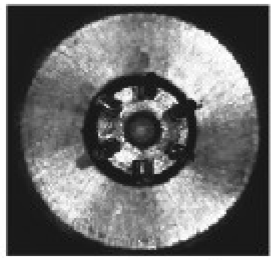
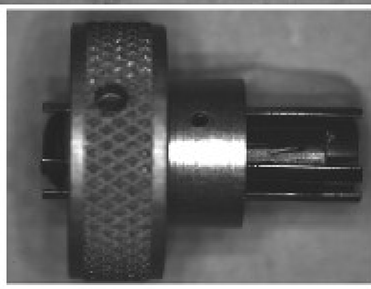
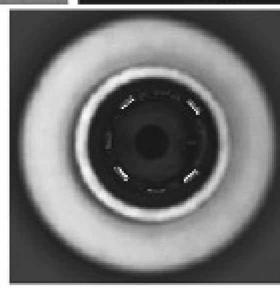
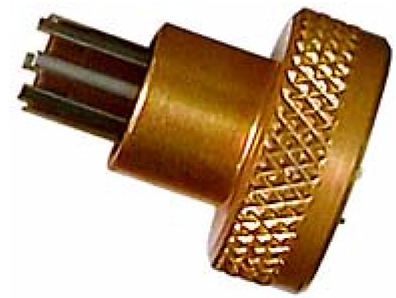
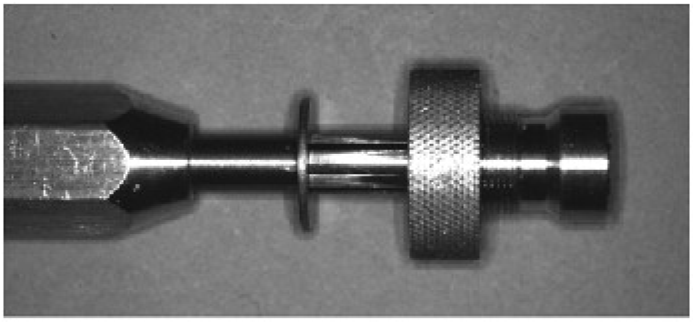
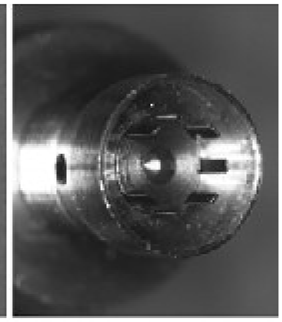
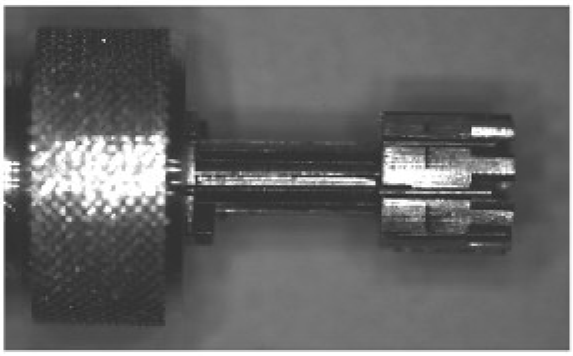


Figure LSS+3142 HPC and other vendors produce complete lines of axial picks and decoders to open virtually every variety of this mechanism, even the high-security UL listed lock.

Decoders are available for almost every configuration, at least in the United States. HPC and other companies offer a wide array of tools to quite effectively pick and decode these mechanisms. The picks are available for both regular and high-security cylinders containing seven to eleven tumblers in standard and "peanut" diameters.


Most of the devices employ moveable shims that are “pumped” in a series of “bind and depress” motions until each pin reaches shear line. Other tools allow the individual manipulation of each pin, somewhat resembling a “rotary” pick. Locks are picked and impressioned in one motion. Once the lock is open, the tools can be decoded to determine the depth of each pin based upon the position of the shim.

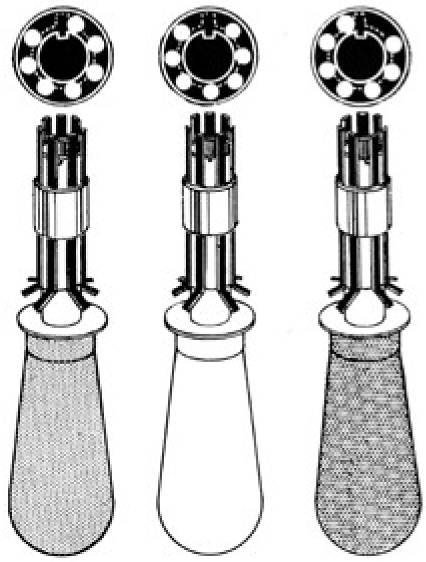








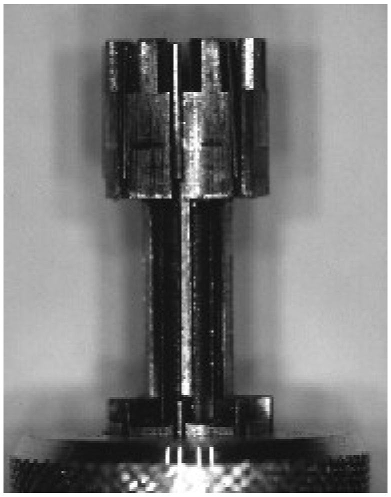
Exploded view 1, 2, 3.

Four primary patents have been issued for axial pin tumbler pick and decoding tools since 1937. In that year, Tarrie (**2070342(339)**) developed a device to open the tubular lock manufactured by the Chicago Lock Company. This tool was the basis for the subsequent inventions relating to picking, impressioning, and decoding this type of mechanism.



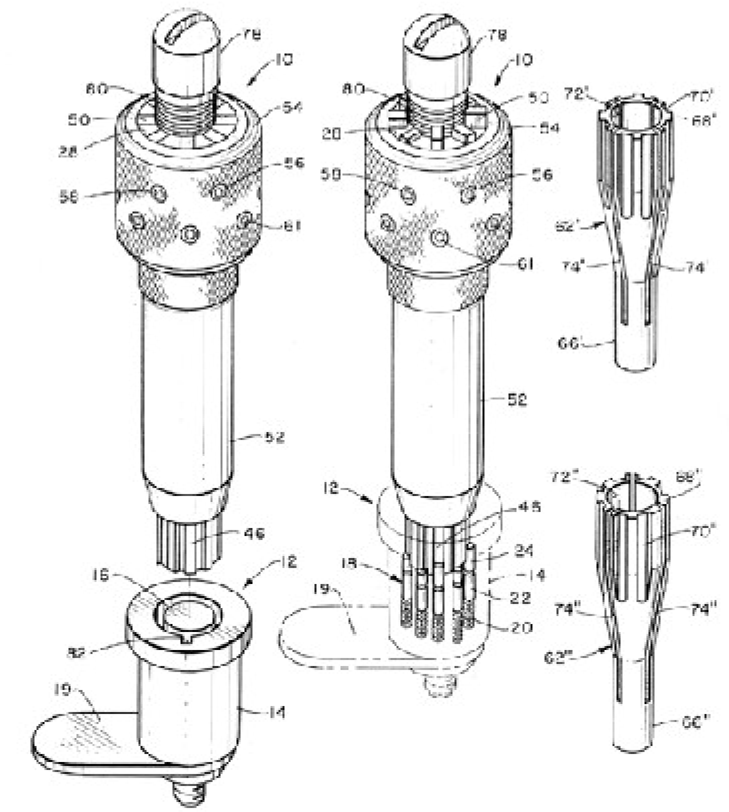
The decoder was designed for the original seven-pin lock. It utilized sliding shims to first pick and then decode the position of each tumbler. In 1953, Wilson (**2655808(340)**) improved upon the Tarrie device, providing individual adjustment and locking for the seven extendable feeler pins. Once the lock was picked, each feeler could be secured in a position to allow the decoding and duplication of a key.

In 1966, Gruber (**3251206(341)**) patented the most famous of the axial decoding tools. This device also utilized sliding shims that could be individually manipulated by the user. Their movement was restrained and controlled through the use of a circular rubber or plastic collar so that when the tool was inserted into the lock, the shims would slide backwards in concert with the force of the pin tumblers.



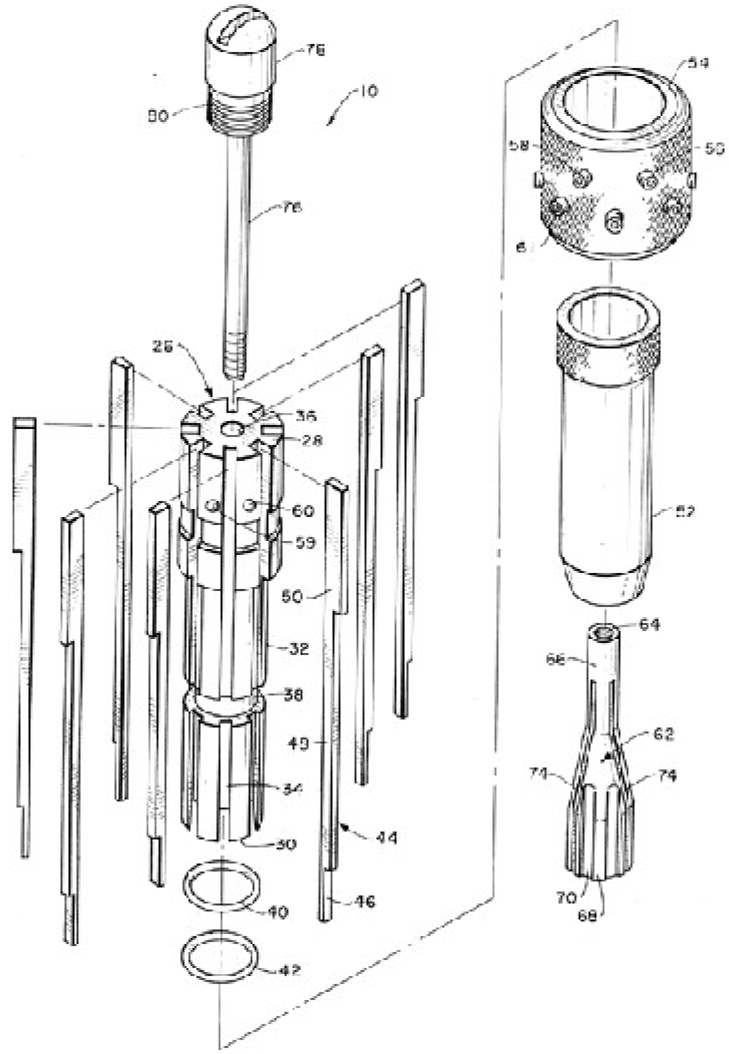
The Gruber tool was placed into the keyway so that the sliders would abut the first set of tumblers. The tool would then be depressed and twisted in order to tension the plug. As the tool was moved forward, the shims would retract in correlation to the position of a pin. Each shim would stop moving when its corresponding tumbler was engaged at shear line. Once picked, the position of each pin was identified, based upon where the sliders had stopped. It was a simple matter to decode their length and produce a key.

In 1978, Hughes (**4094176(342)**) received a patent for an even more sophisticated decoder. This device would allow reading any axial lock with any number of pins by interchanging the head that contained and controlled the individual sliders. The entire tool could be disassembled and reconfigured for a lock with a different number of tumblers. Once picked, the tool would display the results using a decoding gauge that formed the rear portion of the device.

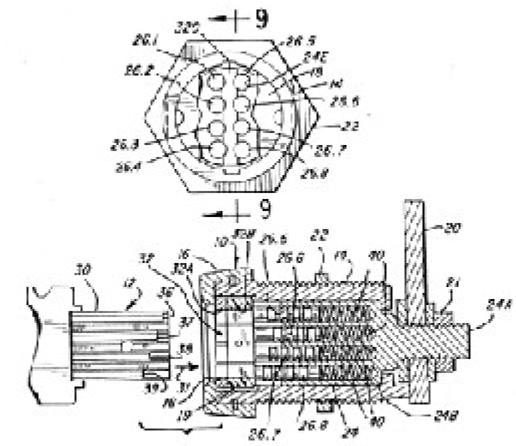


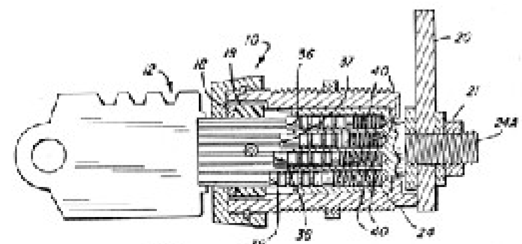
Exploded view.

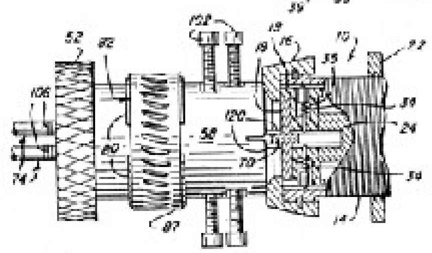
In 1986, a rather complex tool was patented (**4617813(343)**) by Christopher for picking and decoding the Chicago Tubar series eight-pin tumbler axial lock. The Tubar differed from the traditional axial mechanism in that two rows of four tumblers were arranged in a coplanar fashion. The lock is more particularly described in Chapter 17.



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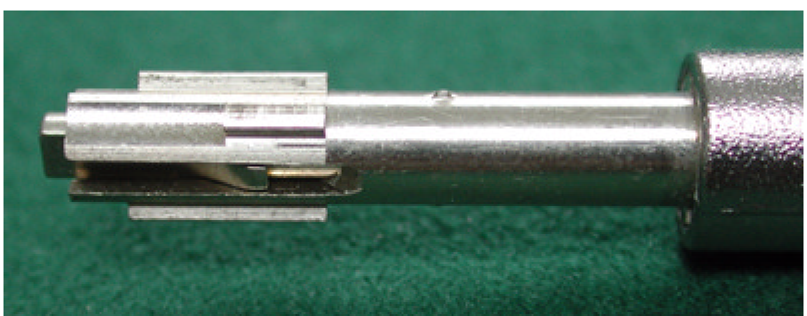


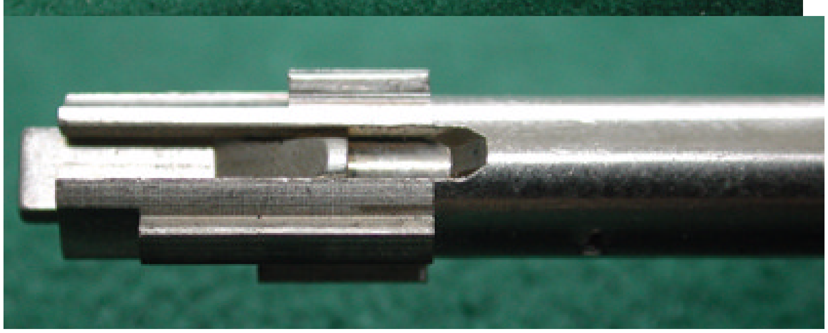




31_4.6.3.1 Axira Radial Pin Lock Pick and Decoder

LSS302: Axira lock decoding system, by John Falle





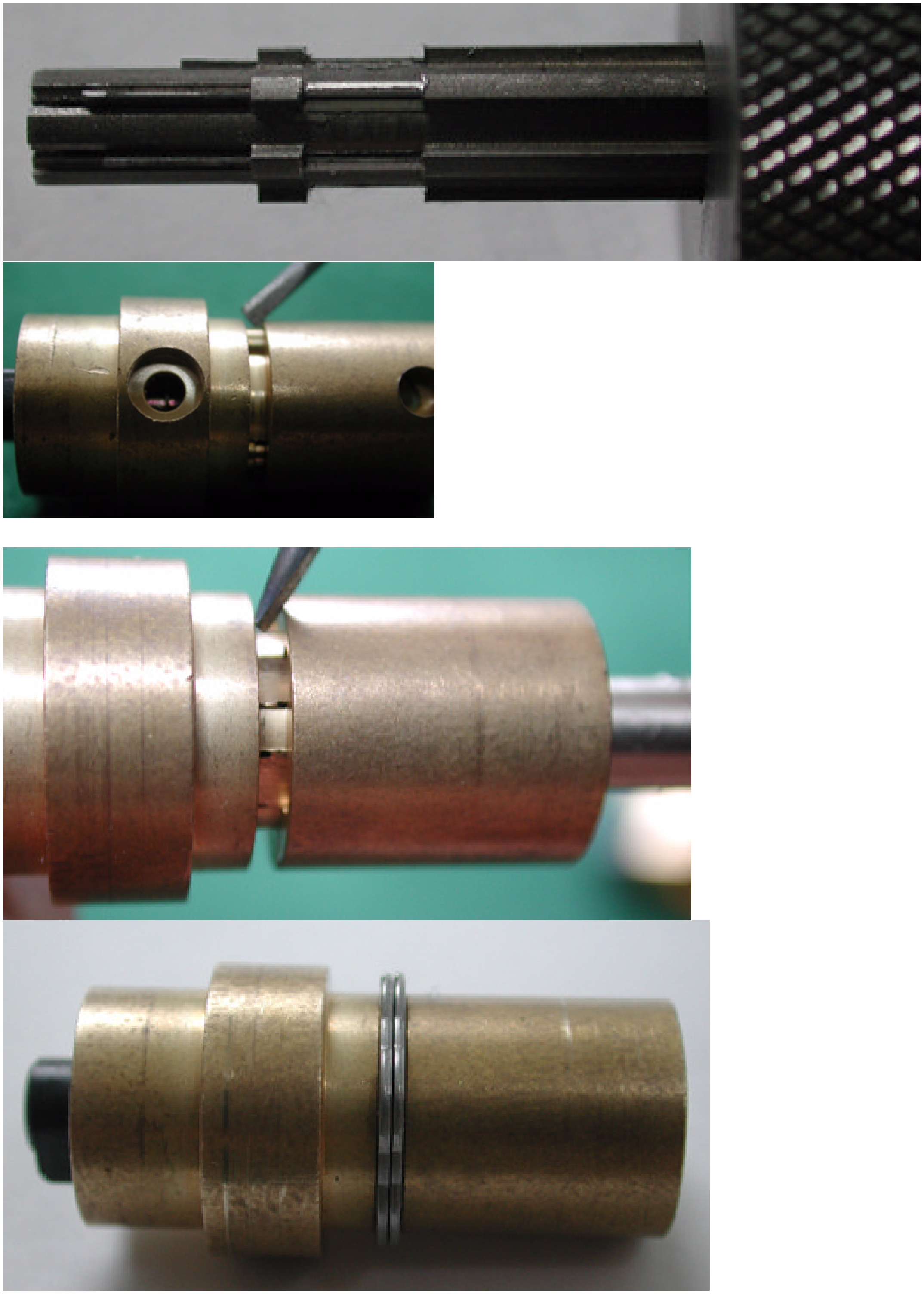


Figure LSS+3129 The Axira lock is similar in design to the Picard. The Falle decoder works in almost

identical fashion for both locks.

This John Falle decoder is a sophisticated picking tool for use on the AXIRA Radial pin lock. This mechanism has a particularly modern design and requires an advanced tool in order to open it. It is believed that the lock originates from France but is also common in Italy and Spain. The tool is both a pick and also a decoder; the lock must be opened before the code can be determined. Although the lock contains only five detainers, they are heavily notched. The Falle system is the only method available to open the Axira.

As with all picking tools, the main limitation in this system is speed. A skilled operator should easily be able to open the lock within four or five minutes, but this time can be interrupted. The design of the tool allows individual pins to be locked into position, thus allowing the decoder to be quickly removed in an emergency. The tool can then be reinserted and the user can continue the picking procedure. If the user requires a code in order to make a key, this can be done in less than one minute and can be achieved at an alternative location.

If the user is familiar with radial pin picks, then no significant training is required. Otherwise, a few hours of instruction are required to become competent.

31_4.6.3.2   Picard Decoder





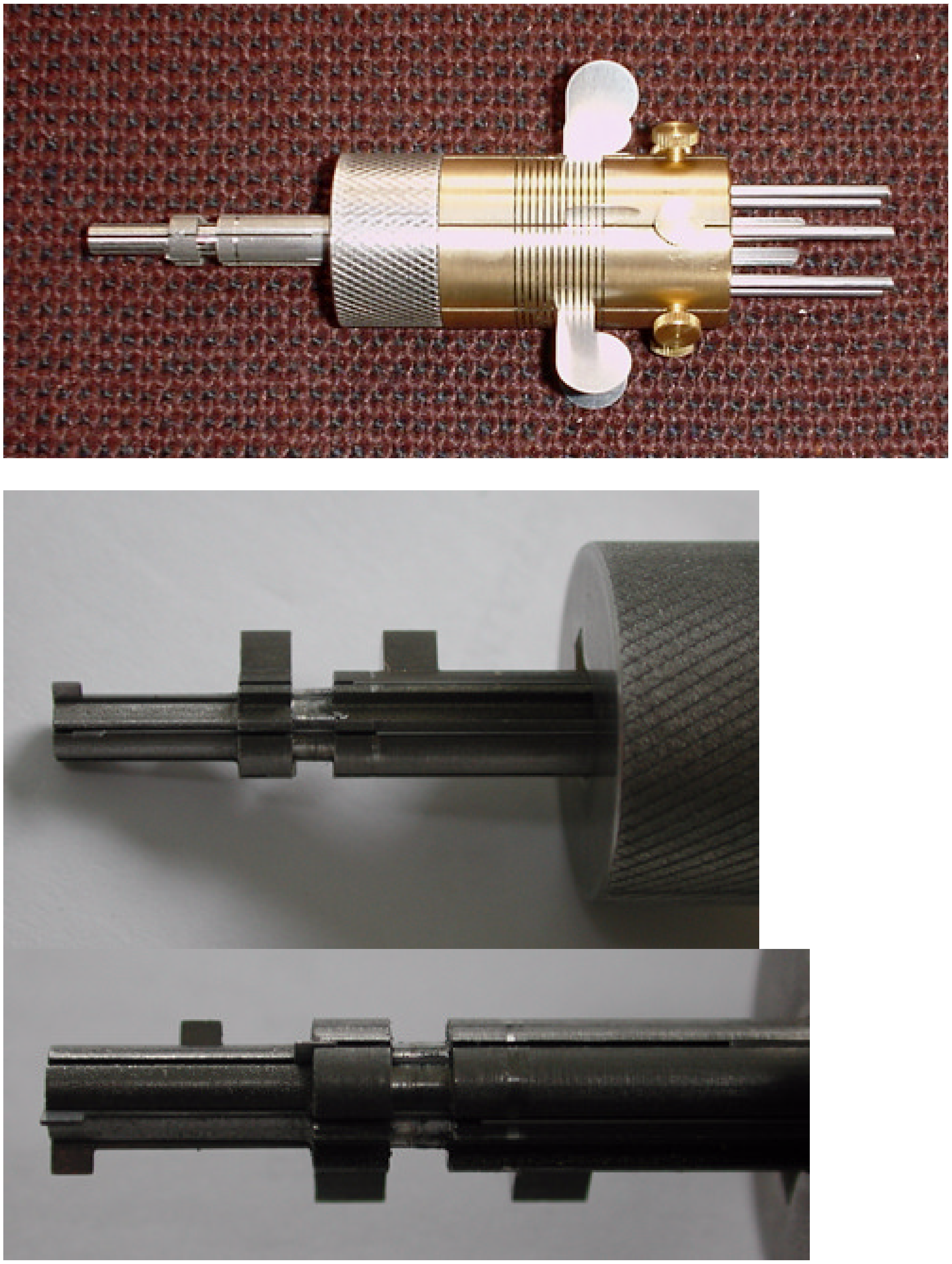


Figure LSS+3130 The Picard pick and decoder tool by John Falle.

The John Falle decoder is of a very similar design to the Axira device. The **Picard** lock is also of French origin and like the Axira, it contains five tumblers of a radial pin design. This **decoder** will open the lock and also provide a code for future entries.

The only limitation to system use is speed. Before the lock can be decoded, it must be picked and the time this takes will depend upon the skill of the technician. This lock is a great deal easier to pick than the Axira. If the user is interrupted during the bypass procedure, the tool can be immediately extracted. On reintroduction, the picking process can be continued from the point of interruption. The time required to pick this lock should not exceed two minutes. A further one or so minutes will be required to attain the code, but this can be accomplished at an alternative location.

If the user is familiar with the picking of radial pin locks, then no training will be required in the use of this tool. If not, then the user could learn this system as part of an Intermediate or Advanced course in only a few hours.

31_4.6.4 Dimple Pin Tumbler Lock Decoders

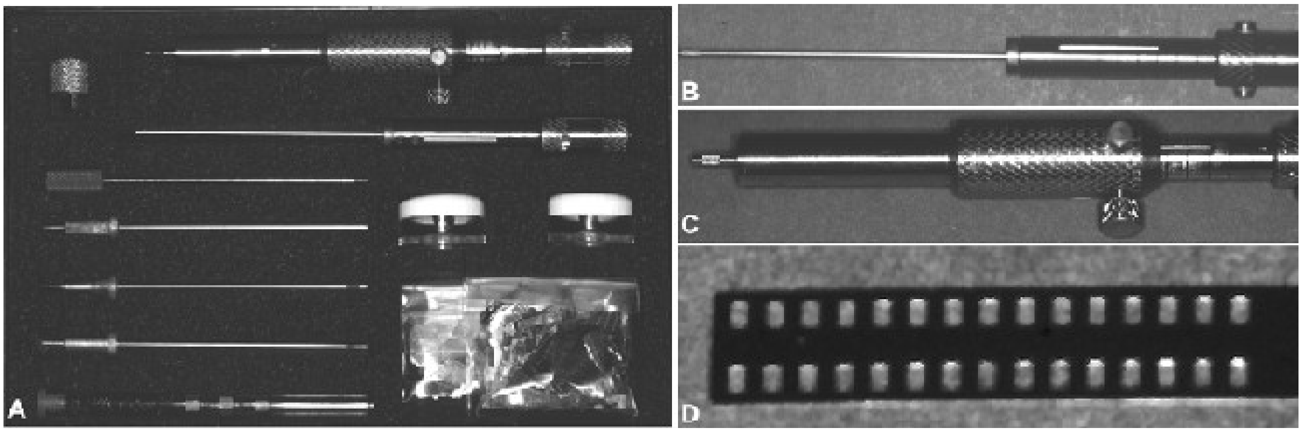
Dimple pin tumbler locks are unique in their design because there are several rows of active components that must be picked and decoded simultaneously. As noted elsewhere in this text, many of these locks can be easily picked, impressioned, or decoded using a variety of techniques. These locks generally contain two, three, or four separate rows of pin tumblers, each facing a surface of the key. For example, the Keso, produced in Switzerland, has three rows with up to fifteen pins. Dimple locks have become extremely popular, and are now produced in many countries.

Falle produces two types of dimple decoders that are discussed in this chapter. The standard system will decode locks produced by DOM, Ezcurra, MCM, UCEM, Keso, Tesa, Azbe, and Lince. Dies can be developed for virtually any dimple configuration.

31_4.6.4.1 Core Shim Decoder

The core shim decoder, by Falle, was initially designed to function with dimple pin tumbler locks, although it is expected to be modified to operate with conventional cylinders as well. See **Chapter 17** for a discussion of dimple mechanisms. Falle devised an extremely innovative system that relies upon a simple technique described in **Chapter 26** regarding the disassembly of pin tumbler cylinders using a shim. The process of inserting a fine shim wire at the rear of the plug (at shear line) while concurrently removing a blank key to force the wire between each

pin set has been simulated by Falle.



Exploded view 1, 2.

The tool is designed to introduce a shim through the bottom of the keyway to travel between the plug and shell. The shim is thin enough to revolve around the outer circumference of the plug. Using a geared mechanism, it is forced to move from the base of the keyway 180° to where the pin-stack intersects plug and shell.

The decoder consists of a hypodermic tube with two slots on either side of its tip. The distance that the tube is inserted can be calculated by reading the markings on the gauge body. This allows a precise determination as to which tumbler is being probed by the shim. On the side of the tube, a slot is located where the blank key is inserted into the lock. Contained within the tube is a miniature gear that can be rotated by turning a knob at the rear of the tool. A micro-perforated shim, measuring exactly 10 mm in length by 4.5 mm in width and resembling a 35 mm filmstrip, is fed into the slots. It can be extended and retracted by the gear.

In use, the shim and the tube are inserted into the keyway at a position as far to the right as possible against the inside of the plug. The shim is then extended around the outer ridge of the plug until it contacts the sides of the pins. If the diameter of the plug is known, then the point at which the shim reaches the sides of the pins will always be constant. A series of step-keys are next inserted into the lock. When the correct bitting depth raises the target tumbler, the shim can be extended further so that it goes between the pin and the driver, thus verifying the correct depth. Once the first pin has been decoded, the shim can be extended to the second pin and the

procedure repeated for all pins.

31_4.7 Tactually Decoding the Tumbler Positions

The design of some decoding tools relies upon the manipulation of tumblers to sense their size, distinct type, and position. The operation of the Schlage wafer decoder, described earlier, depended upon the manual sensing of the shape of the corners of each type of wafer in order to determine the combination. The Falle Abloy decoder likewise relies upon the sensing of true and false gates on each of the discs in order to rotate them to alignment.

Some of these devices are quite complex and require a high level of skill to operate successfully. The Falle Medeco decoder and the earlier device described in the Idoni patent is an excellent example. These tools demand extensive knowledge of the internal workings of the lock and the ability to translate subtle measurements and feelings into code data.

31_4.8 Picking and Then Decoding the Lock

Most decoders described throughout this chapter require that the lock be picked prior to decoding. Essentially, these devices provide for a method to measure each active locking component once it is positioned at shear line (or equivalent). Some instruments can decode the size of each component without the necessity of picking. The axial pin tumbler lock pick/decoder described in **Chapter 29** allows a precise determination of the length of each pin during the picking process. Such data can then be translated to produce a working key. The Falle pin lock decoder allows for the extrapolation of the length of each pin without picking. Using this tool, a fine shim is introduced into each pin chamber in order to compute the distance from the base of the pin to the bottom edge of the driver.

31_4.9 Other Means of Deriving Tumbler Combinations

Based upon their design, information about individual keys and key systems can be extrapolated and compiled from one or more locks that have been picked or disassembled. The author, for example, was able to pick an extremely popular lock cylinder used in the lodging industry and then decode the master key for an entire system by reading the tumbler positions with a borescope

or otoscope in **one** lock. In another case, the author covertly captured the signatures of several magnetic card locks within a complex, and was able to derive the master key code by making a composite key from all of the data. Described below is a technique for decoding and extrapolating the bitting of the top level master key (TMK) within a master key system. The reader should thoroughly review the materials detailed in **chapter 11** in conjunction with the materials that follow.

31_4.9.1 Shimming a Pin Tumbler Lock with Depth Keys

LSS203: Matt Blaze on shimming a cylinder to determine all pin segments

A pin tumbler lock may be decoded without disassembly by shimming the cylinder. Standard shimming practice has been described elsewhere in this text. The following procedure is slightly different because the goal is to **decode** the lock, rather than simply to open it. This is accomplished by inserting a fine shim stock between the shell and plug while using a set of depth keys to determine the depth of each split. This technique may be especially useful in operations that require the covert determination of all pin splits within each pin stack. This would generally occur when attempting to derive the top level master key when it is not feasible to disassemble the lock, and a change key is not available. The disadvantage to disassembly is the inability to reconstruct the master key system if the pin stack combination for any chamber is lost or altered. Shimming eliminates this problem.

A set of depth keys must be prepared prior to the procedure. Each individual depth key is cut in all bitting positions for a single depth. If, for example, a Schlage five pin lock were to be decoded, then ten depth keys would be cut with the following codes: **00000 11111 22222 33333 44444 55555 66666 77777 88888 99999**. Because Schlage uses ten different depths for our target lock, a total of ten keys must be prepared. Each key is cut so it is completely flat across the bitting surface for ease of insertion and removal. Then, each key is marked on one side to indicate the position of each chamber and how far the key has been inserted into the lock.

In practice, the cylinder is removed from the door and the rear tailpiece is taken off. A shim wire is inserted into the gap

between plug and shell, and the first depth key is inserted fully into the plug while applying pressure with the shim against the pin closest to the rear of the lock. Each chamber is tested for each depth with each of the different keys until the shim can be pushed across the shear line for that specific pin. When a pin segment is decoded, the reading is noted, and the shim slightly withdrawn so that the decoding process can be **repeated** for that specific pin. When all possible depth codes have been tested for the first pin, the shim wire is forced to the second chamber and the process repeated. The depth keys are now inserted to reach the fourth chamber, because the fifth chamber is blocked by a shim wire between top and bottom pin. In like order, each of the chambers is tested by inserting the depth keys to the third, second, and first chamber positions. When all five pins have been sampled, all of the possible **combinations** of pins have been determined. With that information, the codes for change keys, master keys, and top level master keys can be determined for any lock or groups of locks within the system, and which are associated with the target lock.

31_4.10 Decoding and Extrapolation(344) of Master Key Systems

31_4.10.1 Introduction

A great deal of emphasis has been placed upon methods to make locks more secure against picking, impressioning and decoding. Manufacturers have concentrated on sophisticated designs to insure that high security cylinders cannot be compromised by such techniques unless extremely sophisticated tools and procedures are employed, such as described in this text. In covert operations, however, it is preferred to take the path of least resistance and reduce the exposure to detection. If there is an alternative to the more sophisticated methods of entry, then they should be exploited whenever possible.

From the author's perspective, it is far better to secure a key that will open all locks that lead to the target rather than taking the risk to open one lock at a time by picking, impressioning, or decoding. The following material relates to a circumvention of the traditional techniques of entry within a master key environment in favor of obtaining the top level master key, thus gaining access to a desired location with minimal risk of detection. Obtaining the TMK will allow a compromise of system security for any cylinder that is associated with the top level

master key.

Most buildings are master keyed: some systems are very simple while others are quite complex. Some utilize conventional technology while others use secondary locking systems for enhanced security. All conventional cylinders can be master keyed with a variety of schemes to generate secure bitting for the required keying levels.

How many times have you visited a building and attempted to use the restroom, only to find that it was locked and required the use of a key? No problem, because you were always able to obtain the key from the receptionist. Or, how often does the telephone repairman, computer specialist, HVAC maintenance, alarm system personnel, or other service people have or obtain keys to locked areas. It is a sure bet that within most facilities those rooms are not only locked, but they are on the master key system. The result: anyone that has access to a change key can obtain the TMK and open every lock in the system. But what about employees? If they have an office or require access to any locked area, then they have or can obtain a change key.

As explained in previous sections within this chapter, there are many ways to obtain change keys other than as an employee. Keys can be copied, borrowed, purchased, or stolen using a variety of techniques. All that is required for the successful neutralization of any conventional master key system is the possession of a change key and access to one or more cylinders. Such access does not have to be authorized, because very little time is required to sample a cylinder during the decoding process. It is simply a matter of how many passes are required to fully decode and extrapolate the TMK bitting.

The reality is that virtually any conventional keying system can be easily and covertly compromised at the TMK level by an individual with little training or skill and even fewer tools. Anyone with a change key and blanks has a good chance to obtain the TMK. System compromise can occur during one attack, or over a period of time. The cost to accomplish the task may be less than five dollars. It is therefore critical for anyone charged with the responsibility for securing a master keyed installation to understand the threat. Most systems are vulnerable; there are few countermeasures. This is especially important in the post-911 environment, where the protection against penetration of secure facilities is even more critical.

There are many misconceptions regarding master key systems and their compromise. These myths are examined in **chapter 11**, in section 11_5.3.7.4. Although it is virtually impossible to derive the code for a master key from inspection of one change key alone, it is a simple matter to derive the code for the TMK by **using** the known bittings from one change key to probe a lock within the system. The reader will learn that another belief that the lock must be disassembled to derive the master key code, is also false. The possession of one change key eliminates the requirement to take the lock apart. The reality is that any conventional system can be broken by anyone having a change key, access, and a few blanks. The following discussion will detail the procedures to accomplish this task.

In the materials that follow, the theory, data requirements and procedures will be detailed to allow the reader to extrapolate the TMK for any conventional master key system. As will become evident, the process is simple, straightforward, and does not require very much technical ability. In past years, there have been a few articles regarding the decoding of master key systems, but none have offered an extensive treatment of the subject.

The reader was introduced to master keying theory in **chapter 11** and **chapter 16**. The material in those chapters dealt with both the theory of conventional master key systems and the methods of deriving useable combinations for simple to complex installations. The concepts of multiple shear lines as well as different keying algorithms to derive the top master key (TMK), master key (MK) and change key (CK) were explored. The reader is referred to section 11_5.5 for a detailed explanation of the methodology of the total position progression and rotating constant systems. A thorough grasp of these theories is required in order to understand the concepts presented in this section and the security threat that is posed by any conventional master key system from decoding and extrapolation techniques detailed herein.

From the materials in chapter 11, it can be readily appreciated that the ability to compromise the TMK is virtually absolute by anyone with access to one master keyed lock, its change key bitting codes and key blanks for that lock. That is because in the correctly sequenced TPP or RC system, there can only be one or two possible shear lines created by each set of pins in a chamber. This critical factor will render all conventional systems liable to penetration.

The following discussion will present detailed information as to the required procedure to successfully extrapolate and decode the top level master key within any conventional keying system. The author wishes to acknowledge the assistance of many persons, including Matt Blaze (AT&T Labs), Harry Sher, and Brian Chan (UC Berkley) for their assistance in developing the material in this section.

31_4.10.2 Overview of Methods to Compromise a Master Key System

Many methods have been described in this and other chapters as to how to obtain key codes and to covertly open locks and safes. There are several methods to compromise a master key system. These include:

- **Access to the master key to copy, photograph, or physically decode;**
- **Access to one or more cylinders (with or without a change key) for the purpose of decoding the pin segments. The lock may or may not be disassembled for this process;**
- **Falle pin-lock decoder to measure pin segments through the use of shim wires;**
- **Falle pin-and-cam pin-lock decoder. This tool allows the probing of each tumbler for its position at shear line. It will also allow the operative to quickly decode a master keyed cylinder to extrapolate the TMK and to generate a key;**
- **Shim the cylinder with depth keys to determine the code for each pin segment. This method requires access to the cylinder shear line for the insertion of a shim wire;**
- **Visual inspection of the pin tumblers;**
- **Optical devices to view the tumblers;**
- **Radiographic techniques;**
- **Analysis of one or more change keys to reverse engineer the system;**
- **Extrapolation and decoding through the use of a change key, as described in this section.**

31_4.10.3 Decoding and Extrapolation of The Top Level Master Key

LSS203: Brian Chan on TMK extrapolation

LSS203: Harry Sher on the decoding of a top level master key

LSS203: Matt Blaze on the extrapolation of a top level master key

LSS203: Harry Sher on covert methods of entry

31_4.10.3.1 The Theory of Extrapolation of the TMK

It is expected that the reader has reviewed the materials presented in **chapter 11** with regard to master keying theory for different progression techniques. The underlying principle that allow the derivation of the top level master key within a conventional system is quite simple and is also the reverse application of the use of "system keys" developed by Chan and examined in detail elsewhere in this text. Essentially, every conventional master key system relies upon the creation of virtual shear lines through the use of split pin keying. All traditional cylinders have one physical shear line: that place between the plug and shell where pins must break in order that the plug is free to rotate. Within the master key environment, each pin segment within each pin stack creates a virtual shear line or another break point. Accepted master keying algorithms utilize split pin segments to create different combinations or bitting patterns that can open a given lock. In total position progression and rotating constant, methodology, no more than two lower pins will be present in each chamber to create the change key **and all master key combinations.** The permutations that are generated for master keys (including the TMK) are derived as the result of the combined use of the different shear lines that are created by the combination of lower pins within each chamber.

Incidental master keys rely upon a **composite** of break points of change and master key values for their creation. The top level master key, however, does not rely upon such combined use of virtual shear lines between it and any change key. Rather, it requires that no TMK depth value be shared with any change key in the total position progression system. It follows that no virtual shear line that is used by a change key can ever be used by the top level master key. This is the critical issue that allows

locks to be decoded: each virtual shear line that is created can either be for a change key **or** TMK. It follows that if the **change key** is used to sample each chamber, then if another virtual shear line is discovered, **it must be associated with the top level master key.** There are a few exceptions to this rule but they are rare. Controlled cross-keying or selective master keying that utilize double pinning would create the exception.

The extrapolation of the TMK requires that each chamber of a cylinder be sampled individually to test and determine the height of each bottom set of pins through a comparison process with the change key value for that position. The change key provides the constant measurement for each chamber in the form of the depth of bitting associated with each position. That constant is equal to the length of one of the **lower pins(345)** within each chamber. The length of the remaining lower pin (which is required to make the TMK operate) can be determined by altering the bitting depth of the change key by one increment for the specific chamber, then probing the pin stack to determine if the master pin is at shear line. If it is not, the bitting is again altered until the proper depth is determined. This process is repeated for each individual chamber until all have been derived.

31_4.10.3.2 Overview of the Process

The procedures detailed in this section apply equally to systems that have two or more keying levels as long as the change key is associated with the TMK. Reliability and complexity of the process is assured for both total position progression systems and rotating constant systems. As discussed subsequently, issues may arise which can make the decoding of a lock and generation of keys more complicated. These include:

- **The master key system does not utilize total position progression or rotating constant schemes;**
- **The master key system utilizes more than two lower pins (bottom pin and master pins), thereby creating more than two virtual shear lines;**
- **The "change key" that is being utilized to decode the system is actually:**
    - **a master key;**
    - **a change key or master key for a different group of locks that are not associated with the target lock;**
- **The sampled lock is not related to the lock that is to be**

opened;

- **The lock to be opened is not on the master key system;**
- **The lock to be opened is not associated with the top level master key.**

These and other issues are discussed throughout this section. It can be seen that although a low skill level is required to actually decode a target lock, a significant amount of intelligence regarding the target may be required in order to successfully produce a key that will open the intended lock or group of locks.

31_4.10.3.3 Security of Master Key Systems

The security of a master key system is based upon its hardware, method and type of progression, levels of keying, design of the TMK, system control, and other issues that are listed below. All will affect the ability to decode the TMK and produce a working key as well as the overall security of the system.

- **Master key and change key design, following standard protocols for the derivation of all combinations within the system;**
- **Design of the top level master key;**
- **Total number of useable combinations within the system. This number is affected by the type of progression and minimum depth increment (one or two-step), the number of available chambers, and MACS rules;**
- **Type of master key system (total position progression, rotating constant);**
- **The number of individuals that have access to master keys and top level master keys;**
- **The security of keys, locks, and code data;**
- **Inability to gain access to a cylinder to disassemble it;**
- **Ease in decoding a disassembled cylinder. This is particularly relevant in the Corbin master ring lock because of the ease in determining the master key code by analyzing all pins that break at the ring shear line;**

- **How long ago was the system implemented. The average life of a master key system is fifteen years, although many have been in use for a much longer period;**
- **Secondary locking system and security enhancements;**

- **Ability to alter sidebar codes within one master key system;**
- **Access control systems that are operated in parallel with mechanical locks;**
- **Proprietary keyways that are protected by patent and copyright;**
- **Difficulty in replicating blanks. This may be especially difficult if side millings, overhangs (Schlage Everest), and specially designed ward patterns and activation of sliders (Medeco M3) or mechanically linked sidebars have been implemented. However, secondary locking mechanisms and the apparent difficulty in replicating restricted blanks may not actually provide the expected level of security;**
- **System monitoring and restrictions with regard to any person having access to keys or locks;**
- **Whether common areas that are accessible to the public are on the TMK. For instance, a locked bathroom that is part of the master key system can allow the system to be easily compromised;**
- **Ability for change keys to be modified to become a master key or TMK;**
- **Unauthorized access to code data for the system;**
- **Security of cylinders, in terms of their ability to be easily removed without notice. Remember, a cylinder does not have to be taken apart to be decoded;**
- **Implementation of two or more systems of physical security within the lock that operate independently and in parallel with each other.**

31_4.10.3.4 How Do You Know that the TMK Has Been Decoded

The initial thought of many security professionals that have examined this procedure is disbelief or a lack of understanding as to how one can be certain that the TMK, rather than an incidental or intermediate master key has been decoded. In evaluating the methodology for this process, the reader can determine mathematically that indeed the process can only yield the TMK **if a change key is used as the sample for decoding.** Remember that within the TPP scheme, the CK is really a composite of the intermediate level MK and CK bitting, and the intermediate master key is a composite of the TMK and CK bitting values. In the case of the change key, it will never utilize a specific depth and position that has been designated for the TMK. In the RC and PPP systems, this is not the case because the value of one

or more chambers will not be progressed and thus will be common to all levels.

Within a conventional system where there is only one physical shear line, there can only be one result. This of course does not hold true where there are two physical shear lines, such as with the Corbin master ring or interchangeable core, discussed elsewhere in this text. Likewise, a positional system cannot be **decoded** by this procedure but is open to compromise by other techniques analyzed elsewhere in this text.

The extrapolation technique relies upon the fact that there is a maximum of two lower pins in each chamber (bottom pin and master pin). The use of additional pin segments (master pins) would complicate the process and create additional possibilities of virtual shear lines for each chamber and the required generation of more keys to accurately decode the TMK. It would also necessitate the testing of more than one cylinder to verify that indeed the TMK has been produced. The technique of double-pinning is not prevalent in most master key systems.

Sectional keyways do not pose any significant problem so long as the master blank can be obtained or milled and there is only one TMK for the entire complex, regardless of the number of sectional keyways that are employed. Even high security systems that incorporate sidebars can be decoded. Rules regarding MACS, key bitting design, number of change keys and master keys or levels, or the number of locks within the system will have no effect upon the ability to decode and extrapolate the TMK. Regarding MACS, it may require a higher degree of knowledge of the manufacturer specifications to change the cutter angle where required to compensate for MACS violation in the test keys.

If a change key is utilized as the constant, then the TMK will most certainly be derived. Conversely, if any incidental master key (other than the TMK) is used as the standard for sampling, then up to 31 different keys for a five pin lock, or 63 keys for a six pin lock would have to be produced in order to determine the top level master key. One or more of these keys will open the target lock.

If sample keys are cut by code, then the keying system must use standard depth codes in order for decoding to be accomplished. If irregular depths were selected or a specific manufacturer utilizes more than one constant depth increment for the same kind of lock, then information must be determined with regard to each

depth and its correlation to a direct bitting code, or keys must be filed by hand, much like impressioning. Examples: Corbin-Russwin utilized different depth increments in their System 70 and pre-System 70 cylinders. Likewise, Best utilizes different increments for their A2, A3, and A4 removeable core locks.

31_4.10.3.5 Other Issues

There are a number of system keying issues that can make the decoding process more difficult and present potential obstacles for the covert operative in deriving the TMK. These relate to hardware, method of progression, special keying requirements, security enhancements, and levels of keying. All such issues must be taken into account prior to and during the extrapolation process. A number of common problems are summarized below.

- **A target lock may be single-keyed, which means that it will not be combinated to work with any keying level. Likewise, a lock may be part of a master key system, but be non-master keyed (NMK). Although in this case one would expect the lock to be controlled by one or more master key levels, it will not. In either of the above cases, the TMK will not work in the target cylinder;**

- **A lock that is directly associated with a specific master key level but none other would allow the derivation of that level only (in sampled lock). Thus, in the example of a four level system where a change key is directly associated with the grand master key, then only that level could be decoded through the process described in this chapter;**

- **If a master ring cylinder is utilized, it will be impossible to derive the TMK from a change key. This is because the lock contains two distinct physical shear lines. If access is provided to a master key, then it can be used to derive the TMK, because all levels of master keying must utilize the ring shear line.**

- **If the master ring lock is disassembled, it is a simple matter to derive the TMK;**

- **The number of levels of keying within a system is irrelevant to the decoding process;**

- **The sequence of progression is irrelevant to the decoding**

process, but may be important if several change keys are available for analysis (if trying to predict how the KBA was derived);

- **If visual key control(346) is utilized within a facility or standard sequence of progression correlates to locks keyed in sequence and placed on doors in a specified order, then it is a simple matter to compute codes for several locks in a defined order. If a contract installation is completed and the installer utilizes locks that have been keyed using the SOP, and those locks are sequentially installed, then the system can be decoded;**

- **A rotating constant system can be difficult to visually decode by evaluating several change keys because there may be no apparent consistency in the sequence of progression or constant (held) chambers;**

- **If the cylinder is maison-keyed, added problems can arise because there may be several master pins in one or more chambers, thereby increasing the number of possible keys that may have to be generated. It must also be verified that maison-keyed cylinders are part of the master key and TMK;**

- **If there are selective master keys or cross-keys for a cylinder that is being sampled, then additional master pins will be present in one or more chambers. This will make the decoding process more difficult because of the increased number of permutations that may be required to derive the TMK;**

- **Sectional keyways may be utilized. Unless a blank for the top level keyway is available, the TMK may not work in the keyway of the target lock.**

- **There can be no TMK if the system is not master keyed. However, in all master key systems, there will be a TMK, whether it is cut or not;**

- **Secondary locking systems or other security enhancements may make the decoding process difficult if not impossible. Special hardware such as the Medeco Biaxial or M3 may complicate the process;**

- **The decoding process will be very difficult if non-standard depths have been utilized, because sampling of each chamber may fail to detect the master pin. In such an event, impressioning skills may be required;**

- **If single-step and two-step progression rules have been violated, then the decoding process will be more difficult because there may be a failure to detect master pin values unless every possible depth is tested. Likewise, if parity rules are violated within the KBA, then every possible depth may need to be tested;**

- **If the number of pins within all cylinders within the system is not the same, then difficulty may be encountered in decoding a specific lock if it is not consistent with the target cylinder. The sampled cylinder must have the equal or greater number of pinned chambers as the target lock;**

- **If an incidental master key has been unknowingly obtained in the belief that it is a change key, then the process of decoding becomes more complicated because there is no assurance that the TMK value, rather than a change key, has been decoded for any specific chamber;**

- **Decoding a rotating constant system may cause confusion when no master pin is found in one or more specific chambers. It should not make any difference for the decoding process as to which chambers are found to be constant, even if a different progression pattern has been utilized for the sampled and target lock. In fact, if enough different locks were sampled for those chambers that were common between the change key, master key, and TMK, then theoreticlally the TMK could be derived in that manner;**

- **If a non-standard method of master keying has been utilized, especially if double-pinning of one or more chambers is present, then the decoding process will be vastly more complicated because of the potential number of permutations that are generated in the sampling process;**

- **The number of keying levels is not relevant unless a non-standard master keying system has been implemented;**

- **If extra master pins have been added to a pin stack, then added permutations are created, requiring that additional keys be tested. In such an event, the TMK cannot be readily identified from one cylinder, and more keys must be generated to account for the added number of permutations.;**

- **If a master ring is implemented, then the decoding process will not work (if a change key is utilized). In such a case, a master key can be used for the decoding process, but a total of 63 trial keys may be required in a six pin lock;**

- **If sidebar (Medeco Biaxial) or slider codes (Medeco M3) vary between master key level, or between the target and sampled lock, then the process can become more difficult to accomplish unless those codes can also be determined;**

- **Key interchange issues within the Biaxial lock that relate to certain fore and aft cuts that rest on the ramps of a specific cut and may indicate that a certain angle and depth has been correctly decoded, when in fact it is a false positive. The problem relates to a fore cut, for example, that rests on the ramp of the key that has an aft cut. The pin may appear to be at shear line, but it really is not. This issue has been discussed elsewhere in this text.**

31_4.10.3.6 Data Requirements for Decoding

As with any covert operation, a prior analysis of the system to be compromised is always recommended. Although the process detailed in this section is relatively easy to accomplish, a significant amount of intelligence should be gathered regarding the target lock and master key system in order to make the decoding process more efficient and reliable in terms of time and resources. Although not critical, it is suggested that the following issues be evaluated and addressed prior to attempting to decode a cylinder.

- **Relationship between the target locks to be opened and the lock that is to be tested with the change key bitting test keys;**
- **Conventional or positional master key system;**
- **Has a Medeco Biaxial or other system been implemented that**

allows a variance of sidebar codes within a master key system? The term "sidebar code" as used in this context refers to the rotation angles of pins, finger pins (such as Schlage Primus), or side millings (such as Assa) whose combination must match that of the sidebar;

- **Has a standard method of progression been utilized for the system (total position progression, rotating constant, partial position progression);**
- **Is the target lock on the master key system;**
- **Is it certain that a change key is available and that the change key is associated with the target lock;**
- **Have standard depths been utilized;**
- **Estimate of the required security of the system;**
- **Change key code of the sampled lock;**
- **Identification of the lock manufacturer;**
- **Is a maison-keying system implemented;**
- **Was the master key system established by the manufacturer or by a local locksmith;**
- **Number of keying levels. This becomes especially important if a master ring system is in place, because double-pinning at the ring shear line may be required;**
- **If construction keyed cylinders are utilized, there may be a potential to lock out the use of certain keys during the extrapolation process. See the discussion in chapter 11;**
- **Information from systems that have implemented visual key control can provide intelligence as to keying levels. Thus, if GM or AA12 is stamped on a key, for example, it provides information regarding the number of levels and keying groups; Other special function cylinders can affect the decoding process. This would include limited rotation, hotel function, prison function, and key change cylinders such as Instakey;**

Obtain all manufacturer data for the specific cylinders under attack, to include:

- **Tolerance between plug and shell;**
- **Rules and limitations with regard to keying;**
- **Number of useable differs for the master keyed cylinder, based upon a key bitting array for either TPP or RC schemes;**
- **Keyway protection with regard to ability to duplicate keys;**

- **Ability to replicate or obtain blanks;**
- **Depth coding and computation of the space between depths (minimum depth increment);**
- **Likelihood that a single or two-step progression would be utilized in the master key system;**
- **Integration of high security locks with conventional profiles, such as Schlage Primus and Medeco bilevel (available in Europe);**
- **Cross-keying issues and whether there are more than two virtual shear lines created by the master keying scheme. Although this is extremely rare, it can occur;**
- **Utilization of standard or non-standard bitting depths;**
- **Violation of MACS rules;**
- **Use of non-standard cuts that may require a cutting wheel with a special angle to generate test keys. This is a MACS problem, because generation of certain test keys may create depth combinations that were never meant to be cut. In such a case, the cutting angle must be altered to compensate for the problem;**
- **Identification of the keyway(s) used within the complex;**
- **Identification of all sectional keyways and the TMK keyway, or the highest section;**
- **Number of active chambers within each lock;**
- **Whether the master key system was created by the manufacturer or by a local locksmith;**
- **Number of master key levels;**
- **Special design rules for change or master keys;**
- **Applicable MACS rules by this particular manufacturer;**
- **Use of secondary locking systems, such as sidebar, magnetic or electronic;**
- **Use of trap pins or functions that would change the combination if a pin was lifted to an improper depth and the plug was rotated. This condition can occur in the Corbin construction lockout system, described elsewhere;**
- **Use of special key change functions that could alter the pin stack;**

31_4.10.3.6.1 Information From the Change Key

A great deal of data can be obtained from an evaluation of the change key itself, assuming that the manufacturer has been identified. Much of that information will provide an insight into

the type of master key system, the potential number of test keys that will be required, and an idea of how the master key and change key levels are progressed. Keys can still be generated if the manufacturer or identification of the blank cannot be ascertained. See the information on the Easy entrie profile milling machine, below.

Information that can be derived from the change key includes:

- **Identification of keyway and available blanks;**
- **Identification of sectional keyways and all of the potential sub-sections as well as the keyways that control each section and which would be utilized for the TMK;**
- **Number of active chambers within each cylinder;**
- **Whether a one or two-step progression is utilized;**
- **Parity system;**
- **Depth and spacing data;**
- **Change key code;**
- **MACS rules;**

31_4.10.3.6.2 If the Sample Key is a Master Key

Although it is preferred to obtain a change key for the decoding process, it is not vital to the success of the operation. A change key will produce the TMK, assuming that the cylinder is part of the master key system. In the event that an incidental master key is utilized, the same procedure is followed but the result will be different and more complex. In a cylinder that utilizes a true total position progression system, there will always be one master pin within each chamber. In a five tumbler lock, this means that a total of thirty-two (2^5) different combinations will be decoded. Thus, one or more of the possible permutations will open the target lock(s). However, if an incidental master key is utilized for the decoding process, then the results may be varied, because such keys may be a one, two, three or four pin master key. However, there will still the same number of permutations, based upon the number of chambers and lower pins in each chamber. See the discussion in **chapter 11** regarding row, block, horizontal group master, vertical group master, and page master key.

31_4.10.3.6.3 Information from a Change Key and

Master Key

If a single change key and one master key are both available for comparison, much more information can potentially be learned about the target system. The ability to compare bittings within the same area of a facility can often provide valuable insight into how the system was designed and progressed. The data listed below may be particularly relevant when reverse engineering a system. Information that may be obtained from a comparison of the two keys includes:

- **Whether the system is a rotating constant or total position progression. Generally, this cannot be derived from just two keys, but if several samples are available, then it may be possible to make an educated guess as to which systems has been implemented;**
- **The possible progression sequence;**
- **Which chambers have been progressed for the master key and change key;**
- **How many chambers have been progressed;**
- **The possible total number of master keys that can be assigned within the system;**
- **The number of possible change keys under each master key that can be assigned;**
- **System parity;**
- **The possible depths that have been defined for the TMK, based upon their non-use in the master key and change key;**
- **Any depths that are found in the change key will not normally be used in the TMK. This is not the case for the master key. In fact, a comparison of the master key and change key can identify depths that are used in the TMK. Remember: the master key and TMK will share at least one or perhaps two or three common depths that will usually not be common to the change key;**

31_4.10.3.7 Inferences and Assumptions About the TMK or Master Key

LSS204: Brian Chan on assumptions regarding master keying

Based upon information that can be gathered about the target lock and its location, certain facts about the master key system and

the top level master key can be deduced, inferred, or assumed. These include:

- **The first cut toward the bow of the TMK will not be too deep, in order to insure its structural integrity;**
- **The key bitting will not assume a stair-step pattern, either ascending or descending;**
- **At least one of the cuts will be shallower than any change key cut, and one cut will likely be deeper than any change key cut to prevent jiggling;**
- **None of the bitting depths in the change key will appear in the TMK if a true total position progression system has been implemented. In the partial position progression system, this is not the case. There may indeed be one chamber that is shared between all keying levels. Similarly, if a rotating constant scheme is employed, one or more depths will be shared between the top level master key and change key. The constant or shared pin can be in any position, and may vary between locks within a system;**
- **Based upon manufacturers specifications, depth increments, and from an analysis of at least two change keys, in some cases, it may be determined whether a one or two-step progression has been utilized. A measurement of the depth coding for the change key will yield this information. The covert operative will then know whether every depth (single-step progression) or every other cut (two-step progression) must be tested;**
- **A visual inspection of the pin stacks (stack probing) may yield some information regarding shallow cuts. If splits in the pin stacks can be observed, then an educated guess can be made as to the depth of each pin that is viewed;**
- **The color of a pin may yield information as to its length. This may be especially true if after-market pins have been used and the color coding for each depth for that vendor is known. Caution: color coding for a manufacture may be different, based upon whether there is a .003" or .005" difference between pin lengths. Pin kits may use one format or the other;**
- **If the change key can be inserted into locks within different areas of the facility, this would provide a good indication that sectional keyways are not in use;**
- **Based upon the change key, the number of active pin chambers within the target lock can be ascertained;**
- **The number of pins within the lock will usually be from four to**

seven;

- **There will usually be a total of between four and ten depth increments;**
- **There will be the same number of pins in every lock in the system. This is generally the case, but may not always be true, depending upon the security requirements of the system;**
- **The change key design and blank information will indicate whether this is a conventional master key system, and whether high security enhancements, such as sidebar, are being utilized;**
- **Based upon manufacturer, information should be available to indicate whether a master ring is being utilized, which would frustrate the process. Master ring cylinders are generally larger in diameter than standard configurations with one physical shear line;**
- **Letters may be stamped on keys or locks that may yield information about keying levels. See chapter 11 regarding the Standard Key Coding System;**
- **Special rules will apply to Medeco Biaxial systems. See section 31_4.10.6;**
- **Depending upon the manufacturer, the presence of a sidebar may not prevent the system from being decoded;**
- **The system probably does not employ master rings;**
- **The presence or absence of security pins will not affect the decoding process;**
- **There will likely be one TMK for all locks within the facility, even if different sectional keyways are employed;**
- **If considering a government or other high security installation, it may be assumed that certain locks will not be on the master key system, and thus, neither the target lock nor locks within that group may be compromised. Locks that may not be master keyed might include perimeter access, non-administrative areas, locations where explosives or weapons are stored, and areas where critical information is contained;**
- **Standard depth coding and increments can be assumed, unless intelligence about the facility indicates otherwise;**
- **There is no rule with regard to the position or order within the pin stack of bottom and master pins. Any assertion that the bitting of the change key will be below or above that of the master key or TMK is false;**
- **There is no guarantee that the target lock is not single keyed (SKD), or not master keyed (NMK). In such a case, it will be impossible to derive the TMK;**

- **If a lock is directly associated with a keying level below the TMK but not with the TMK, then it will not be possible to extrapolate the TMK directly. In this instance, it may be necessary to generate more permutations. The likelihood in this instance will be that the target lock will not be on the TMK;**
- **It is not necessary to probe the depth value of the change key for each position;**
- **In a single-step progression, every possible depth (other than that of the change key for a specific position) must be tested;**
- **In a two-step progression system, all odd or even depths (other than that of the change key) must be tested;**
- **If a rotating constant or a TPP system(347) is implemented and all chambers are not progressed (PPP), there may only be one depth in any one chamber. In such case, the value of the change key bitting for that chamber will be shared with the master key and TMK;**
- **One depth in any chamber would indicate that the master key scheme is rotating constant or partial position progression;**
- **Unless the system is extremely large, only one or two chambers will be progressed for the master key; the remaining chambers will be progressed for the change key. Note that this is not a hard and fast rule, because some large systems may have many master keys and few change keys, so the key division would be different;**
- **In a Biaxial system, rotation patterns may be varied for different keying levels or groups of locks. This can make the decoding of the TMK virtually impossible;**
- **It is likely that chambers (positions) are progressed in order, rather than staggered;**
- **It is likely that the first one or two chambers will be progressed for the master key, although this is not a fixed rule;**
- **Any depths that are used in the change key will not be found in the TMK within a TPP system. This is not true for depths utilized in a master key in a total position progression system;**
- **If the cylinders contain six pins (regardless of the division employed) there will generally be a total of 64 potential master key combinations. If several change keys are available, then it may be possible to accurately guess the division of the key, although without further information, such a determination is not reliable;**
- **If a number of change keys are available for evaluation, they may not provide any meaningful information if they are associated**

with different master key levels;

- **Sidebar systems that utilize side millings can make the replication of keys more difficult but will generally not affect the decoding process, assuming that there is only one sidebar code that is utilized for every cylinder in the system. This may not be the case if the Medeco Biaxial or M3 system is implemented;**
- **Stair-step patterns are not utilized;**
- **There should not be three adjacent equal depth cuts on one key. Most manufacturers will allow two consecutive depths, however;**
- **If there is not a master pin in one or more pin stacks, then the lock is part of a rotating constant or partial position progression system;**
- **TMK values for each position can be above or below those of the change key;**
- **All depths for each position, other than the change key value, must be sampled. This depends upon whether a one or two-step progression is employed;**
- **Plug or key markings may provide information about the system and levels of keying. See the discussion in chapter 11 regarding the Standard Key Coding System;**

31_4.10.4 Decoding a Target Cylinder

The information presented in the following sections will provide the tactical and operational procedure to derive the top level master key for most conventional cylinders. The preceding materials in this chapter and in **chapter 11** provide the underlying theory of the extrapolation process. The procedure requires that a change key be available that is part of the master key system within the target facility. The procedure may also be accomplished with a master key, but it is more complicated. The availability of blanks for the target lock is also required. These may be obtained through normal channels or may be created in the event they are restricted. Detailed information is provided in **chapter 8** regarding the creation of blanks through the use of profile milling machines. Note that in certain instances, patent protected profiles may need to be replicated. The reader is cautioned that the generation of certain keyways may violate federal patent statutes.

31.4.10.4.1 Variables in the Process

It is important to understand and anticipate the variables that may be encountered in any process of covert entry. There are a number of conditions that can make the decoding of the TMK more difficult or impossible. Each of these factors has been discussed in earlier sections relating to this subject and must be taken into account prior to and during any operation to derive the top level master key. The primary variables to obtain the TMK include:

Sectional keyway: If a different sectional keyway is utilized for the sampled lock and the target cylinder, then the derived TMK from the sample cylinder will not be able to enter the keyway of the target lock.

Selective master key or cross-keying: See **Double pinning**, below.

Rotating constant or partial position progression system: IN a rotating constant or partial position progression system, then one or more depth values of the TMK will be common to the master key and change key. The practical implications of this condition will require that every possible depth be tested in order to determine the TMK value. Recall that in the TPP system, the values of the TMK depths are never shared with any change key, and thus, the specific depth for each position of the change key does not need to be sampled in order to derive the top level master. However, in the RC or PPP system, one or more chambers may only contain one bottom pin (no master pin).

An interesting permutation of this issue would occur if a selective master key (SMK) or cross-keying of one or more cylinders was utilized within a rotating constant or PPP system for certain progression patterns. Then, one or more chambers would contain two lower pins: one pin would be equal to the shared value of the change key, master key, and top level master key, while the master pin would be utilized to turn on or off a selective master key or create a cross-key. This could be very confusing to the operative because he might wrongly assume that the TMK utilized the second pin for a specific chamber, resulting in the misidentification of the system as TPP rather than RC or PPP and the generation of a key that was not the TMK. Note that the integrity of an RC system is based upon the premise that a single pin will be in one or more chambers. If that rule is violated, then key interchanges that result will be impossible to analyze.

Master ring: A master ring will prevent a cylinder from being

decoded through the use of the change key. This assumes that (1) all change keys operate at the plug shear line, and (2) all master keys and top level master key functions at the ring shear line. If the system has more than two keying levels, then double-pinning may be required at the ring shear line. It may then be possible to derive the TMK, if a **master key** is available. However, it is not possible to utilize the change key that is operating at one physical shear line (plug) in order to determine TMK values at another physical shear line (ring).

Double-pinning in one or more chambers: If double-pinning exists in one or more chambers, then additional permutations of possible TMKs will be generated. Double-pinning can be present if selective master keying or cross-keying is required.

No master pins: A lock that is single-keyed or non-master keyed would usually not contain master pins in any chamber. A master ring lock would act as if it did not have any master pins. A **Medeco cam lock(348)** only has one set of pins, and relies upon bores within each pin to control the sidebar. Finally, if an error is made in the KBA that results in the duplication of a TMK value for the change key or master key, then only one bottom pin may be present for a specific chamber. In such an event, the cylinder can still be decoded.

Master keyed but not on the TMK: A lock that is master keyed but is not associated with the top level master key cannot be decoded for the TMK, but may allow derivation of one or more master keys. Some locks may be combinated for certain master key levels, but will not be operated by the TMK. In such an instance, decoding will yield incidential master keys, but not the TMK.

Violation of minimum depth increment rules: If the .023" minimum depth increment rule is violated and depths have been programmed into the KBA that do not meet this specification, then change keys and the TMK may utilize depths that would not normally be tested through the extrapolation process. In such a case, every depth that the manufacturer makes available within the specific cylinder must be tested against the change key.

Single-step progression where a two-step progression is expected: See the preceding section. If it is expected that a two-step progression has been utilized in writing the key bitting array, but in fact a single-step progression was employed, then every depth must be sampled rather than every other depth. There are cases where single-step progression is utilized where the minimum

depth increment is less than .023", but this is compensated for by tightening manufacturing tolerances.

Different depth increments for the same type of lock produced by the same manufacturer: A manufacturer may utilize different depth increments for the same type of lock. The Best A2, A3, and A4, and the Corbin-Russwin System 70 present such an example.

Parity rules not followed between the TMK and change key: If parity rules are not adhered to between the values of the TMK and other keys within the system, then all depths for each position must be tested against the change key.

Non-standard depth coding: If non-standard depth coding is employed, then a measurement of the bitting for one or more change keys may be required to determine all potential depths that may have been utilized for the TMK. This information may be theoretically extrapolated from one change key by measuring each of the individual positions and the increment between depths and then adding or subtracting the value of such increments to determine the total number of depths and their measurements.

Different sidebar bitting codes for the TMK and change key: If there are different sidebar bitting codes, slider codes (Medeco M3), or other security enhancements that distinguish the change key from the top level master key, then it may be impossible to derive the TMK unless those unique bitting patterns can be simulated in order to generate master key blanks.

Error in the KBA from which combinations for the TMK and change key were derived: A discussion of KBA errors was presented in **chapter 11, section 11_5.3.6.3.** If an error is made within the key bitting array (as shown in the above section) wherein a value of the TMK is repeated for use as a change key or master key, then for that position and combination, a master pin may not be present. This condition could lead to an erroneous conclusion that the system was RC or PPP. The results of such an error may not be relevant.

31_4.10.4.2 Tactical Considerations in the Decoding Process

There are several methods to decode the TMK that will require either a single session with the sampled lock or multiple sessions. Although a change key is the primary means for

extrapolation, the lock may also be shimmed to derive all pin stack information, or the Falle decoding system may be utilized. The decoding processes that are detailed in section **31_4.10.4.3** will describe procedures relating to the different methodologies.

The following general issues must be addressed and verified prior to any decoding procedure:

- **Determination that extrapolation is the best method to derive the TMK, and an elimination of picking, impressioning, and alternate decoding methods as more desirable procedures;**
- **Verification that there is only one master key system;**
- **Verification that the change key is to be used for sampling;**
- **Verification that the proper blanks have been obtained;**
- **Label each system key by chamber position in order to avoid confusion. A tactical situation may dictate a different procedure;**
- **Any secondary locking mechanism, such as a sidebar, must be the same for both the change key and top level master key;**
- **Within what time frame is the decoded TMK required. This will in part determine whether a lock is sampled in one or multiple sessions;**
- **Verification that the number of pins in the sample and target lock are the same;**
- **Verification of the depth coding for the sample lock;**
- **Only one change key or master key is required. Note that it is not as desirable to generate the change key through impressioning or picking and decoding, because the product may be an incidental master key. A key may be obtained by an employee, or as a duplicate obtained from an employee or service person. It may also be a stolen key or borrowed and copied or decoded;**
- **Access (whether authorized or unauthorized) to a cylinder that is associated with the top level master key;**
- **If sectional keyways are employed, then verification must be received that the proper blank is available for the target lock;**
- **Ability to reproduce bittings for each sample key. This may be done by hand file and a micrometer or a decoding device, such as the HPC HKD-75 or a code cutting punch such as the pack-a-punch or key machine;**
- **If the Falle pin-lock decoder is being utilized, verification that the proper keyway has been supplied;**
- **Determination of the number of samples that can be obtained**

from the test lock at one time, or over a period of time;

- **Access to more than one cylinder, if required;**
- **Sufficient number of blanks to complete the sample process;**
- **The time available for the decoding process and any time constraints on the process;**
- **The visibility of the sample and target lock;**
- **An analysis of the work area where the decoding is to occur in order to determine power requirements, lighting, visibility, sound transmission, video surveillance, alarm systems, and likelihood of interruption;**
- **The specific location of the target and sample locks;**
- **The number of locks to be tested and verified;**
- **If reprogrammable locks are installed, such as Instakey, then bottom pins or master pins may be inadvertently removed or parked, thereby changing the combination of the lock and providing a false positive indication of the TMK;**

31_4.10.4.3 Decoding Methods

The following methods may be utilized to derive the top level master key within a conventional master key system:

- **Decode the TMK with a change key in one session while at the test cylinder;**
- **Decode the TMK with a change key in multiple sessions, requiring several individual samples to be taken from one or more cylinders;**
- **Decode the TMK with a change key in multiple sessions with precut system keys;**
- **Decode the TMK with a master key in one session. In actuality, up to 32 or 64 keys would be generated in this process, but the actual value of the TMK (which key was the TMK) would not be known;**
- **Decode the TMK with a master key in multiple sessions;**
- **Shim a cylinder to determine the composition of each individual pin stack, generate all possible permutations of the TMK at a remote location, then visit the target lock in one or more sessions to determine which of the generated keys will actually open the target lock. Just because the lock can be opened does not mean the top level master key has been utilized to do so;**
- **Utilize the Falle pin-and-cam pin-lock decoder system to decode**

and possibly generate a working TMK during one session;
- **John Falle Pin lock decoder (original model).**

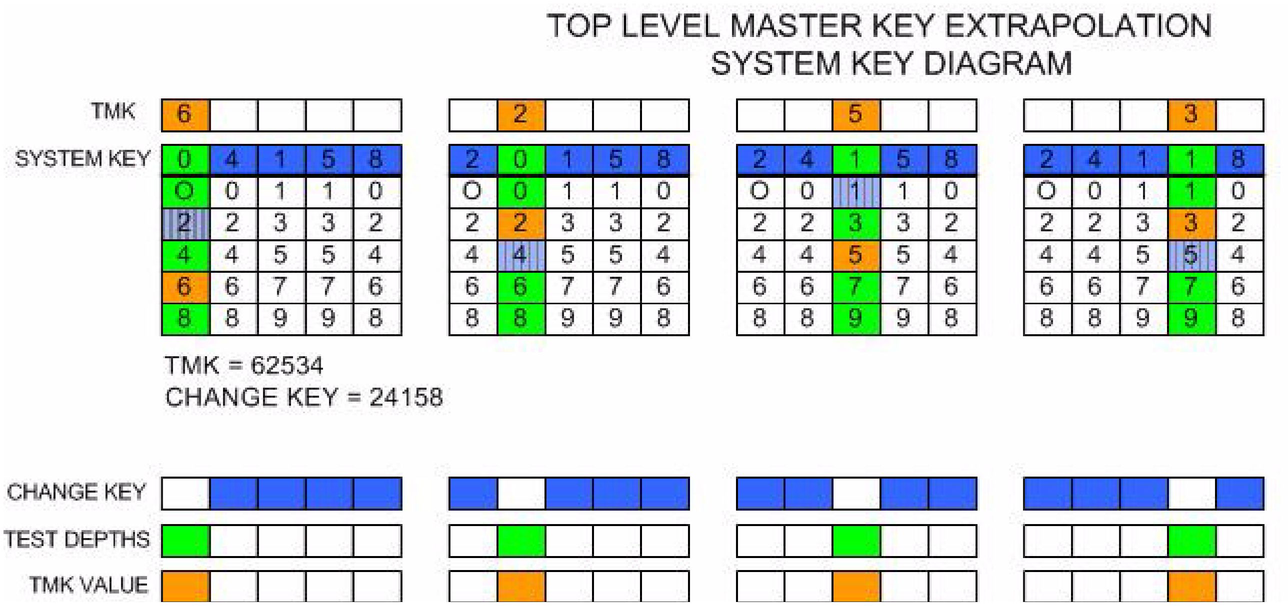
Each method is described below.

31_4.10.4.3.1 Decode the TMK With a Change Key In One Session;

In this technique, a TMK is produced in one session by decoding each pin stack in succession. The minimum number of blanks that will be required will be equal to the number of chambers within the lock, although this number can be reduced if multiple chambers are sampled on one key. This depends upon whether TMK cuts are above or below those of the change key. If they are below, then more than one chamber can be tested, although there is a danger in this shortcut if double-pinning of a chamber is present. At the conclusion of the process, one extra blank may be needed to cut the compiled values of the TMK.

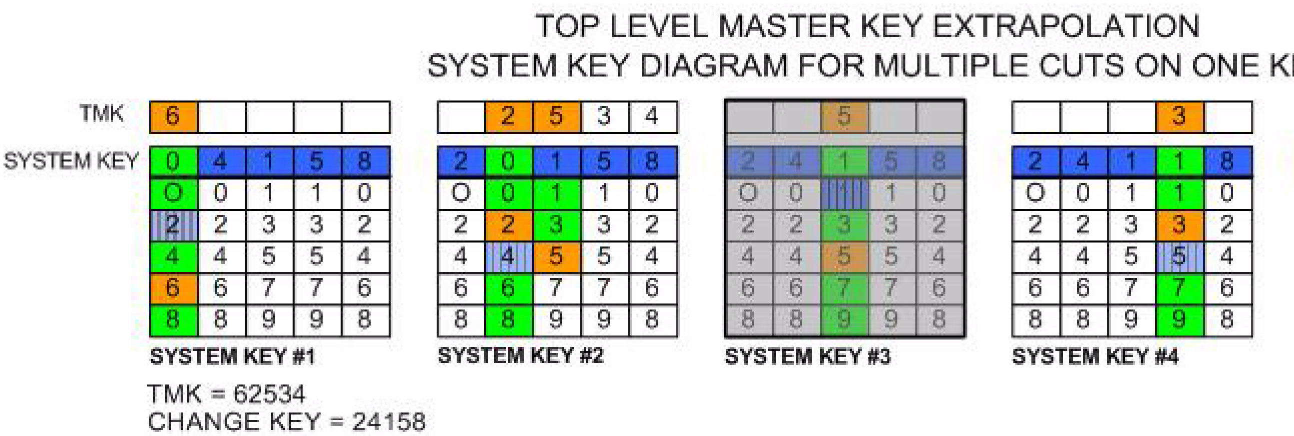
In preparation for the procedure, keys must be precut for the lock, to equal the number of chambers. We shall use a five pin Schlage cylinder as an example, with a change key code of **24158** and a top level master key of **62534**. Recall that the shallowest cut for a Schlage lock is 0; the deepest is 9. Schalge minimum depth increment is .015", so a two-step progression is utilized. Parity must be maintained and can be assumed to be the same for the change key position and that of the TMK.

Five system keys would be produced for this lock as shown in the diagram: **04158 20158 24158 24118 24150**. Note that the shallowest cut is placed on the bitting surface for each chamber to be tested (shown in green). Refer to chapter 11, section 11_5.6.2.1 for a detailed discussion of system keys, as introduced by Chan. The keys that must be cut in our example are system keys but their purpose is to test for the TMK rather than for the change key.



The diagram shows a modified key bitting array, with all possible depths entered into the matrix under the system key code. Each system key is the change key with one bitting position set at 0 to allow a sample to be taken for each available bitting value. Each grid represents one key. The depths marked in green are each cut in sequence, with all other depths for that particular system key (blue) remaining constant. The depth that is equal to the change key is not cut (shown in cross-hatch blue). As the system key is tested for each available depth, the lock will open when the TMK value is cut (shown in orange). Note that all depths are tested (other than the change key value) to insure that double-pinning has not been implemented. At the conclusion of the process, five keys will have been cut, and the top level master key will have been derived. A sixth key can then be generated by code for the TMK. The exception to this rule would be where multiple cuts are made on one system key.

Multiple samples may be made on one system key, depending upon the change key bitting, which system key is utilized, the value of the next TMK depth, and which chamber is sampled. In the diagram below, four system keys are required to sample a five pin lock. In this example, if each new test key is cut to the derived TMK depths as they are decoded, then five keys will be required.



Two chambers can be sampled in system key #2 because the bitting value of the change key in the third position is shallower than the TMK value. Thus, the "1" cut in position "3" can be tested for a "3" and "5" (the value of the TMK). System key #2 cannot be utilized to sample the fourth position because the bitting value of the change key is "5", which is lower than the "3" assigned to the TMK. In our example, Schlage has a MACS of 7. If a TMK position value was 9, for example, and the adjacent depths included a 1, then it would not be necessary to cut that value because it would create a MACS of 8. Thus, in our example, adjacent cuts of 09, 08, 19 would not be utilized and could be skipped.

In practice, a file, pack-a-punch, code cutting machine, or code punch can be utilized to physically cut the system keys and test each depth for each chamber. At the conclusion of the process, the composite is cut on a new blank and tested in the target lock, (or more than one lock if the target is not available).

31_4.10.4.3.2 Decode The TMK With A Change Key In Multiple Sessions

The same procedure is employed as in 31_4.10.4.3.1, but each depth for each position is tested during a separate session, reducing the risk of detection and the potential of being caught with key cutting implements or blanks. The lock is sampled for each position and each chamber and the appropriate depth cut is made on the system key for that chamber. At the conclusion of the procedure, a system key will have been produced for each position. A composite TMK can then be generated by code.

31_4.10.4.3.3 Decode The TMK With A Change Key In Multiple Sessions With Precut System Keys

The change key can be used to generate system keys in advance of decoding that will allow a rapid determination as to the TMK value for each position. This procedure will allow a lock to be decoded in one session or over a period of time, depending upon the sensitivity of the operation and whether an operative can run the risk of being caught with multiple system keys. In either scenario, a set of keys are generated to provide all possible permutations of each positional value. In our original example in section 31_4.10.4.3.1, the change key code was 24158. Based upon a two-step progression, the even values would be 0,2,4,6,8 and the odd values would be 1,3,5,7,9. Four system keys are required for each position, replicating the process used by Chan and discussed in **chapter 11**. The system keys for this cylinder would require a total of twenty blanks and would be cut as follows:

SYSTEM KEYS FOR CHANGE KEY 24158				
POSITION #1	**POSITION #2**	**POSITION #3**	**POSITION #4**	**POSITION #5**
04158	**20158**	**24358**	**24118**	**24150**
44158	**22158**	**24558**	**24138**	**24152**
64158	**26158**	**24758**	**24178**	**24154**
84158	**28158**	**24958**	**24198**	**24156**

Each key would be tested in sequence against the test or target cylinder. For each position, one of the four keys will open the lock if the master key system was derived through total position progression. If a rotating constant or partial position progression system is employed, then one or more systems key sets will not work for a particular position. That would indicate a held position that was common to the change key, master key, and TMK. This fact should be noted, and the value utilized when generating a composite TMK by code.

31_4.10.4.3.4 Decode The TMK With A Master Key In One Session

Decoding a cylinder using a master key rather than a change key

becomes more complicated because composite combinations are being evaluated, rather than the clear distinction that exists between the change key and top level master key. In order to utilize the master key to determine the TMK, a two-step process must be completed: each position must be probed for all values, then all permutations must be produced in order to test the lock. Recall that the **master key** is actually a composite of the division of the key: one part is assigned to the master key and the remaining portion is **shared** with the TMK. If the master key is utilized for extrapolating the TMK, then the problem becomes one of determining which decoded value for each position is part of the TMK/MK and which belongs to the master key/change key. Up to 64 permutations will be produced in a six pin lock that is set up on a total position progression system. Each of these permutations may need to be produced and tested against the target lock to determine the true TMK. If the system was established using a rotating constant, then there will be fewer permutations but the process will require the same procedure.

31_4.10.4.3.5 Decode The TMK With A Master Key In Multiple Sessions

The same process as explained in 31_4.10.4.3.4 is carried out, but in multiple sessions. Each

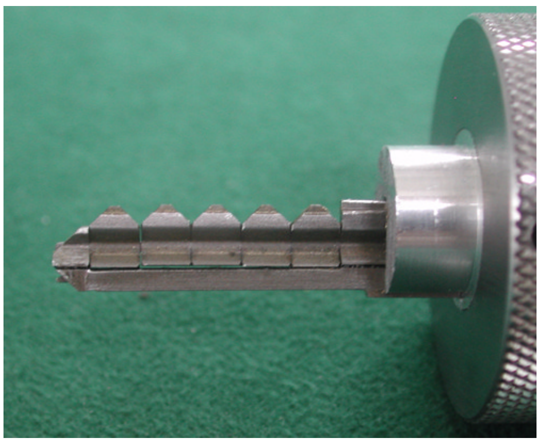
31_4.10.4.3.6 Shim A cylinder

LSS203: Matt Blaze on shimming a cylinder to determine all pin segments

A cylinder can be shimmed and decoded by using a set of depth keys but without the need for disassembly. This topic was detailed in section 31_4.9.1. The process requires that a set of depth keys be produced for the target cylinder. A shim is inserted at the back of the lock and each depth is probed for each position, beginning at the tip of the key (rear of the plug). Notation is made of each value that allows the shim to pass. When all chambers have been probed, a replication of each pin stack will have been produced. Test keys can then be cut by code for all permutations. A cylinder containing six pins that is set up for total position progression will generate a total of 64 combinations (2^6). One of these will be the top level master key.

31_4.10.4.3.7 Utilize The Falle Pin-and-Cam Pin-Lock Decoder System

The John Falle pin-lock pin-and-cam decoding system described in section 31_4.6.1.2.2 can be utilized to generate system keys if the correct profile is available for the tool. As shown below, the Falle system can replicate each bitting value for each position, eliminating the requirement to physically cut each system key.





This sophisticated tool allows the code for the change key to be entered into the bitting selector. A composite key is then instantly produced that will open the lock at the change key level. Each bitting increment is then tested in sequence for each chamber until the TMK value is determined for each position. This system is extremely compact and can allow the covert decoding of a cylinder within a very short period of time.

31_4.10.5 Obtaining Sample Change or Master Keys for the Extrapolation Process

In order to perform the extrapolation procedure, a change key is required. As detailed elsewhere in this text, there are a number of ways to secure this key, including:

- **Obtaining possession of an authorized key as an employee, agent, contractor or other legitimate status;**
- **Obtain a photograph or facsimile copy of the key and then generate a physical duplicate;**

- **Obtain a copy of the change key through the normal duplication process or by impression using clay, silicone, or other materials;**
- **Obtain the direct code from numbers stamped on the key;**
- **Obtain the code by compromise of the database where such information is contained;**
- **Obtain the code from the locksmith that set up the master key system;**
- **Obtain the code or a copy of the key from the manufacturer through authorized or unauthorized channels;**
- **Obtain the code for the key by visual inspection or by physically measuring it;**
- **Obtain the code for the key through shimming of the cylinder, discussed in previous sections;**
- **Impressioning the lock. This procedure may yield a change key, incidental master key, or TMK;**
- **Use of certain decoders that are produced by John Falle and others to determine bottom pin lengths for each chamber;**
- **Use of the Falle pin and cam pin lock decoder to determine the actual pin stack values for each chamber. This procedure would provide the codes for all lower pins segments. Test keys could then be generated with the same tool to derive the TMK, through a process of testing each combination against the target cylinder;**
- **Other methods that are summarized in chapter 28.**

31_4.10.6 Special Rules for Decoding Specific Locks

Certain locks will be extremely difficult to decode and extrapolate for the TMK. This results from the integration of secondary locking mechanisms that utilize independent systems that are not directly related to each other, or for which there is no constant. Even though traditional methods of defining master key systems (TPP, RC, PPP) are utilized for the generation of bitting codes, ancillary locking systems may yield information that is of no value in the decoding process.

31_4.10.6.1 Medeco Sidebar Systems

Detailed information regarding Medeco locks can be found elsewhere in this text. The company received the first patents for the sidebar locking concept based upon rotating tumblers,

both in cam lock and traditional pin tumbler configurations. Subsequent to the original designs, Medeco introduced its Biaxial system, and in 2003, the M3 enhancement. It expects to release the M3 upgrade and biaxial for cam locks in 2004. In the United States, Medeco has achieved the greatest market penetration as a high security lock manufacturer. Their locks are preferred in many applications within the public and private sectors because of the security that they provide against all forms of covert attack. Although certain of the mechanisms are subject to the more sophisticated forms of bypass, others are not. Our discussion will focus on methods to compromise master key systems that have relied upon Medeco hardware for security. Sophisticated tools and techniques have been discussed in earlier sections of this chapter with regard to methods of decoding and bypassing Medeco cylinders.

The author has always believed that the design philosophy that Medeco adopted for the implementation of the sidebar principle for pin tumbler locks was the most secure, as compared to techniques employed by other manufacturers. The integration of rotation and elevation within the locking component (pin tumbler) can make this mechanism extremely difficult to neutralize or decode. The Biaxial addition provided an extension of the original patent protection and offered the ability to implement extremely large master key systems without the problems of key interchange and insufficient differs for the definition of multiple keying levels.

The choice by Medeco not to split conventional pin tumbler locking technology (vertical movement across a shear line) with the rotation of the pin distinguishes the design from all others that have chosen to implement the sidebar as a secondary locking technique. Virtually every other manufacturer that utilizes the sidebar to secure the plug against rotation is limited to one arrangement, position, elevation or rotation pattern for all locks within a system (that have a common top level master key). This is not the case with the Medeco Biaxial and M3 designs, and therefore makes it unique with regard to the extrapolation process discussed in the preceding sections.

31_4.10.6.1.1 Medeco Cam Lock

The Medeco cam lock relies upon a single set of pins and does not have a traditional shear line. Rather, each tumbler has one or more bores that correspond to a protruding pin of the sidebar, as shown in **Figure 17-21A.** Master keying is accomplished by placing

multiple bores within each pin. The function of the key is to lift and rotate the tumbler in order to line up all bores so that the sidebar can retract into the plug. The M3 and biaxial schemes will be incorporated in 2004.

If a change key is obtained for any cam lock within a master key system then the TMK can be decoded by varying the elevation and rotation of each bitting position, using the change key as a constant. Even though the cam lock is a relatively low security mechanism in fact, it offers greater resistance against the extrapolation technique than does a conventional pin tumbler design because of the requirement to generate multiple permutations of bitting and rotation values for each chamber.

31_4.10.6.1.2 Medeco Original Pin Tumbler System

The original design of the Medeco pin tumbler lock provided for three rotation angles: left, center, and right. Within a master key system, the pattern of angles must be defined for **all** locks and cannot be altered, once established. Thus, all keys will bear the same angle pattern. It can be seen that once any key for any lock can be obtained, the information regarding the angle of rotation for each chamber is known. In order to defeat the original Medeco system, the same procedure is followed as for conventional locks, with the exception that the rotation pattern must be replicated for every test key. Although more time will be required to accomplish the extrapolation process, it will not prevent the successful decoding of the TMK. This is only true with respect to the difficulty of generating keys with sidebar codes. It is recommended that any master key system that relies upon the original Medeco design be evaluated as to the risk of compromise through the extrapolation technique. It is not a difficult matter to duplicate Medeco key bitting or angles, and so the threat is significant, depending upon the requisite security level of the facility. As discussed subsequently, use of the Biaxial or M3 cylinders will insure that a great deal more difficulty is encountered in compromising the TMK for those locks. Note that key blank distribution will continue to be restricted by Medeco after the expiration of applicable patents, so blanks may be difficult to obtain through normal channels.

31_4.10.6.1.3 Medeco Biaxial System

The Medeco Biaxial concept adds a layer of complexity and

security to the original design and also provides for many more differs for master key systems. The Biaxial and M3 will make the extrapolation of the TMK exceedingly difficult, but not impossible. A detailed discussion is presented here because of the prevalence of Biaxial cylinders in high security applications worldwide.

31_4.10.6.1.3.1 The Biaxial: An Overview

The Biaxial mechanism, as described in chapter 17, is a modification of the original pin tumbler design. It altered the location of the root of each tumbler position by creating an offset chisel point that rests be**fore** or **aft**er what would be the root center point in the original configuration. Although the lock functions in identical fashion, a total of 6^6 or 46,656 possible permutations of sidebar patterns were created. In the view of the author, the Biaxial is a lock that is extremely secure against the process of extrapolation, unlike most other mechanisms that employ a sidebar as a secondary locking system.

The original Medeco design, as well as those of other manufacturers, employ the sidebar as a totally separate locking system. However, unlike other designs, the rotation and elevation of the pin is integrated into the pin tumbler, rather than occurring as separate mechanical operations. Both Assa and Schlage, for example, utilize separate side millings on the key to interact with finger pins or side grooves on tumblers. In both examples, the side milling portion of the key can be separated from the bitting portion, thus allowing the lock to be picked. This is not possible with the Medeco designs.

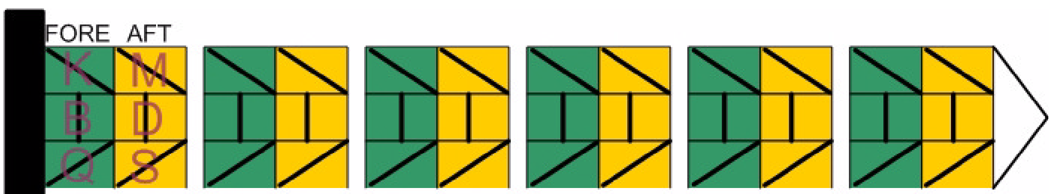
The use of rotating pins is unique to Medeco and creates two parallel locking systems; one that is conventional and which relies upon the pin tumbler being raised to a shear line, and one that can be compared to a positional system that relies upon the rotation of each pin, and which can be varied throughout a system as graphically illustrated below. Although Emhart also introduced a rotating pin concept, it is interlocking and is of a different design.

Security against the compromise of the TMK relies upon the ability to vary the sidebar patterns throughout a complex master key system. This feature can effectively prevent the use of a change key to probe the pin stack of each chamber. The Medeco Biaxial and the Assa V10 are the only known systems that offer the capability to alter sidebar combinations within one system,

although this option is rarely implemented.

31_4.10.6.1.3.2 Master Keying Theory for Biaxial Cylinders

The biaxial system allows for two possible tumbler positions (fore and aft) for each chamber that can be rotated twenty degrees from center to create three angles. In the original Medeco design, the angles were labeled as **R** (right) **C** (center) and **L** (left), denoting the orientation of each chisel point at the base of the tumbler. In the Biaxial, the base of the pin is formed by an offset chisel point that positions it be**fore** or **aft**er center; thus the positions are referred to as **fore** and **aft**, referenced to the shoulder of the key. To avoid confusion with earlier versions of the lock, the pins are designated with letters that denote whether they are fore or aft, as shown in the chart below.



MEDECO BIAXIAL ROTATION ANGLES

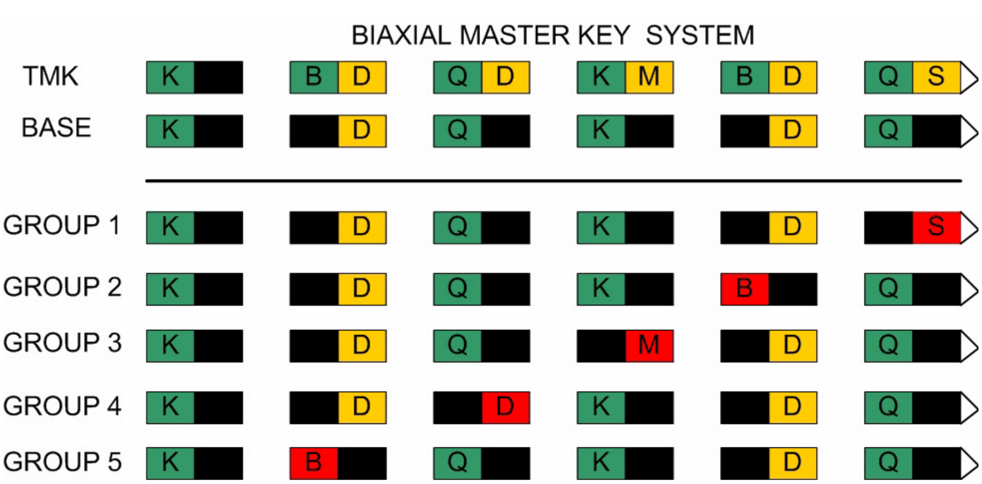
With respect to the pin stack, Biaxial locks are master keyed in the same manner as conventional cylinders. Bottom and master pins are utilized to create virtual shear lines based upon combinations that are generated by total position progression, rotating constant, or partial position progression schemes. It is the rotation angles and their integration with the dimension of each pin tumbler that distinguishes this system and makes it so secure against attack. A pattern of angles is first defined for the entire system. We shall refer to this as the "base pattern." It can be a combination of fore and aft positions and any one of three rotations for each chamber position. We then progress this pattern based upon the design of the system. The chart defines our hypothetical system, having five groups, each assigned their own sidebar pattern. The TMK, as shown in the graphic representation of a composite key, will open any lock in the system with any of the sidebar patterns shown in the chart.

MEDECO BIAXIAL MASTER KEY SYSTEM

MK GROUP	SIDEBAR PATTERN
BASE	K D Q K D Q
GROUP 1	K D Q K D **S**
GROUP 2	K D Q K **B** Q
GROUP 3	K D Q **M** D Q
GROUP 4	K D **D** K D Q
GROUP 5	K **B** Q K D Q
TMK	K D Q K D Q - B D M B S

It can be seen that each group of locks has a unique sidebar pattern. A key from group one, for example, can never operate a lock in group two, because the rotation angles would not allow the sidebar pins to mate with all pin tumblers. The unique property of the Biaxial design that allows the use of multiple sidebar patterns is the ability to **double cut** a key, or place a fore and aft cut in the same bitting position.

This feature replicates a positional master keying system and in effect allows multiple rotational patterns to be combined in one key. The TMK is actually a composite of the differences in rotation angles for each group of locks (shown in red), and also contains the base pattern from which each group is progressed. The TMK that will operate all locks in our example is shown below.



31_4.10.6.1.3.3 Decoding the Biaxial Master Key System

The conventional portion of the Biaxial lock can be decoded through the use of a change key. That is, the master pin value for each chamber can be determined through the normal extrapolation process. The bitting values will always remain constant throughout the Biaxial master key system, as with any other TPP or RC matrix. It is the rotational patterns that are varied and provide the system security.

The security of the Biaxial cylinder is based upon the following rules and design parameters, which affect the decoding process:

- **Rotation angles can be varied throughout a master key system;**
- **The position of cuts can be varied (fore or aft);**
- **Two separate locking systems are incorporated within one cylinder. Variance of the rotation angles can prevent accurate decoding of the TMK;**
- **All of the required data for any specific lock is not available and cannot be derived from another lock unless in the same group;**
- **There is no constant with regard to rotation patterns that can be utilized to probe the target cylinder as there is with the bitting values of the change key;**
- **Total position progression, rotating constant, or partial position progression is utilized to define the bitting values of each bottom and master pin, as with a conventional cylinder;**
- **Bitting values can be determined through the normal extrapolation process, as defined elsewhere in this section;**
- **A lock cannot be decoded for the TMK unless the bitting value, position, and rotation angle can be determined for the target lock;**
- **One "base" rotational pattern is established for the entire system which defines the fore or aft position and angle for each bitting position. This base pattern is then progressed or altered for each desired group or level of cylinders;**
- **The TMK is a composite of all rotational angles and positions that are used for every cylinder. In this regard, the rotational patterns can be viewed as a separate and distinct positional master key system;**
- **The rotation angle for any given fore or aft position cannot be varied once it is defined for a group of locks. For example, if a fore left angle (K) is utilized in the base pattern, it can never be altered for that position. That means that a B or Q cut can never appear in that location, but any aft angle could be used**

(M, D, S);

- **The TMK and intermediate master keys can be double cut so that they can operate cylinders that utilize either fore or aft cuts in the same bitting position;**
- **If the rotational patterns are varied between locks, then the sampled lock and target lock may not have the same patterns. In such a case, there is no way to derive pattern information for the target lock from any other cylinder, unless intelligence exists to indicate that the lock that is sampled has the same pattern;**
- **High tolerances are maintained for all components, including plug-shell interface and sidebar-pin interface;**
- **The "base" pattern code cannot be determined unless all locks within the system were to be analyzed through disassembly or physical decoding of all change keys;**
- **The progression pattern that alters the "base" code cannot be determined for any specific lock or groups of locks;**
- **Added security can be obtained if the bitting values as well as rotation angles and position are varied for different groups of locks. Normally, it would be assumed that the bitting values of both fore and aft cuts for any position would be the same. However, these may be varied within certain parameters. Thus, for example, a fore cut of 3 and an aft cut of 4 could be utilized in one position. This would make the decoding process infinitely more difficult;**

- **MACS for Biaxial is based upon an increment of .025" for six depths and is computed from bow to tip of the key. The system is single-step, with an 86 degree cutter:**
  - **if fore follows aft, MACS = 2**
  - **if fore to fore, or aft to aft, MACS = 3**
  - **if aft follows fore, MACS = 4**

- **Any angle can be utilized in any fore or aft position. No information will be available as to whether a specific position has been altered and if so, whether the angle for fore or aft has been changed; If an angle has been altered within a system, then the complement of that angle must be utilized. That is, two different fore (or aft) angles cannot be utilized within the same master key system if there is to be one TMK, because double cut keys can only have one fore and one aft angle for any one**

chamber;

- **From the change key, it is impossible to determine which positions and angles are different between the sample and target lock;**
- **If more than one bitting position is altered with respect to fore or aft cuts and angle, then decoding of any lock would require up to 3^6 permutations or 729 different angle patterns to be produced with the same bitting to determine the TMK for a specific cylinder;**
- **The TMK will be a composite of fore and aft angles for all cylinders;**
- **The TMK will contain the value of each fore an aft cut of the base pattern, and the progression of each position that is assigned to a specific group of locks. In order to derive the pattern for the target lock, the precise value of each change key position, or the three values of the opposite cut must be probed. This means, for example, that if the change key has a value of K (fore left) for the first cut position, then the TMK can only have the value of K or M, D, S (aft cuts) in that same position. The K will never be a B or Q anywhere in the system;**
- **During the extrapolation process as each lock is probed, positive locking will occur with respect to any pin whose angle or position is incorrect. Depending upon system progression, this may require that all possible permutations be tested against the sample lock;**

Intelligence as to how a specific manufacturer implements its master keying may provide information that will aid the decoding process. Methodology employed by Medeco can make extrapolation more complicated or easier. Certain patterns are more prevalent, especially in larger systmes. Likewise, the use of procedures that are not predictable will enhance the security of a system. It should be noted that sidebar patterns will rarely be varied within a master key system unless there are an extremely large number of locks. However, the author would recommend the implementation of varied sidebar codes in critical areas;

- **Double cut keys always use a MACS of 2. This may provide information with regard to depth cuts, but not to angle extrapolation;**
- **Added information for a target cylinder can be gained by impressioning to determine whether a fore or aft pin has been utilized in a specific position.**

An example will illustrate the difficulty in decoding a Biaxial cylinder. Let us assume that the change key and sample cylinder have a rotational pattern of **KDQKDS** and the target lock of **KBQKDQ.** It can be seen that the change key, in two positions (chambers 2 and 6) have different angles and fore/aft positions. Let us also assume that we have been able to derive the bitting values for the TMK from the sample cylinder. How do we produce the TMK for the target lock?

If we were to probe the sample lock in an attempt to derive all rotational values, we would have to generate a total of 729 keys, but still would not have the needed information. Why? Because the sample lock does not contain the same information as the target lock. Remember, this is a positional system and can be compared to the Sargent Keso, discussed elsewhere in this text. Different values appear in different locks but are not constant to all locks in the system. Therein lies the problem. There is no way to determine the values in the target lock (D and B, chamber 2, and S and Q, chamber 6) from the sample lock. In order to derive a key that would open the target lock, it would theoretically be necessary to run all 729 permutations, because there are two variables, and their position is unknown. The normal probing of one chamber at a time that is used to determine bitting values will not work in this instance, unless special procedures are employed.

If the lock was master keyed with different bitting values between the base pattern and target cylinder, then the process could be very difficult to achieve. That is, if the fore and aft cuts had different bitting, many more permutations would have to be generated to probe the cylinder. If the M3 system is implemented, even more security is achieved, as detailed below.

31_4.10.6.1.3.4 Decoding the Biaxial for Two Different Groups of Locks

This procedure assumes that each group of locks has a different sidebar code, as shown in the table in 31_4.10.6.1.3.2, and that only one rotational position is varied for each group. In this and the subsequent method of extrapolation, it is assumed that the conventional bitting has already been derived from the sample lock. The procedure will allow for the identification of two individual groups within a system (that of the sampled cylinder and a second cylinder, which may be the target lock). The identification of the second group can lead to the subsequent

identification of other groups in the system, and ultimately result in the derivation of the sidebar double-cut coding for the TMK. Note that this procedure will not provide the coding for the TMK unless unique angles for all groups are decoded. A change key must be utilized for this sequence, and contemplates double-cutting of the test keys to be done as the sample and target cylinders are probed. Subsequent probes can be carried out to determine the coding for the third, fourth, and fifth groups (and the TMK code). As will be described in a later section, there is a simpler approach to determine sidebar coding for a target lock that may only require a very few samples to be taken.

In the previous example, it was demonstrated that unknown rotational values in two positions require up to 729 theoretical permutations of the sidebar code to be run in order to identify the actual sidebar code of the TMK. In fact, this number can be reduced to a maximum of 135 iterations. In this procedure, pairs of sidebar complementary values are run against four constant chambers. Recall that for any position that is altered, the complement (fore or aft) of the value in the change key is changed, as shown in the table. Although there are 729 permutations of the sidebar code for use in the double-cut TMK application, we only need to find the value of the one that differs from the base code for the sample key and the target lock.

In order to identify two sidebar code groups, we utilize all combinations of complementary rotational values for two positions, against four constants (there are a total of six positions). In practice, all depths for the TMK and all angles as determined from the sample lock and it's change key are cut for every test key. The two complementary angles are then double cut and the key is tested. If this key does not work then the next pair of complementary angles is cut on the next test key and tested until one of the set of 135 complementary angles opens the lock. This requires that up to fifteen pairs of values must be tested, each requiring up to nine permutations (3^2).

IDENTIFICATION OF TWO GROUPS		
COMPLEMENTARY ANGLES VARIED	**CONSTANT FOR CHANGE KEY**	**PERMUTATIONS**
1+2	3456	**45 (3 x 3 x 5)**
1+3	2456	
1+4	2356	

1+5	2346	
1+6	2345	
2+3	1456	**36 (9 x 4)**
2+4	1356	
2+5	1346	
2+6	1345	
3+4	1256	**27 (9 x 3)**
3+5	1246	
3+6	1245	
4+5	1236	**18 (9 x 2)**
4+6	1235	
5+6	1234	**9 (1 x 9)**

If the tactical situation allows testing of these 135 keys in the target lock, then one of these keys will open the cylinder. If the tactical situation limits access to the target lock, then the above testing is done in a group two lock (a lock that does not open with the correct TMK depths and change key TMK angles).

With two positions identified, we can find the third rotational variable by testing a total of four positions. All depths for the TMK and all angles as determined from the sample lock and it's change key, and the two complementary angles found above are cut for every test key. A group three lock (a lock that does not open with this test key) is then tested. This requires up to twelve different keys to be generated (4 positions with three rotational values). The fourth position can be determined by testing up to three positions (9 total keys), and the fifth position, in like manner, will require up to six keys. The final position will require up to three keys to determine its coding. Thus, a total of 165 possible test keys may be required to determine the TMK coding for the system. Note that this procedure would require access to and identification of cylinders in each of the different sidebar code groups. In addition, it is assumed that there is only one rotation variable for each sidebar group, and that there are a total of six groups within the system.

31_4.10.6.1.3.5 Decoding the Biaxial with Impressioning Information

The most reliable and expedient means of compromising a Biaxial system, with the least number of permutations of test keys,

requires that additional intelligence be obtained about the target lock, especially if the **TMK** sidebar code is needed. If the sidebar code is different in the target lock, or if all group codes are required, then added information is needed to avoid the requirement of running up to 165 separate combinations.

Recall that the scheme that Medeco has employed to allow for multiple sidebar codes within one system requires that the variance between the base sidebar code and each group is premised upon the use of the complementary fore or aft cut for each position. This rule cannot be violated because the TMK is a composite of all individual rotation angles and positions. Thus, there can never be a different rotation value in the same position and with the same fore or aft orientation. For example, a system could never have in the first position of any key an **M** and **D** (aft cuts) or **K** and **B** (fore cuts) in any cylinder. The complement of such a cut can be used, but never the same one.

This rule allows a Biaxial cylinder to be easily decoded for a different sidebar code in a different group of locks, if additional information can be derived from the target lock. This also presupposes that there is only one variable for each sidebar code group. The procedure will become more complicated if two or more variables are utilized, and will require that more permutations be run. However, the ability to identify which positions must be progressed remains the same.

In the previous section (31_4.10.6.1.3.4) that described the decoding process to obtain two or more sidebar code groups, the procedure required up to 165 different keys to be generated to derive the information. The number of different iterations of sidebar codes is required because no information is available form the target lock with regard to its code, and none can be extrapolated from the change key that is utilized for probing, or from the sample lock.

However, if information as to the fore or aft orientation of each pin tumbler in the target lock can be observed, then the decoding process becomes quite simple and requires very few different combinations to be tested. This is based upon the fact that there will only be a variance in two positions of the six pin tumbler positions in the target lock, as compared to the sampled lock. These variances will provide the critical information that will indicate which positions and orientations to sample in order to derive the sidebar code permutations that must be tested, and eliminate unneeded permutations. The target lock as well as other

locks in other groups can then be probed in the same fashion as is done for the TMK conventional bitting values, using one position at a time.

Referring to the table in 31_4.10.6.1.3.2, let us assume that we are using a change key from group one, having a sidebar code of KDQKDS. We are probing a Group five cylinder that has a code of KBQKDQ. When we insert our test key into the target lock, there are two positions that will not match the code of that lock: 2 and 6. In order to successfully open the target lock, we must determine the values for 2 and 6, and how they differ from our sample change key. A critical examination of the table reveals that there will always be a variance of two positions between a sampled and target cylinder. If we are able to identify these two positions, then we can test a matrix of combinations until we find the correct one. The keys that are used for probing of the target cylinder are double cut with the original change key angle values and TMK depths and the probed complementary values.

The required information can be obtained by overlaying a carbon film on a blank key, inserting it into the target cylinder, and causing each pin tumbler to mark the blank. From this, we can determine whether a fore or aft cut is employed. We then generate up to nine keys (three rotational values for two positions, or 3^2) based upon the two positions that indicate a variance from the original change key code. This will provide the sidebar code for the target lock. For each position that is progressed, we only use the fore or aft position that is the complement of that which appears on the change key for the sampled cylinder. This fact also allows us to double cut the test keys.

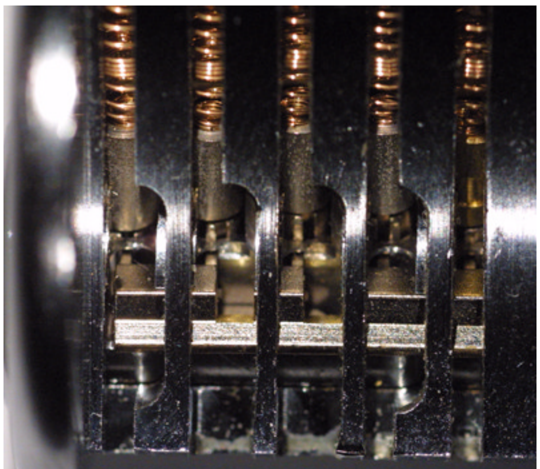
To deriver the sidebar code for other groups of locks, we utilize the same procedure to obtain information about another target. The number of blanks that are required to determine one additional sidebar group can range from one to three, depending upon luck and the particular sidebar code for the target. To obtain all sidebar codes for all groups within a system, we must run up to three permutations for each additional position to be probed. Generally, we would need to produce from six to twenty one blanks (nine to probe the first two positions, and twelve to identify the remaining four positions) and then take all of the information for each position and cut a composite TMK.

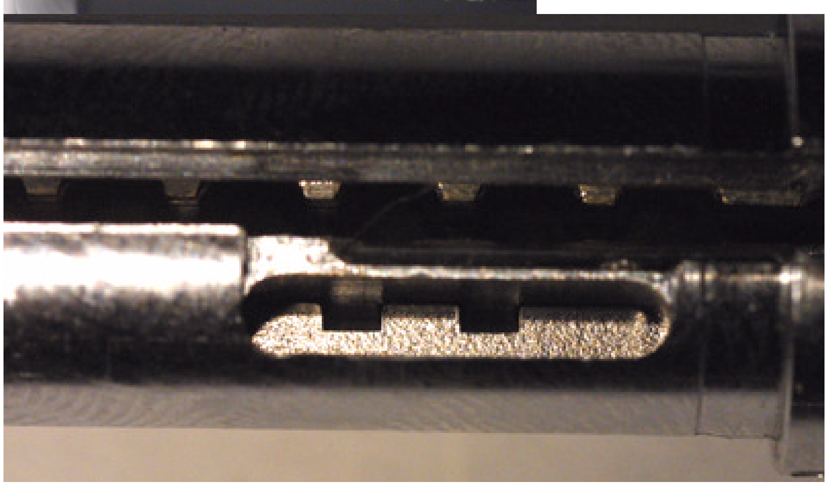
Although the method of generating multiple sidebar codes that has been chosen by Medeco will increase the security and theoretical available combinations of a master key system, unless more than

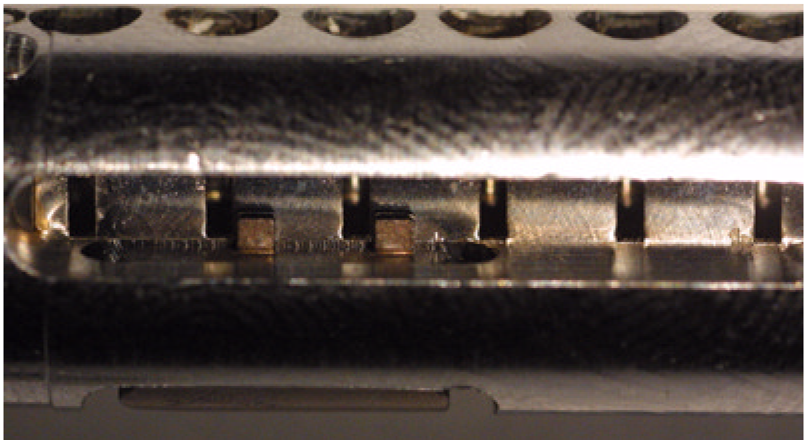
one variance of rotational values is assigned to each position, the system is relatively simple to decode.

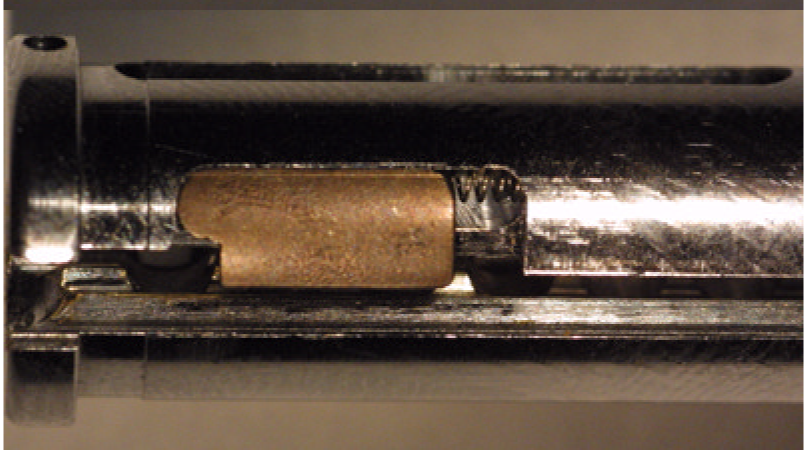
31_4.10.6.1.4 Medeco M3 System

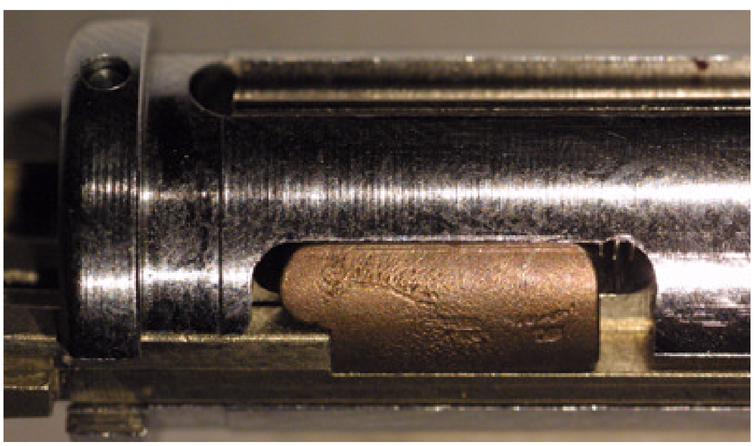
The Medeco M3 system was introduced in 2003 and is discussed more fully in **Chapter 17.** The M3 offers a third level of security against all forms of covert attack, but particularly with respect to extrapolation of the TMK. Although the information regarding the slider can be determined, its presence will make the decoding process more difficult. There is no backward compatibility between the M3, Biaxial, and original designs.











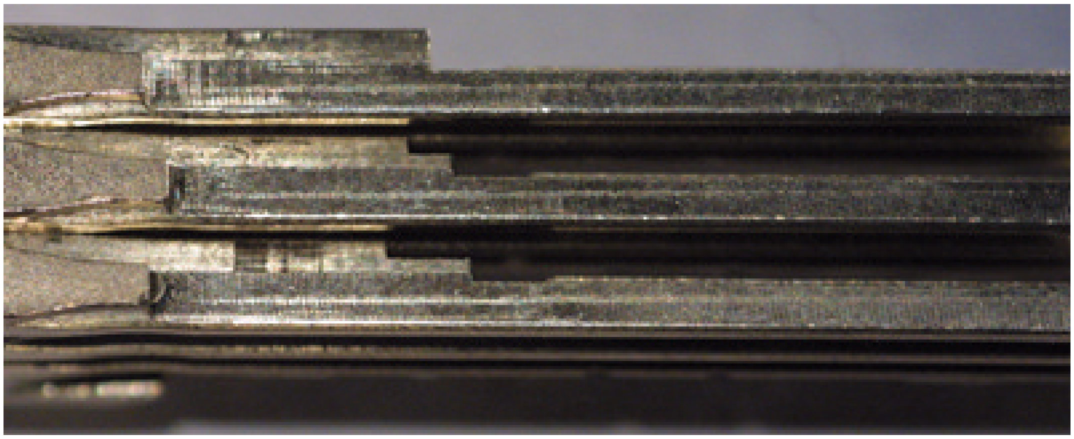


Figure LSS+3145. Sequence of photographs showing the operation of the Medeco M3 and the interaction of the slider with the side milling of the key. (Top left) shows the face of the cylinder with the edge of the slider visible. (Top right) shows the sidebar partially inserted into the plug. The two gates must mate with the slider, which has been removed from the plug but would occupy the space immediately above the sidebar in the photograph. (Middle left) shows the sidebar channel with the protruding locking tabs from the slider. Note the six channels for the sidebar pins and the relationship with the slider tabs. If the slider is not moved into its precise position to mate with the gates of the sidebar, the sidebar is blocked from entering the plug. (Middle right) shows the slider in the biased and locked position, with no key inserted into the keyway. The spring (right side of slider) will always force it to the front of the plug. (Bottom left) shows the interaction of a master key side milling with the MK slider. Note how the milling forces the slider backwards for proper alignment with the sidebar. (Bottom right) shows three different keys with side millings to mate with MK and CK sliders. The top key is for an MK slider.

31_4.10.6.1.4.1 Overview of the M3 Design

The M3 is a Biaxial cylinder with an added component. Called a slider, this moveable piece is controlled by side millings on the key that protrude into the keyway and make contact at one of two points. There are 27 slider permutations, based upon the position of the interface, and its control function. Sliders can allow or block keys from accessing cylinders that are designated for change keys or master key function. Thus, a change key can be coded so that it will never open any lock that is designated to be operated by a maser key only. Likewise, keys that are coded as master keys can be blocked from operating any cylinder that is set for change keys only. The third possibility allows a cylinder to be accessed by change keys or master keys. In such instance, the slider has two steps: one that makes contact with the change key milling, and one for the master key milling.

The slider is integrated with the sidebar and has two locking tabs that protrude. Corresponding gates in the sidebar must be aligned with these tabs in order that the sidebar can retract into the plug. Any misalignment between the sidebar and slider will result in a lockout. Tolerances are such that torque cannot be applied to the plug to bind the sidebar prior to the proper rotation pattern being set for all pins. However, a shim can be utilized to depress the slider as the lock is sampled.

The dimensions of a slider can be derived without difficulty. This results from the following design parameters of all sliders:

- **All sliders have a constant overall length;**
- **The locking tabs for all sliders are in the same position;**
- **The slider is accessible from the keyway and can be measured from the edge of the change key or master key step to the front of the cylinder.**

Even though the slider code can be derived, the information will not help in decoding the rotational pattern of the lock.

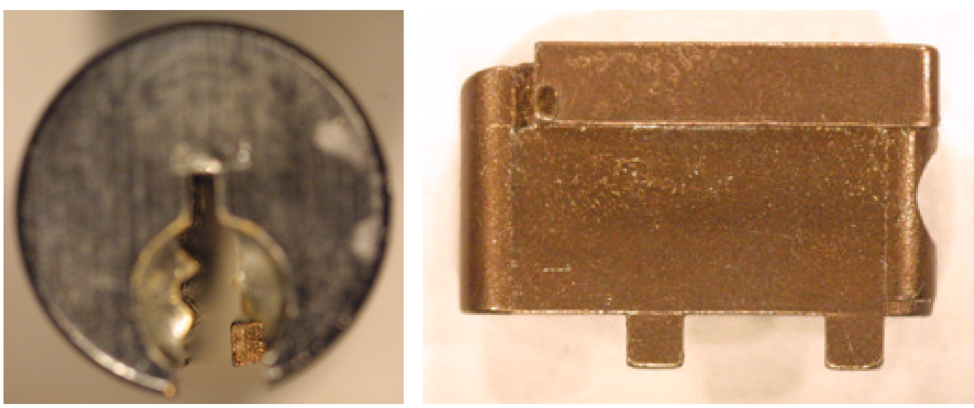


Figure LSS+3146 The Medeco M3. The slider moves along the keyway and is visible from outside of the plug.

31_4.10.6.1.4.2 Decoding the M3 for the TMK

Decoding is more difficult in the M3 than in the Biaxial because of the slider component. The M3 cannot be opened unless the following occurs:

- **Proper bitting is determined;**
- **Proper rotation and fore or aft position of each pin tumbler is ascertained;**

- **Proper keyway is utilized;**
- **Proper slider code is determined, with regard to:**
    - **cylinder coding: change key only, master key only, or change and master key combination;**
    - **one of six possible positions.**

The security of the M3 with regard to extrapolation of the TMK results from:

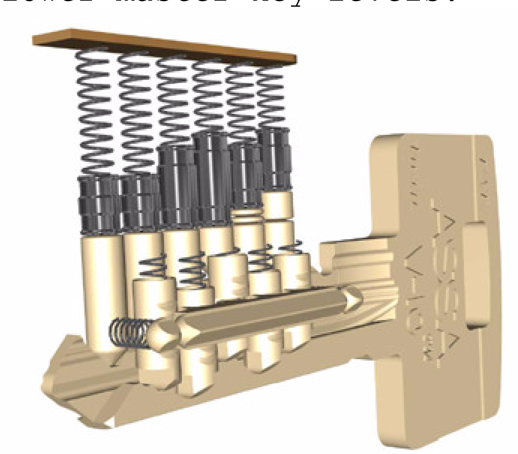
- **Slider must be properly aligned with the sidebar in order to probe the lock;**
- **Difficulty in replicating blanks with side millings to make contact with the slider;**
- **Lack of information regarding the target lock and whether a CK, MK, or CK/MK slider is present;**
- **The slider provides a third parallel level of security; the proper bitting, rotation angle and position, and slider position must be correct before the lock can be probed or opened. Each of the three systems operate independently;**
- **Although a change key can be used to extrapolate the bitting values of the TMK, it will not provide sufficient information to derive the rotational patterns. A key with side millings that restrict its use to cylinders designated for change keys only can still be used to decode the bitting for the TMK. However, the change key blank, if replicated, would not open a lock that is coded only for master key operation.**
- **Blanks cannot be altered to operate different slider codes. Thus, a CK only blank cannot be made to operate the slider in a MK only lock;**
- **The slider code must be determined for the target lock before any probing can occur;**
- **If the slider code is not determined and replicated for the target lock, then that lock can never be decoded and opened, even with the correct bitting and rotational pattern;**
- **Unless the slider is manually manipulated in the target lock for each sample, there are 27 possible permutations that must be generated in order to probe the sidebar for the correct angle and position for each chamber;**

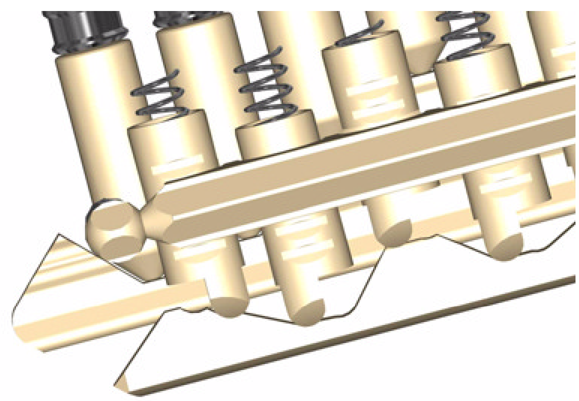
Although Medeco introduced the M3 primarily to extend the patent protection of the Biaxial design, the addition of a third security layer makes the process of extrapolating the TMK more

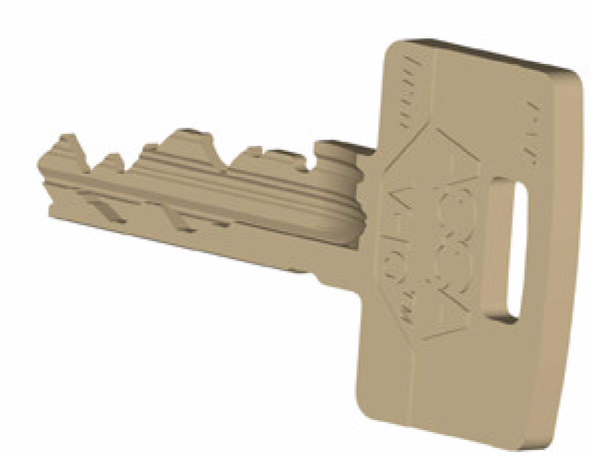
difficult and time consuming, and will insure a high level of security for any master key system.

31_4.10.6.2 Assa 7000 V10 Sidebar System

Assa has designed the V10 system to provide for increased master keying flexibility and useable differs without compromising security. These systems are employed within extremely large installations, where hundreds of thousands of cylinders must be keyed to multiple keying levels. The Assa V10 and Medeco Biaxial can deter the compromise of a master key system through the extrapolation of the TMK. While other sidebar systems may make picking and decoding extremely difficult, they do not adequately address the problem of extrapolation. Virtually every sidebar lock (other than Assa and Medeco) is limited to one sidebar code that is shared by the TMK and all cylinders that are keyed to lower master key levels.







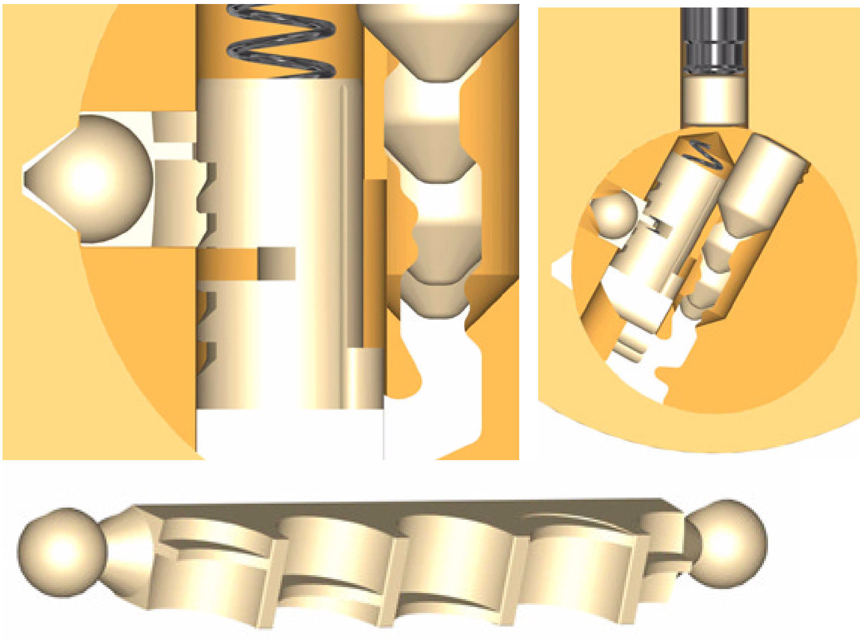
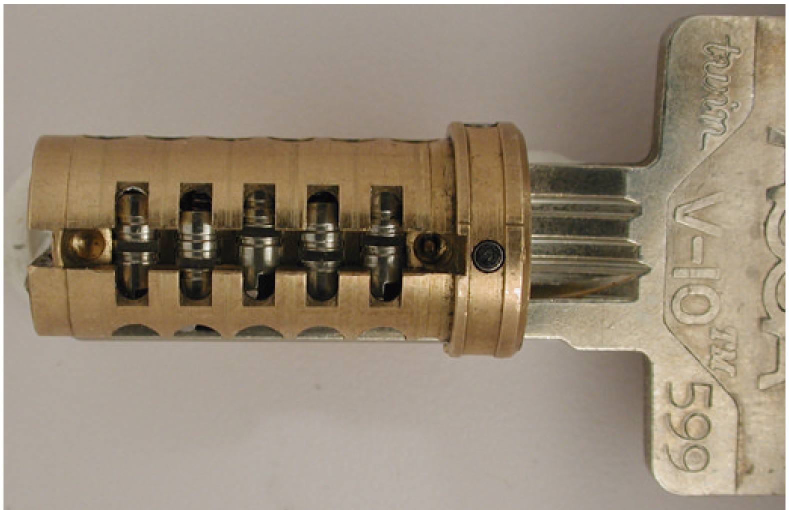
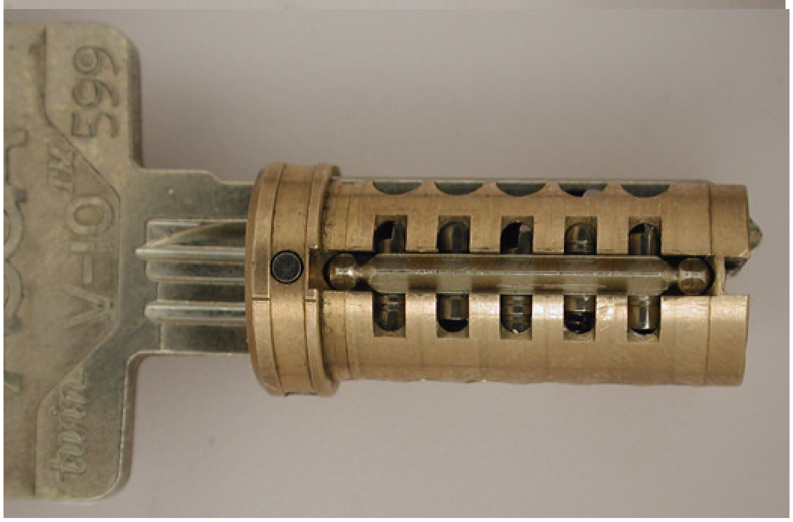
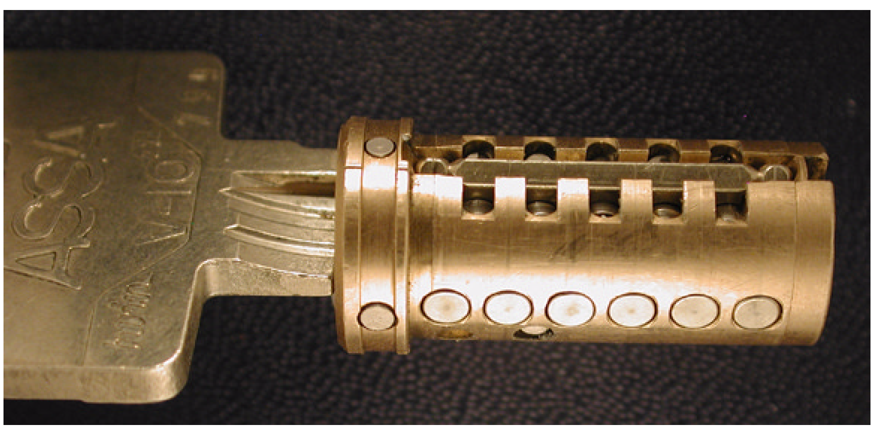


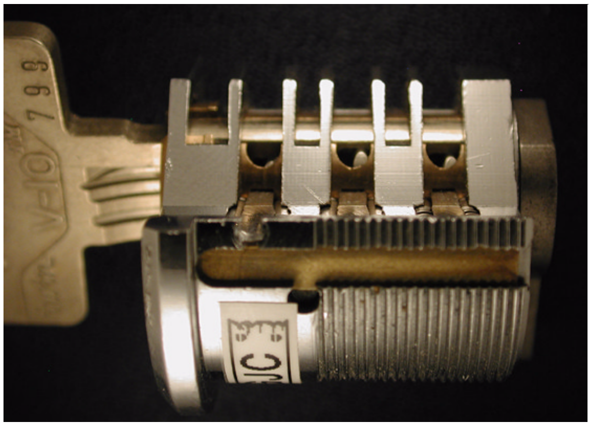
Figure LSS+3151 The Assa V10 system utilizes a sidebar with a fixed code for individual groups of locks or for all locks within a system, depending upon the security level. Note that there are different depth increments on the sidebar that correspond with finger pins that make contact with the side milling of the key. Courtesy of Assa.

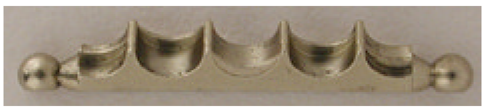
The Assa 7000 series V10 sidebar lock allows variations of one sidebar code, or multiple sidebar codes to be utilized in one master key system, much like the Medeco Biaxial or M3. Assa only utilizes this design in large master key systems that require the highest of security. Few systems exist in the United States. The lock is mainly used in Europe but with limited implementation. In many respects, the approach that Assa has taken is similar to that of Medeco in the way that they provide for the use of more than one sidebar pattern under the control of one top level master key. The photographs show the relationship between the gates in each individual finger pin and the sidebar fence that mates with its corresponding pin. The photograph of the cylinder face shows the finger pins in the keyway (lower left). A comparison of the bitting of two different sidebar codes for the same key demonstrates the capability for multiple sidebar codes under one TMK.





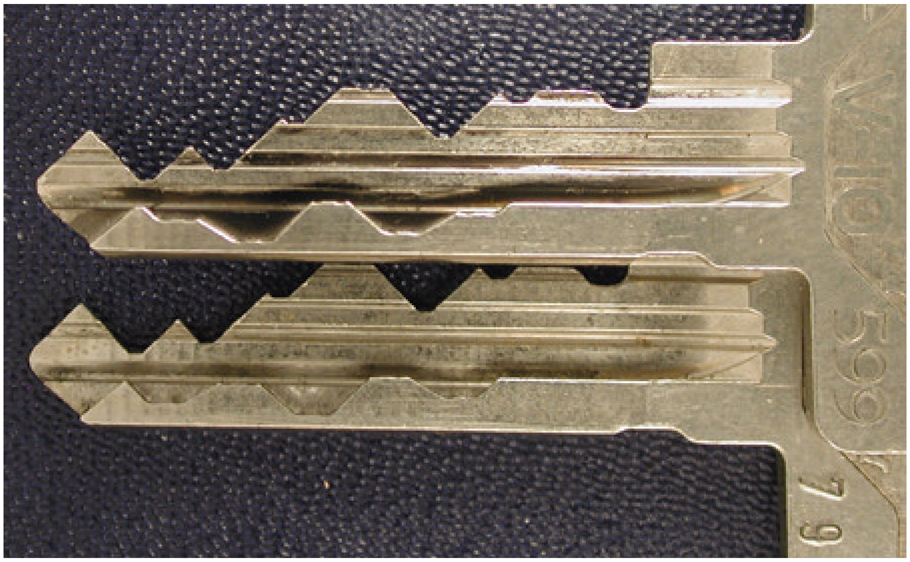









SSA
ASSA
V-10




Assa offers two subsystems of multiplexed sidebar codes to increase the security and number of differs within a master key environment. In one system, Assa **simulates** different codes for each group of locks, although in actuality, there is one common code for all locks. In the higher security series, there are actually different physical sidebar codes for each group of locks. Each approach will be examined in this section, because like Medeco, Assa can provide a serious obstacle to the extrapolation of the TMK.

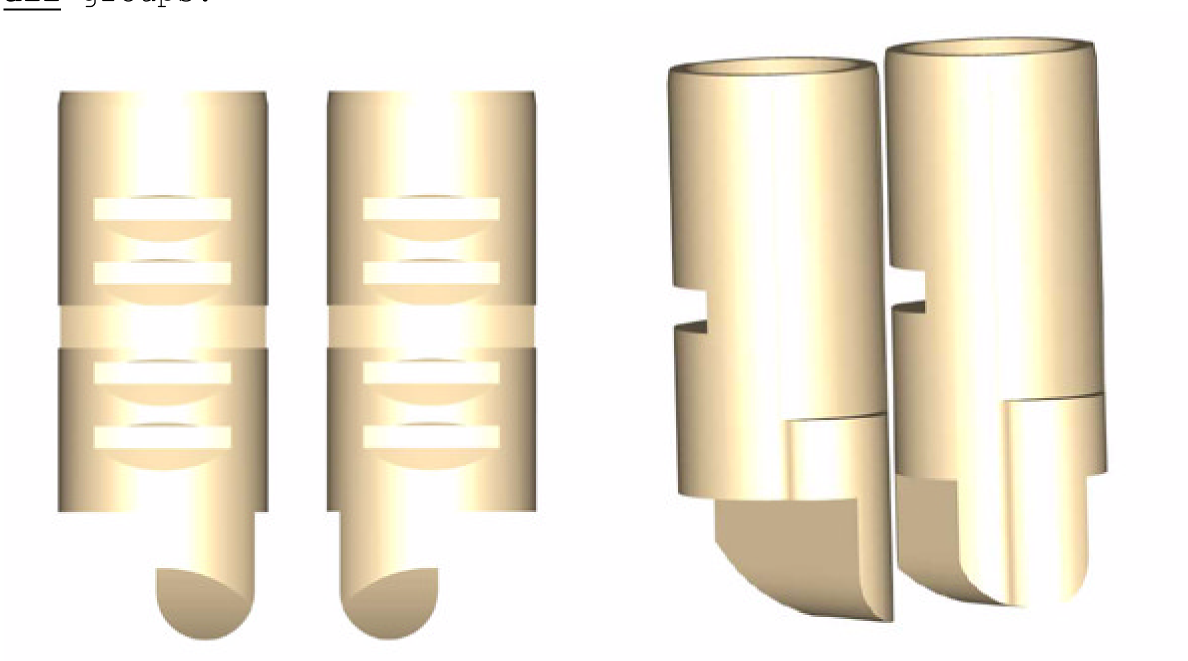
31_4.10.6.2.1 Overview of the Assa Multiplex Systems

Within a traditional sidebar master key system such as the original Medeco cylinder, a Biaxial cylinder where multiple sidebar codes are not employed, a Schlage Primus system, or even other Assa systems **not** utilizing multiplexing, security is based upon the secondary locking action of the sidebar. With regard to master keying, no additional security is provided to protect against the derivation of the top level master key. Sectional keyways, Everest undercut, and other schemes have been implemented, but none offers any protection against extrapolation. The Assa sidebar code scheme is an integral part of the keyway design and a form of virtual keyway subset that provides positive locking when the wrong key is inserted. In some respects, Medeco achieves a similar but higher security result with their M3 slider.

The Assa V10 utilizes a fixed sidebar for secondary locking. As

shown in the photograph above, the sidebar has the capability of five different depths in five positions, or 3,125 (5^5) theoretical permutations. This assumes that the sidebar can be reversed within a system. There are actually two physical sidebar code possibilities if the reverse image is also utilized. Assa reports that there are actually 1402 useable sidebar differs for each orientation within a cylinder.

There are two primary levels of multiplexing of sidebar codes within the Assa V10 series of lock. These two levels can also be combined to form a third hybrid system. Each relies upon a scheme of double cutting of sidebar millings to raise finger pins that interact with the fixed sidebar code. The finger pins for both systems utilize left and right orientations that correspond with side bitting on the key. A matrix of left and right pin positions is selected for each group of locks. As shown in the chart below, there are a total of 32 (2^5) possible permutations of left-right combinations. A unique code is selected for each group, as shown in the example. All of the keys for each group have identical side millings, based upon this selection. The TMK is double-cut so that it can accommodate the sidebar codes for **all** groups.



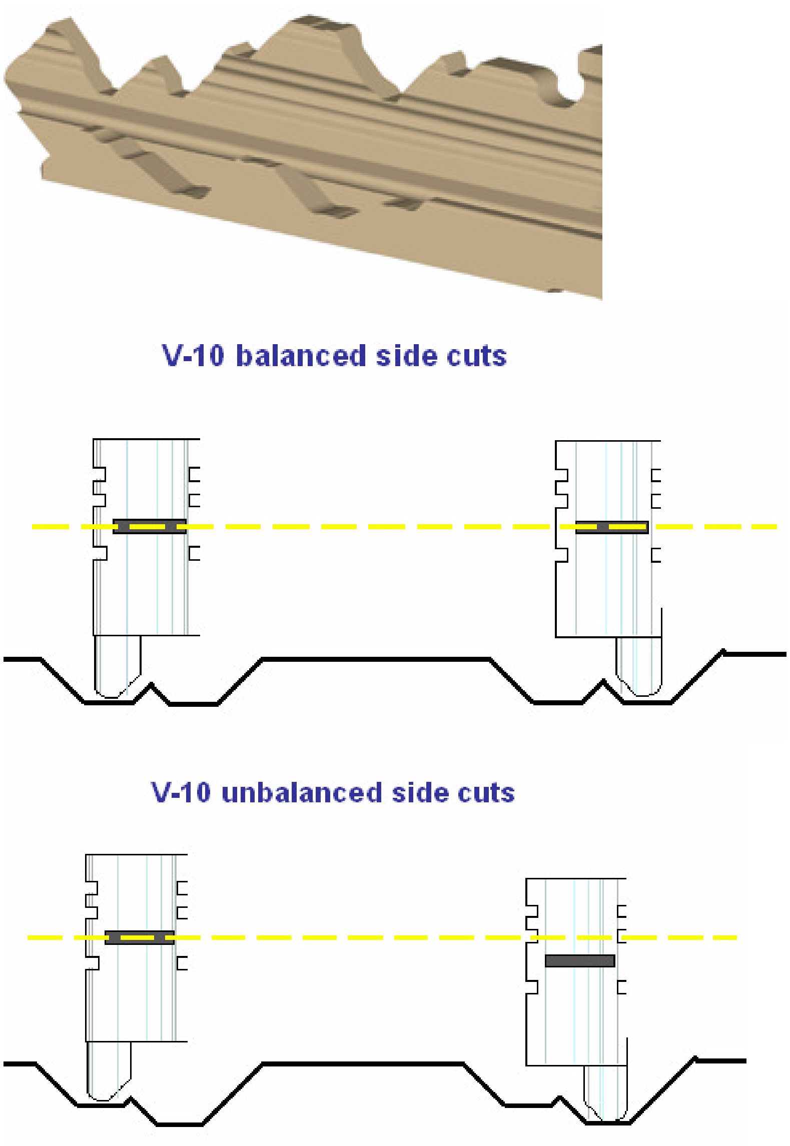


Figure LSS+3152 The Assa V10 utilizes finger pins that provide for a left or right contact point for each bitting position of the side millings on the key. Pins can be balanced or unbalanced with respect to left and right contact and the position of their gates.

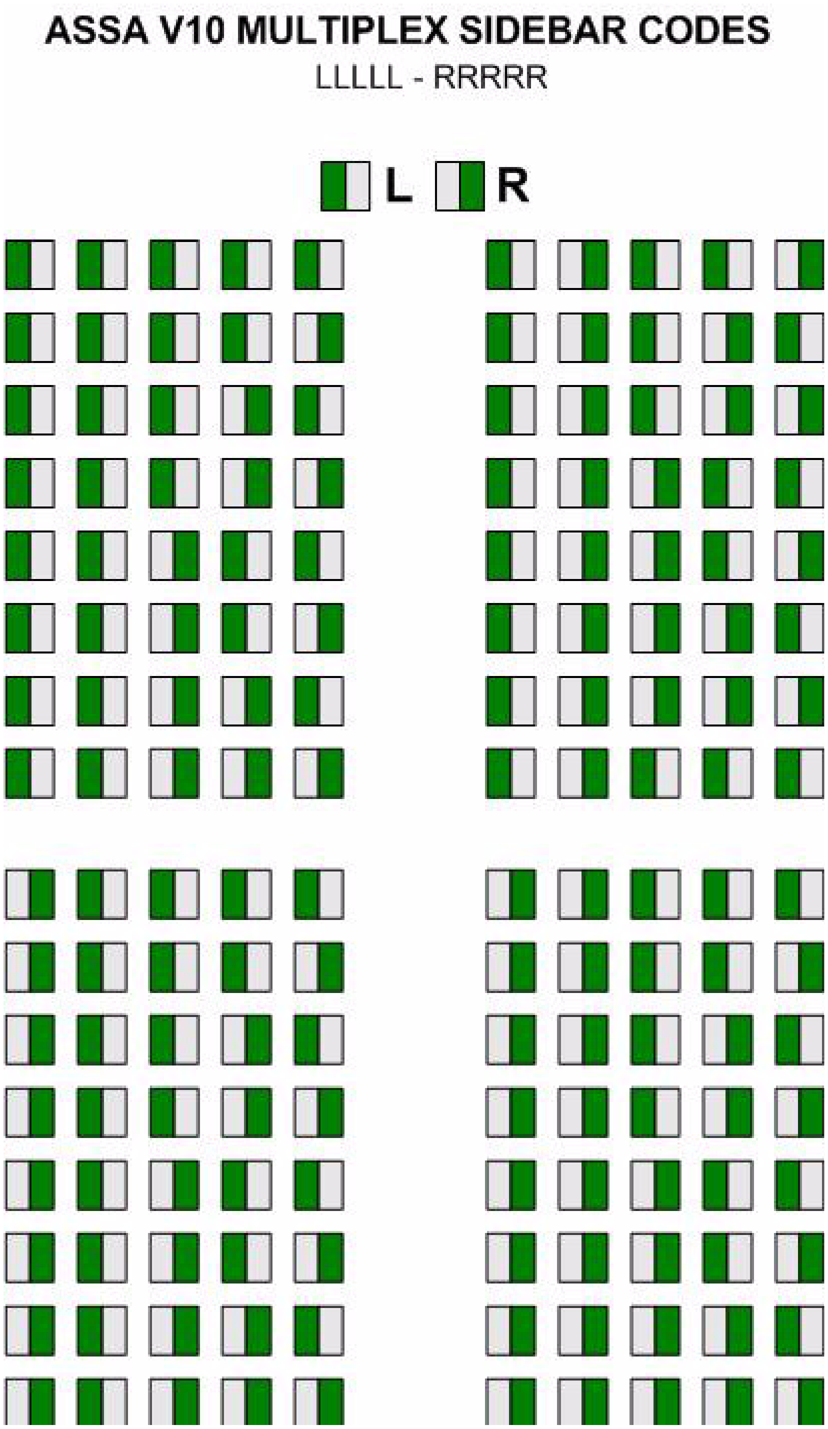


Figure LSS+3153 A total of 32 different sidebar code patterns are available in the Assa V10. These are derived through a matrix of all possible left and right finger pin combinations for five bitting positions on the key. Green indicates the active contact point between finger pin and side milling.

In the first level, which Assa refers to as **"blocking,"** they utilize variations of **one** sidebar code for all locks within the system. Two positions (out of a possible five) on the sidebar milling of each key are double-cut to correspond with the correct assigned group. In all other groups, either the left or right cut will be wrong and will improperly lift a left or right finger pin, thereby blocking rotation of the plug. The scheme, in many ways, resembles the reverse of a warded lock. It will be recalled that wards block entrance of all but the correct key. However, if the material is removed from a key (skeleton key), then it can pass all of the wards. Similarly, double-cutting of side millings performs much the same function, but in reverse. It is an example of positive locking, in that pins are acted upon by the key to prevent retraction of the sidebar and block rotation.

In the higher security **"multiplex"** level, individual sidebar codes are utilized for each group of locks. Double-cutting of two positions on a key is employed and the system can be difficult to decode for the actual sidebar code for a given group unless certain information is known. Much less information can be derived from a single change key, and for the TMK, unless certain procedures are followed. In a hybrid, both multiplexing and blocking are employed.

31_4.10.6.2.1.1 Comparison: Medeco Biaxial and Assa V10

In the author's view, the only way to protect a master key system from compromise through the extrapolation of the TMK is to provide for multiple sidebar codes under one top level master key, and prevent any information from being derived about differences in groups of cylinders. This premise assumes that the manufacturer in fact utilizes more than one sidebar code within the system. This can be an effective security measure if the sampled cylinder has a different code than that of the target lock. In such event, even though the conventional bitting information has been derived, it will not allow other groups of locks (that utilize different sidebar codes) from being opened without certain expertise. Assa and Medeco have adopted different design philosophies in an attempt to accomplish the same result. In the case of Medeco, it may be required to generate up to 729 different sidebar code permutations in order to determine the correct rotation pattern for the target lock. In actuality, this number may be far less. Within the Assa system, fewer permutations may be required to derive the sidebar code. In part, this will depend upon whether Assa employed the lower security

blocking method, or higher security multiplexing of sidebar coding.

Medeco, in their Biaxial and M3, utilize left and right (fore and aft) oriented pin tumblers to achieve multiple coding of rotation patterns. A variance in pattern can occur within any position; thus there are 3^6 or 729 possible combinations that can appear within one system. The TMK is double cut to accommodate all fore-aft permutations. The only real restriction in system design is that fore or aft rotation values cannot be different for a specific position in different groups of cylinders. Recall that Medeco combines rotation angles and pin tumbler depth increments, whereas Assa separates these functions through the use of independent side millings. The difference can be critical to the security of a system for several reasons:

- Sidebar millings within Assa (and other locks) can be replicated separately from conventional bitting values, thus potentially making the extrapolation process simpler by allowing the reuse of the sidebar portion of the key during the probing or picking of a cylinder;

- It may be easier to derive the sidebar codes for groups of locks or an entire system when the sidebar millings are separated from the standard pin tumbler pin stack;

- Assa sidebar information can be read from keys and locks as a result of the physical design of the system.

Assa also uses double cut bitting to generate multiple sidebar codes. However, the approach is slightly different than Medeco. In the lower security level, called **blocking**, Assa actually varies the side bitting for each **group** of cylinders and their keys. These codes are all derived from one "base code" sidebar bitting pattern. In this scheme, two side milling positions are set up for ***either*** left or right contact between the key and finger pins. The Left-Right pattern establishes a form of virtual keyway subset for each group of locks; a key with the wrong Left-Right code will positively lock a cylinder that does not match that code.

The higher security level system is called **multiplexing**. This scheme provides for a different physical sidebar code for each group of cylinders. Variances of each sidebar code is selected, and Left-Right combinations of finger pins are employed to block

or allow access to a specific cylinder. It is more difficult to determine the sidebar code for the entire system when different physical sidebars are utilized within different keying groups, although such information can be extrapolated.

The material presented in this section provide an insight into the Medeco and Assa design philosophy, and demonstrate the following:

- **Each system offers enhanced security over conventional master keying techniques;**
- **Each provides an increased number of differs for master key systems;**
- **Each provides greater resistance against an attack by extrapolation;**
- **Assa has more theoretical differs than does the Medeco Biaxial, but may be easier to reverse engineer and obtain vital system information;**
- **Medeco routinely implements multiple sidebar coding within large systems; Assa does not.**

31_4.10.6.2.2 Basic Rules for Both Assa Systems

Certain rules apply with regard to allowable bitting combinations, establishment of groups, and the interaction of keys within each group. Common parameters are applicable to both levels of multiplexing, while others relate only to systems that incorporate unique sidebar codes for each group of locks.

Basic Definitions

Assa (and the author) have established certain basic definitions for all multiplex master keyed systems.

Profile: Design of the key and cylinder to accomplish access control;

Side codes: Secondary bitting that is cut into the side of the key blade. The term is referred to in this section as sidebar code;

Keyway: A composite of the keyway and side code;

Base Sidebar Code (author definition): This is the physical sidebar code, based upon five depths and five positions, that is employed within a specific lock;

Position: The slot or place that is occupied by one set of left and right sidebar millings in each of five locations for the finger pins;

Contact Points: The orientation of the finger pins, indicating whether they make contact with the left or right hand side of the milling position.

Design rules that apply to all cylinders and both multiplexing schemes

- **All permutations of sidebar codes must be checked for cross-keying issues. Assa refers to these as "ghost codes";**
- **There are no MACS restrictions for side millings;**
- **One of thirty-two multiplex codes of Left-Right cuts will be utilized for each group of locks;**
- **Normally, only two sidebar positions will be multiplexed, although this number can be expanded to four for larger systems;**
- **A variance of one depth increment between left and right cuts is allowed for any one position;**
- **In all positions that are not multiplexed, the left contact point should be utilized. This design parameter allows the bitting values to be easily decoded;**
- **In positions that are not multiplexed, double cut side bittings are utilized but both left and right values are the same. In certain cases, one of these cuts can be a false value;**
- **Multiplex positions are usually constant throughout the entire system. That is, if positions one and two are utilized in one lock, they will be utilized in all locks;**

Blocking Rules

- **One physical sidebar code is utilized for all locks;**
- **Depth combinations for side millings can utilize any value so long as there is only one depth increment difference. Thus, 1-2, 2-3, 3-4, and 4-5 are all acceptable;**
- **A lock can be disassembled and the sidebar code derived for all locks within the system;**
- **Blocking provides a higher level of security than conventional**

master key systems where one sidebar code is utilized. In such systems, there is security against picking, but not against extrapolation. In the Assa system, enhanced security is provided because of the positive locking that occurs if the wrong key is inserted into the cylinder.

- **The sidebar code is divided into five positions, with two cuts in every position (left and right);**
- **The designation for the two cuts within a position are left and right. They are coded by holding the key so that the bow is to the right. Position 1 is closest to the tip of the key;**
- **There are a total of five depth increments for each sidebar cut. These are read in ascending order, from the base of the key blade (1) to the top of the blade (5);**
- **Every cut can be at one of five different heights;**
- **For any one position, cuts can be balanced or unbalanced. This means that a cut can be equal to, one increment higher, or one increment lower than the other, as shown in figure LSS+3152;**
- **Within most systems, only two positions are multiplexed, thus creating four code groups;**
- **The two multiplex cuts can be in any of five positions, although they are usually set so the sidebar can be reversed within the cylinder;**
- **The sidebar code is written as follows: LR LR LR LR LR, so that both left and right positions are designated. In our blocking sample, the base sidebar code is 31524. The blocking code for Group D is 32 12 5 2 4. In this example, the multiplex code is LLLLL. The right cut in positions one and two (3<u>2</u> 1<u>2</u>) would block entry of other keys not associated with Group D. Thus, a key that was double-cut with 32 12 in the first two positions could open all locks within Group D, but in no other groups, because the Right cuts would raise side pins in Groups A,B,C to positive lock the plug. <u>Bold underlined</u> positions indicate blocking or the non-contact position of the finger pin;**
- **Even numbers are selected for blocking codes;**
- **There are three available side milling depth increments that are available for active codes (1-3-5);**

The multiplex positions are changed for every possible permutation, for a total of four different available codes;

- **Left or right cuts are utilized in each multiplex position;**
- **Once an active cut (L-R and depth value) is established for a specific position, no other active cut can be utilized for that position anywhere in the system;**

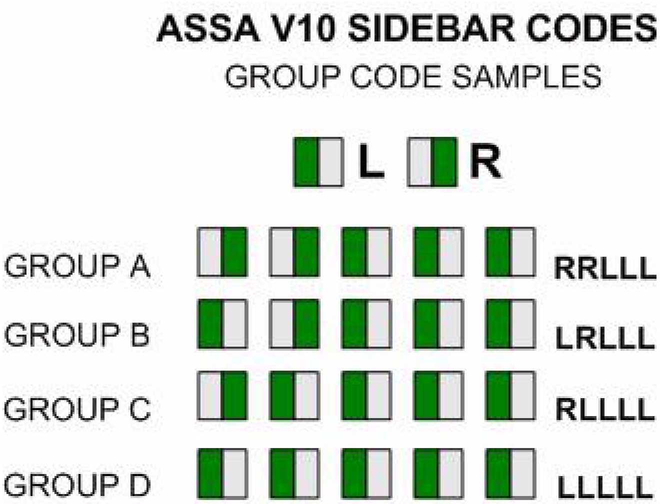
Multiplexing Rules

- **Physically different sidebar codes are utilized for each group of locks;**
- **A matrix of multiplex codes is established to allow one top level master key to pass all codes in all locks;**
- **A "1" depth increment is not normally utilized, due to structural weakness of the key;**
- **Each sidebar code can differ by one cut in any position that is multiplexed.**

31_4.10.6.2.3 Blocking Method

The blocking method of multiplexing utilizes one physical sidebar code for all locks within a system, and is relatively simple to decode. In the diagram below, four groups have been established as an example. The Left-Right codes are **RRLLL**, **LRLLL**, **RLLLL**, and **LLLLL.** These designations represent the location of the finger pins within each bitting position on the key. As shown, a left pin will make contact with the left bitting, and the right pin will be raised by the bitting on the right side of the cut position. In our example, **Group B** has a sidebar code of LRLLL. This translates to the first, third, fourth and fifth finger pins making contact with the left hand side of the bitting for each position; the second pin makes contact with the right. The base sidebar code for every lock within our example is 31524. This means that if a key is cut with this sidebar bitting code, it will open the lock (assuming the conventional bitting has also been properly cut). The use of double-cuts relates to the creation of virtual sub-keyways. By establishing a matrix of patterns, Assa is able to block the use of keys that do not have corresponding left or right cuts in different groups of locks.

A total of four permutations are created for each pair of depths. Thus, if depths 2-3 is utilized for the sidebar code 23524, then 2_3_, 2_ _3, _2 3_, and _2 _3 would be available.


ASSA V10 SIDEBAR CODES
GROUP CODE SAMPLES
L
R
GROUP A
RRLLL
GROUP B
LRLLL
GROUP C
RLLLL
GROUP D
LLLLL

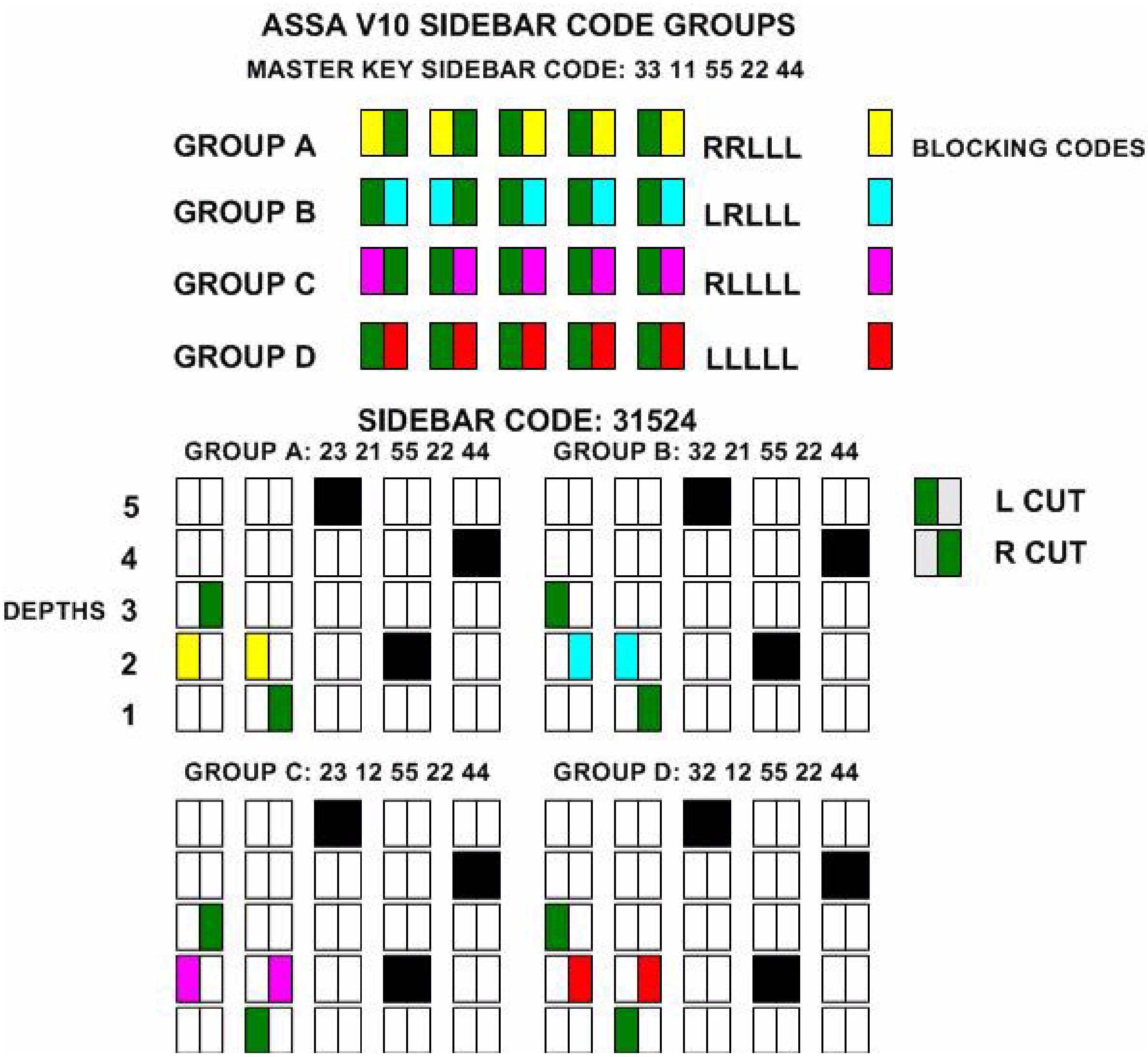
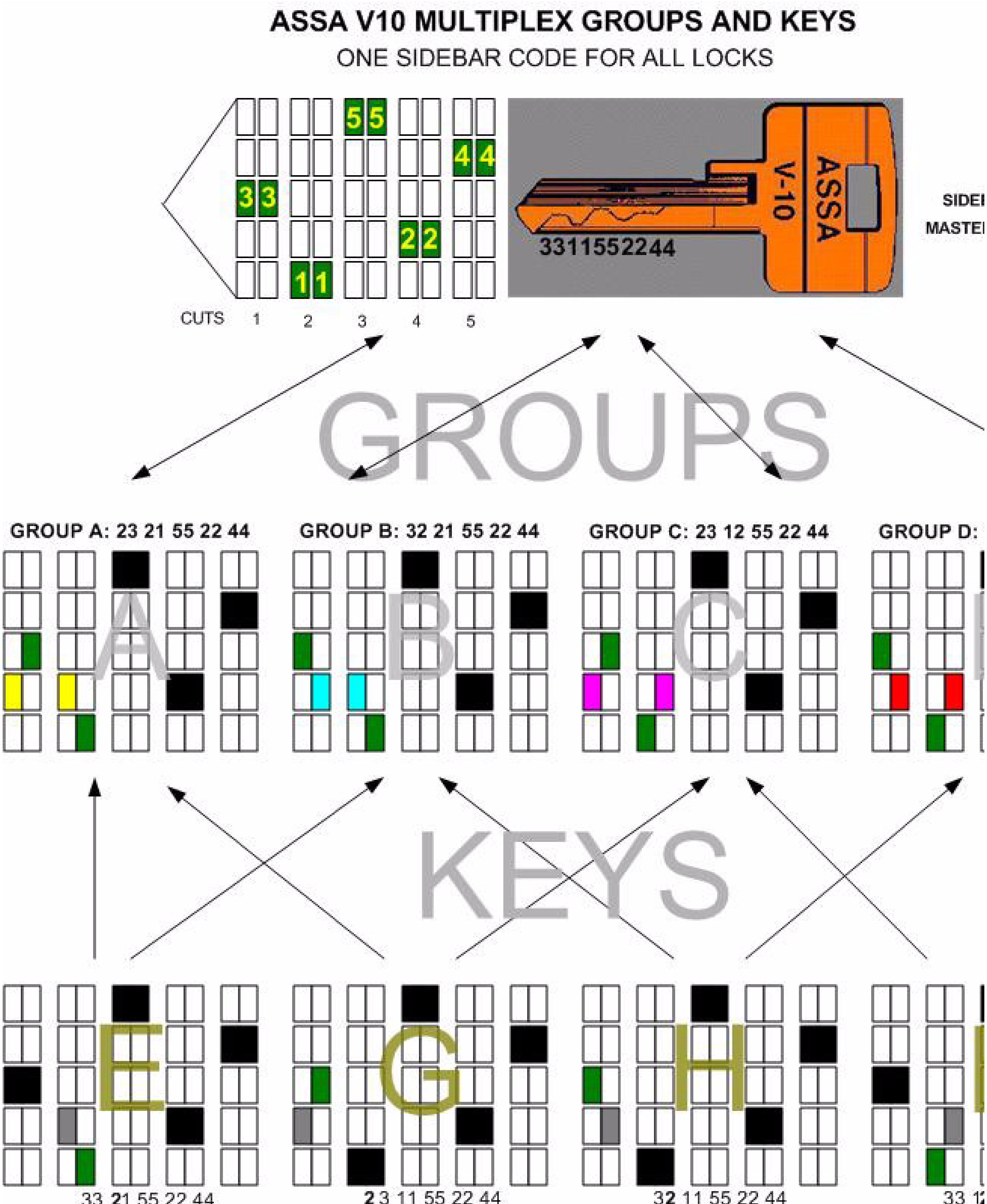


Figure LSS+3154 Four groups have been established, based upon a sidebar code of 31524. Each group has a different matrix for the first two positions.

The first two positions of each side milling are double cut, yielding 2^2 or four combinations. The possible permutations for the first cut is a value of 2 or 3; for the second cut are 1 or 2. A matrix of all combinations yields: **23 21(349) 32 21 23 12 32 12.** We selected Group **B,** which means that the Left-Right matrix is **LRLLL.** This requires that the first position has an active left finger pin, the second position an active right pin. Positions three, four, and five all have Left pins, pursuant to the general rules applicable to all locks. In like manner, different patterns have been established for Groups **A, C, D.** It

can be seen that in each case, the Left-Right pattern is different. If a key with the pattern that is utilized in Group **A** tries to enter Group **B**, it would be blocked in the first position. An examination of each group will demonstrate that its code would positively block the sidebar in every other group.



ASSA V10 MULTIPLEX GROUPS AND KEYS
ONE SIDEBAR CODE FOR ALL LOCKS
5 5
4 4
3 3
2 2
1 1
CUTS 1 2 3 4 5
3311552244
ASSA
V-10
GROUPS
GROUP A: 23 21 55 22 44
GROUP B: 32 21 55 22 44
GROUP C: 23 12 55 22 44
KEYS
E
G
H
33 21 55 22 44
23 11 55 22 44
32 11 55 22 44

Figure LSS+3155 This diagram represents the relationship between groups and keys. Note that the sidebar matrix for each key will work in two groups of locks. Green indicates active contact between finger pin and bitting. Black denotes double cutting in the same position, and is the master key code. Grey represents blocking.

The relationship between the side milling on keys and groups is shown in the diagram above. It can be seen that only one multiplex position causes blocking. The other four positions represent the TMK code. Thus, **"E"** coded keys will work in groups A and B. That is because the second bitting position is the same as these two groups. It is different for **C** and **D**, however, and no key assigned to **E** would work in these two groups. It is also clear that an analysis of one change key from **E**, for example, would yield four of five bitting codes for the TMK. This results from the fact that there is only one true sidebar code for every lock in this system. Thus, if a key is cut for **33 11 55 22 44**, it will open every lock. It would only require two permutations to determine the correct code. If the key **"E"** were utilized as the sample, then it would be required to make keys with the code **33 11 55 22 44** and **33 22 55 22 44**. In other words, the only double-cut position is 2 on key **E**. Thus, we know that the master key code must be one of the two permutations (1 or 2) in the second position.

Decoding Rules

- **All five depth increments may be utilized;**
- **Any position can be multiplexed;**
- **If there is only one position that is double cut for different values, then the system is of the blocking type;**
- **Within a given group of locks, there will be two positions that are multiplexed. For each specific group, there will be only one corresponding position on a key that will have varying left and right cuts;**
- **For any key, only one of the two positions will vary from the TMK multiplex value; the other position will have its left or right cut set to block rotation. Thus, only one active cut within the two multiplex positions on the key is different than the TMK value;**
- **Any position that is double cut and has the same depth increment for left and right has the same value as the TMK;**
- **Only one bitting position will be different than the TMK;**

31_4.10.6.2.4 Multiplex Method for Higher Security

The **multiplex** method of deriving sidebar codes relies upon the use of different sidebar combinations for each group of locks. This system is more secure than the blocking technique because it is more difficult to determine the particular coding of the sidebar from a specific key bitting. In addition, two variables are introduced into each set of sidebar codes at the key level, rather than just the one in the lower security system. In the example, four different base codes are utilized: 55524, 45524, 54524, and 44524. Significantly more combinations can be generated in this scheme with no key interchange potential between groups of locks. One TMK can be designed to open all locks within all groups, as shown in the diagram.

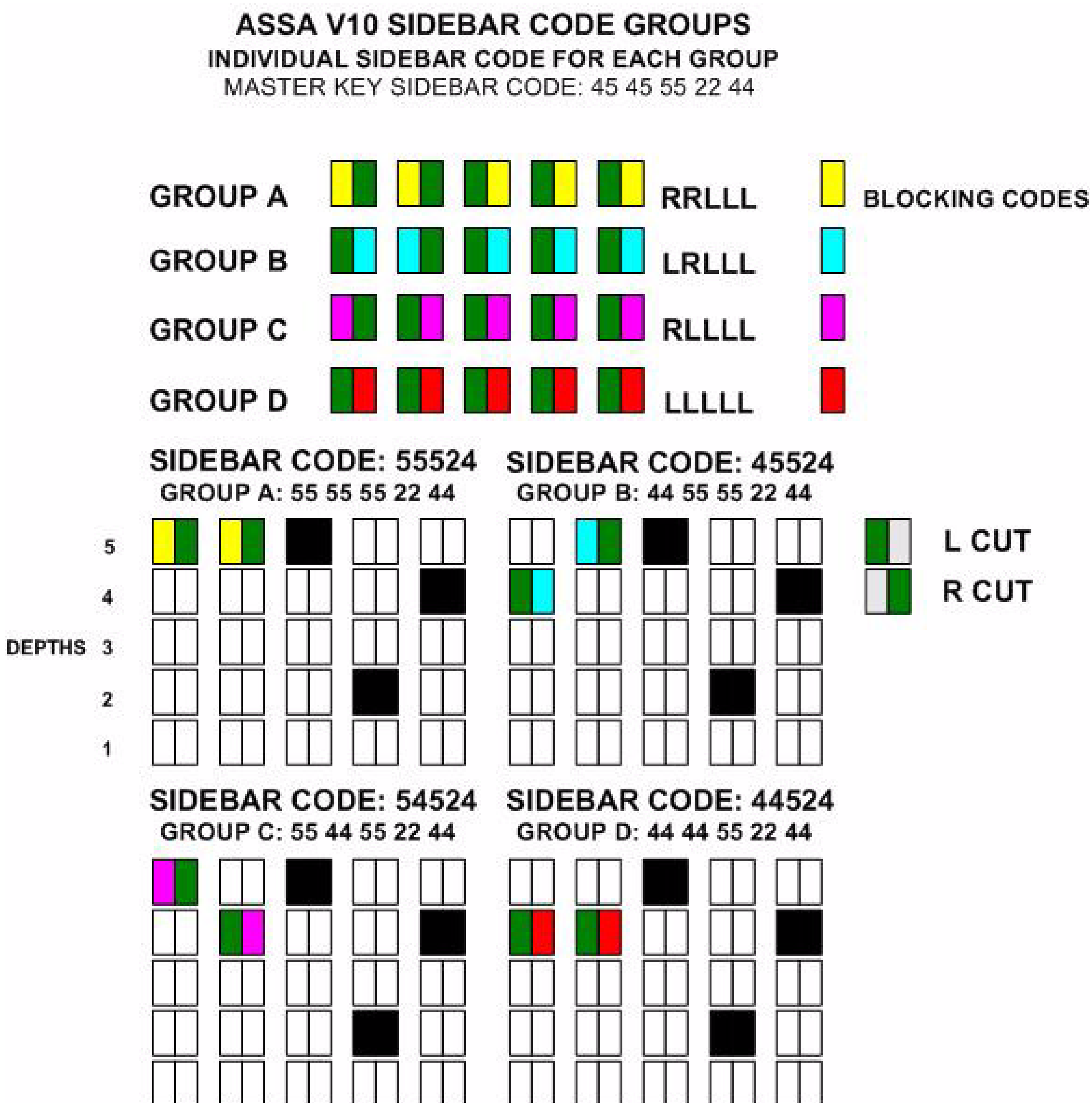


Figure LSS+3156 Sidebar codes for the higher security multiplex system utilize different physical sidebars in each group of lock. Note that the codes for the groups in this illustration are: Group A 55524, Group B 45524, Group C 54524, and Group D 44524.

As with the blocking system, Left-Right code patterns are selected and assigned to multiplex codes for each group. The same four combinations have been chosen for this example. Note that two of five positions are utilized for each group, based upon the Left-Right pattern. A total of four primary progressions are available for each group of two depths. If pairs 2-3 and 4-5 are utilized, then there are 32 possible permutations that can be

applied to a Left-Right matrix. In our example, the following codes would be available to assign to groups:

ASSA V10 MULTIPLEX CODES						
SIDEBAR CODE PAIR 2-3						
All combinations for depth increments 2-3: 22, 23, 32, 33						
COMBINATION	POSITION 1	POSITION 2	SIDEBAR CODE	COMBINATION	POSITION 1	POSI
22	2_	2_	2_ 2_ 55 22 44	32	3_	2_
	2_	_2	2_ _2 55 22 44		3_	_2
	_2	2_	_2 2_ 55 22 44		_3	2_
	_2	_2	_2 _2 55 22 44		_3	_2
23	2_	3_	2_ 3_ 55 22 44	33	3_	3_
	2_	_3	2_ _3 55 22 44		3_	_3
	_2	3_	_2 3_ 55 22 44		_3	3_
	_2	_3	_2 _3 55 22 44		_3	_3

ASSA V10 MULTIPLEX CODES						
SIDEBAR CODE PAIR 4-5						
All combinations for depth increments 4-5: 55, 54, 45, 44						
COMBINATION	POSITION 1	POSITION 2	SIDEBAR CODE	COMBINATION	POSITION 1	POSI
55	5_	5_	5_ 5_ 55 22 44	45	4_	5_
	5_	_5	5_ _5 55 22 44		4_	_5
	_5	5_	_5 5_ 55 22 44		_4	5_
	_5	_5	_5 _5 55 22 44		_4	_5
54	5_	4_	5_ 4_ 55 22 44	44	4_	4_
	5_	_4	5_ _4 55 22 44		4_	_4
	_5	4_	_5 4_ 55 22 44		_4	4_
	_5	_4	_5 _4 55 22 44		4_	_4

Figure LSS+3157 These tables show all possible combinations that can be generated with the four available side milling depths if pairs 2-3 and 4-5 are utilized. The colors indicate those multiplex codes that are used in the example for Groups A, B, C, and D. An underscore_ indicates the inactive left or right bitting.

It can be seen that four codes were chosen at random from the available pool of all multiplex combinations: **_5(350) _5 55 22 44, _5 5_ 55 22 44, 4_ _5 55 22 44,** and **4_ 4_ 55 22 44.** Each pair of digits represents the left and right bitting for each sidebar position. How they are applied with regard to which is the active

contact point and which is the blocking side is determined by the L-R matrix which also provides a total of 32 Left-Right combinations. In the same fashion as the lower security blocking technique, multiplexing provides a matrix of active left and right finger pins. It can be seen that the keys are double-cut in one position for both the active and non-active position. If an **"E"** key whose code is assigned to cylinder Group **A** and **B** attempts to unlock a cylinder in Group **C**, the plug would be positively blocked from rotation because _5 in position two on **E** would not match the code of _4 in Group **C**. Thus, the sidebar would be blocked and could not retract into the plug. A comparison of every blocking position in each key with each of the codes for each group illustrates how each group has a different matrix of left and right finger pin positions in the two multiplexed positions. The system is designed so that only the keys with the correct double cuts can operate locks within a matching group.

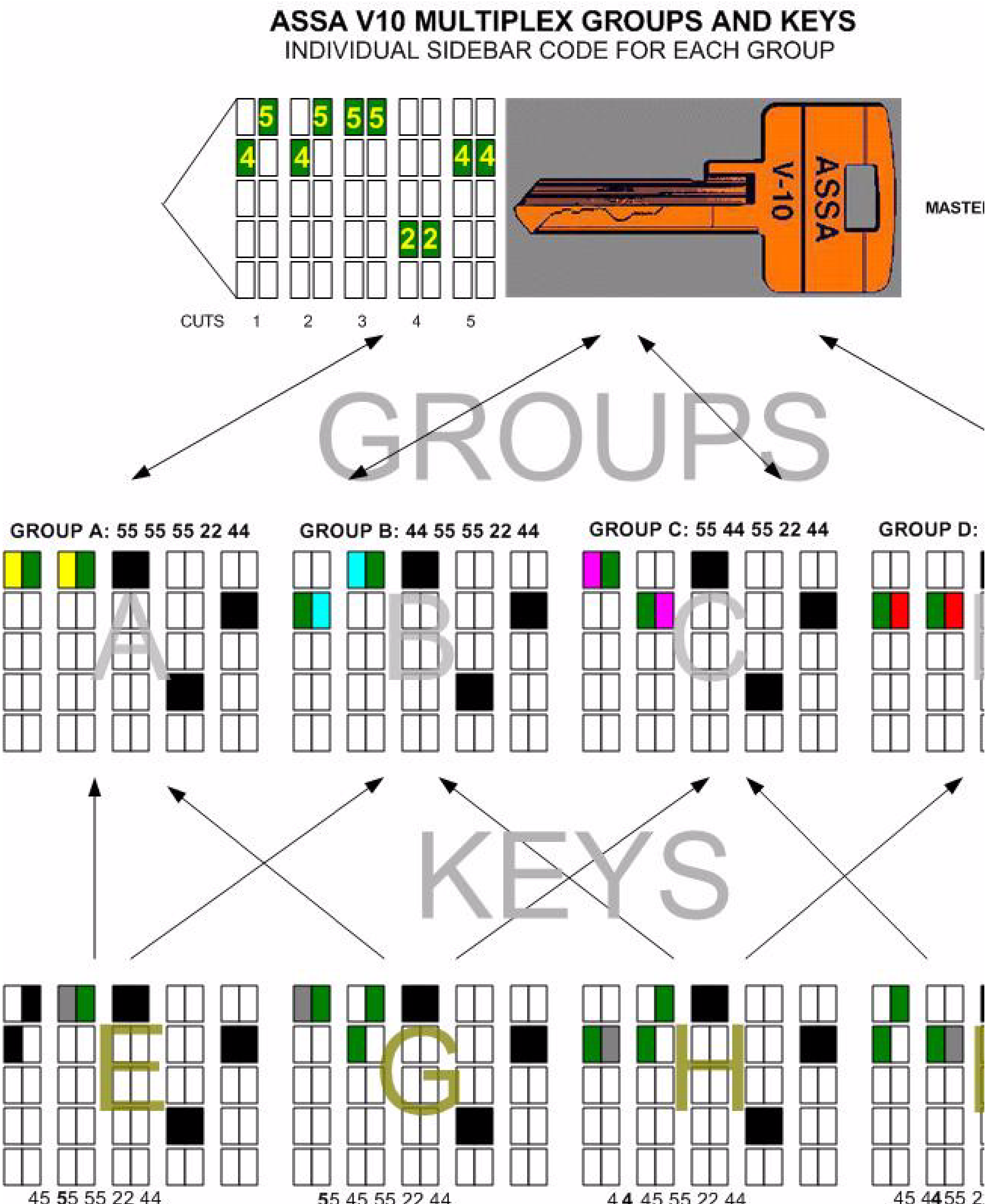

ASSA V10 MULTIPLEX GROUPS AND KEYS
INDIVIDUAL SIDEBAR CODE FOR EACH GROUP
CUTS 1 2 3 4 5
ASSA
V-10
MASTE
GROUPS
GROUP A: 55 55 55 22 44
GROUP B: 44 55 55 22 44
GROUP C: 55 44 55 22 44
GROUP D:
KEYS
E
G
H
45 55 55 22 44
55 45 55 22 44
4 4 45 55 22 44
45 4455 2

Figure LSS+3158 The interaction of keys and groups within a multiplex system differs from that of a blocking system, in that there are variations in both multiplex positions for each key. Numbers in bold underline indicate non-active combinations.

The diagram above shows the relationship between keys and groups and their multiplexed bitting patterns. Each key has two positions that are double cut, to correspond with their respective groups. Green designates the active portion of the bitting (left or right). The **"H"** key, for example, is coded to access Groups **B** and **D.** Note that there is one double cut position (2). In position 1, the active side is Left. Position 2 is double cut as a 45. Corresponding finger pins are shown in **B** and **D.** In the first position in Group **B,** 4 Left matches key **H.** Likewise, in the first position of Group **D,** key **H** again matches 4 Left. In the second position, Group **B,** 5 Right is active. In Group **D,** however, 4 Left is the active pin. Each pattern is unique to a group and key, and none will conflict with any other, so long as the active finger pins are in the correct position. If not, they will be blocked.

31_4.10.6.2.4.1 Decoding Multiplex Systems

The starting point in this process is to understand that every cylinder has a fixed sidebar that is made up of five individual depths and five positions, as with all Assa sidebar systems. Rather than having finger pins that make contact with the center of the bitting increment of the key, multiplex finger pins can make contact on the **left** or **right** portion of the side milling, but not both. There can only be one finger pin for each position, and thus, only one side (left or right) of the side milling is active. Sidebars cannot be double-cut; only keys can be so configured. The geometry of the finger pin is such that there is only room for one pin per position. Thus, it is physically impossible to have both a left and right pin in one position within one lock.

In the blocking method described earlier, double-cuts were employed for certain side milling positions to create a form of virtual keyway. The Left-Right combination of millings must mate with the active left or right finger pin, otherwise positive locking occurs. In the multiplex scheme, blocking is not the primary objective. Rather, two multiplex positions are utilized for each key. These must mate with the appropriate finger pin orientation.

When cylinders are multiplexed, a unique sidebar code is established for each group of locks. These codes, however, must all be related to each other in order that one top level master key can contain a matrix of all left and right bitting positions for each sidebar code. In order for this to occur, there can be a maximum deviation of one depth increment between left and right bittings. This variance allows sidebar codes to be altered to provide different unique codes that do not create key interchange. As with the Medeco Biaxial scheme, Assa utilizes a matrix of left and right active positions between all of the locks to accomplish this result.

A total of four permutations for each pair of depths is available, and a total of sixteen permutations are thus created for all possibilities when two depths are matrixed together. Thus, for example, if depths 2 and 3 are combined for the first two positions of the sidebar code, the primary pairing is 22, 23, 32, 33. In order to expand this to sixteen unique sidebar codes, Assa uses a two digit notation system for each position. If the base sidebar code is 33524, it would be written as 33 33 55 22 44. Let us assume that the multiplexed positions are 1 and 2. The chart in Figure LSS+3157 shows the four different codes that are created. If all four pairs are utilized, then there are sixteen unique sidebar codes that would be available.

In our example, one top level master key can incorporate the attributes of four different sidebar codes. This is accomplished by utilizing each left and right cut for each of the multiplexed positions, and insuring that they do not overlap. As with the Medeco Biaxial, there can only be one depth value that is utilized in any left and right location for each position. This means that groups of locks can be keyed so that, for example, Group **A** utilizes 3_ and Group **B** _3 in the first position, and _3 and 3_ in the second position. However, there can never be a condition that allows 3_ and 2_ to occur simultaneously in the first position. So, it is simply a requirement that a matrix of non-recurring depths be established that do not overlap in the same position and same Left-Right orientation. The TMK is a composite of all left and right positions that have been established for each group of cylinders.

Like the Medeco Biaxial, a great deal of information can be derived from an Assa cylinder if one change key is available that is associated with the top level master key. This information can be utilized to reverse engineer a system, and in some cases, may provide the complete bitting values of the TMK.

Multiplex systems can be decoded to determine a number of critical factors. Some information can be derived from the lock itself, and some data from a change key. Some information can be extrapolated from an examination of both the lock and key.

Information from the lock (and key):

- **The individual sidebar code for a specific cylinder and group of cylinders;**
- **All of the probable sidebar code groups for the entire system;**
- **The L-R matrix that is utilized for a specific group of cylinders;**
- **The active left or right pin for each position;**
- **TMK code;**

Information from the key:

- **Whether the system is of the blocking or multiplex type;**
- **The individual orientation of each finger pin (left or right) for each position;**
- **The multiplex positions that are utilized within the system;**
- **Both of the depth values that are utilized for multiplexing for each position;**
- **The values of each sidebar bitting and how it relates to the TMK;**
- **Whether a +1 or -1 depth offset is utilized for each multiplex position;**
- **The depth of four of five positions that are common to the TMK;**
- **From the double-cut position(s), both values that are used in the TMK can be determined, and in what order. In Figure LSS+3158, the TMK is 45 45 5 2 4. The value of 4+5 in each multiplexed position provides critical information that both a 4 and 5 depth is utilized in the TMK, and in which position;**

Information that cannot be derived solely from the key:

- **The position of the TMK value of the position that is double-cut, but we do know that it is one of two values (left or right);**
- **Whether the Left or Right side of each position is active;**

There are a number of rules associated with the multiplexed system which must be understood in order to derive the TMK values.

Decoding Rules

- **The same rules apply that were defined for the blocking method;**
- **The system utilizes more sidebar codes than in the blocking method;**
- **If two positions that are multiplexed are constant throughout a system, then the TMK can be derived from the change key;**
- **The system can provide a higher level of security;**
- **Depth increments 1,2,3,4,5 are valid for multiplexing;**
- **Any positions can be multiplexed;**
- **In a multiplex system (in contrast to blocking), one side of each position is not active;**
- **Any number of positions can be multiplexed. This depends upon the size of the system;**
- **The TMK must be a composite of all multiplexed positions;**
- **Two depth combinations per position are available (1-2, 2-3, 3-4, and 4-5);**
- **The determination of the sidebar code for one group will yield information about sidebar codes for other groups with regard to those positions that are double-cut for the same depth increment. These positions would be constant throughout the system;**
- **A position that is double-cut and has a left and right depth increment that is different may constitute a TMK value, or only one of the two cuts may be valid for the TMK;**
- **If there are two positions that have different left and right double-cuts, the system is the high security multiplex type that utilizes individual sidebar codes for each group of locks;**
- **Within a given group of locks, there will be two positions that are multiplexed. For each specific group, there will be two corresponding positions on a key that will have varying left and right cuts. For any key, only one of the two positions will vary from the TMK multiplex value; the other position will have its left or right cut set to block rotation. Thus, only one active cut within the two multiplex positions on the key is different than the TMK value;**
- **For any position that is double cut and having different depths for Left and Right, all permutations of multiplexed positions are**

utilized, thus there are four derived codes;

- **Generally, only two positions are multiplexed;**
- **The codes for left and right cuts for any position will only vary by one;**
- **A "1" cut is not utilized, as a general rule;**
- **Any position where both left and right cuts are the same will be part of the TMK;**
- **In any position where left and right cuts are different, only one side will be active;**
- **If two positions are multiplexed, then four different keys may be required to be generated to determine the TMK multiplex values;**
- **The same two positions will always be multiplexed within a specific group;**
- **Usually, the same two positions that are multiplexed will be constant throughout an entire system. However, this is not required. In such case, two positions for Group A could be different than for Group B, making extrapolation significantly more difficult because more permutations of sidebar codes would need to be generated;**
- **Generally, only those positions that have two different cuts must be varied when probing a lock in order to determine all permutations that may contain the TMK sidebar code;**

Decoding a multiplexed lock, based upon the rules cited above, can be fairly direct if both a change key and cylinder are available. The process to extrapolate the conventional bitting pattern of the TMK is identical with any other master key. The problem is to determine the sidebar coding for the target lock if it is different than that of the probed cylinder. This can be done is several ways, detailed in the following discussion. There are two critical issues to consider with regard to sidebar coding: **decoding of the target lock**, and **decoding of all locks** within the system. This analysis is based upon information that is obtained from the key as well as the lock, and depends upon whether the blocking or multiplex scheme has been employed.

- **Determine if blocking or multiplexing is employed;**
- **Determine which two positions are multiplexed;**
- **Determine if there are one or two positions that are double cut;**
- **Determine the value of double cut positions for left and right contact, and whether the same or different values are utilized;**

- **Determine the individual sidebar code for the probed lock. This can be accomplished by first examining the key for all positions that are not double cut. Each of these positions provide direct information about the sidebar code of the TMK;**
- **The positions that are double cut and have two different values will yield critical information: the Left-Right sequence that is used in the TMK, and the values that are utilized in the TMK. One of the two contact points for each double cut position will be utilized to formulate the sidebar code of the probed lock. Remember that all values of double cut bittings must be utilized in the TMK, because the TMK is a composite of all Left-Right values for every key in every group. From the change key, we can learn the depths of all of the side millings. This will provide the needed information with regard to the TMK;**

The orientation of each finger pin (left or right) for each position can be determined through the use of the key, by impressioning. Smoking the change key to produce a carbon residue, then placing pressure on the side millings should yield a left or right contact for each finger pin. This will provide critical information as to the code for the specific lock, and the ability to extrapolate probable codes for the other three groups of locks. Once the orientation of each finger pin is determined, the lock and entire system is vulnerable. Remember, the sidebar code has five depths and five positions. Each depth either has a left or right orientation, but there can only be one orientation per position. Thus, once we know the depth increment and orientation, we know the sidebar code.

Let us assume that we find that the key has a code of **45 55 55 22 44**. This reveals the following information:

- **The TMK must have a value of 45 for its first position**
- **The first position is multiplexed;**
- **Probably the second position is also multiplexed, but this information is only speculative;**
- **The second, third, fourth, and fifth positions are all common to the TMK;**
- **The actual sidebar code for this cylinder is either 45524 or 55524;**

Because depth values can be varied by +- 1 increment, the codes for the other three groups within the system are likely to be 54524, 45524, and 44524, assuming that only the first two

positions are multiplexed. The issue becomes more complicated if other positions are utilized in the process. This possibility is discussed below.

At this point, we know at least three (and possibly four) of five of the Right-Left orientations for finger pins, and the depth values for those pins that are associated with the TMK composite sidebar code. We need to determine the remaining finger pin orientations that can exist in other groups of locks, and which are not present in the probed lock. This can become a bit more complicated in the multiplexed lock because each group of cylinders has their own sidebar code. There are several issues with regard to how the sidebar codes are multiplexed:

- **Two positions are constant throughout the entire system;**
- **Positions are varied throughout the system;**
- **More than two positions are utilized for multiplexing;**
- **All positions on the key are double-cut, making the initial determination of multiplexed • Positions more difficult until the Left-Right contact position is determined.**

If the multiplexed positions are constant throughout the entire system, the process becomes much simpler, and the TMK can be extrapolated from the sample change key. In this event, permutations of each position that is double-cut and has the same depth values must be run. We know that depths can only be varied by one increment. So, in our example, 45 55 22 44, we can be fairly certain that the first position (45) is multiplexed. If we make the assumption that the second position is also multiplexed and constant thorughout the system, then it must have a value of 55, 54, 45, 44 for the TMK. This requires three permutations to be tested against the target lock. The TMK then would have a value of 45 55 524, 45 54 524, **45 45 524**, or 45 44 524. In our example, the actual code is **45 45 524**.

If positions are varied throughout the system, then we must run the known position (the first in our example, 45) against the remaining four positions to determine the sidebar code, based upon knowledge of the Left-Right contact of each finger pin. We know that the combination of our sampled lock is 45 _5 5_ 2_ 4_. Remember that there can be no multiple use of a contact point for any given position; thus we only need test the **complement** of the location of the finger pins in our sampled lock. This greatly reduces the number of permutations that must be run.

This will require a total of five permutations to be tested. In such case, the following combinations would be run:

45 + **45** 55 22 44
45 + 55 **54** 22 44
45 + 55 55 **23** 44
45 + 55 55 22 **45**
45 + 55 55 22 **43**

If the Left-Right orientation for each position cannot be determined, then we must utilize the information available from the key only. In such a case, there would be a total of 20 permutations (four variances for each of five positions) that must be run. This would again require that we change one position against the other four. We would run **1**2345, 1**2**345, 12**3**45, 123**4**5, 1234**5**. The underlined position would be altered with a total of four permutations each. Thus, in our example, the first permutation would require that the following four sidebar combinations be tested in the first position: **55, 54, 45, 44.**

Finally, if the only information we have is from the key, we do not know the Left-Right orientation of each finger pin, and we believe that multiplexed positions are varied throughout the system, (but that there are only two positions that are multiplexed at any one time), then there are total of 3^5, or 243 permutations that must be run in order to be certain that we have the combination for the TMK. This number is derived from a variance of one depth above and below those that are utilized on the sample key. Note that we are not concerned that there are a total of four available depths that can be utilized in the multiplex system (1 is not available). We only require that the actual depth for each position, with a variance of 1 above and below. Thus, in our example wherein the second position is our code of **45 55 55 22 44,** the differs would be **55, 54, 45.** Note that **44**, however, is not a valid permutation, because it would require that we utilize a different value in the same position, which is not possible.

31_4.10.6.3 InstaKey Programmable Cylinder

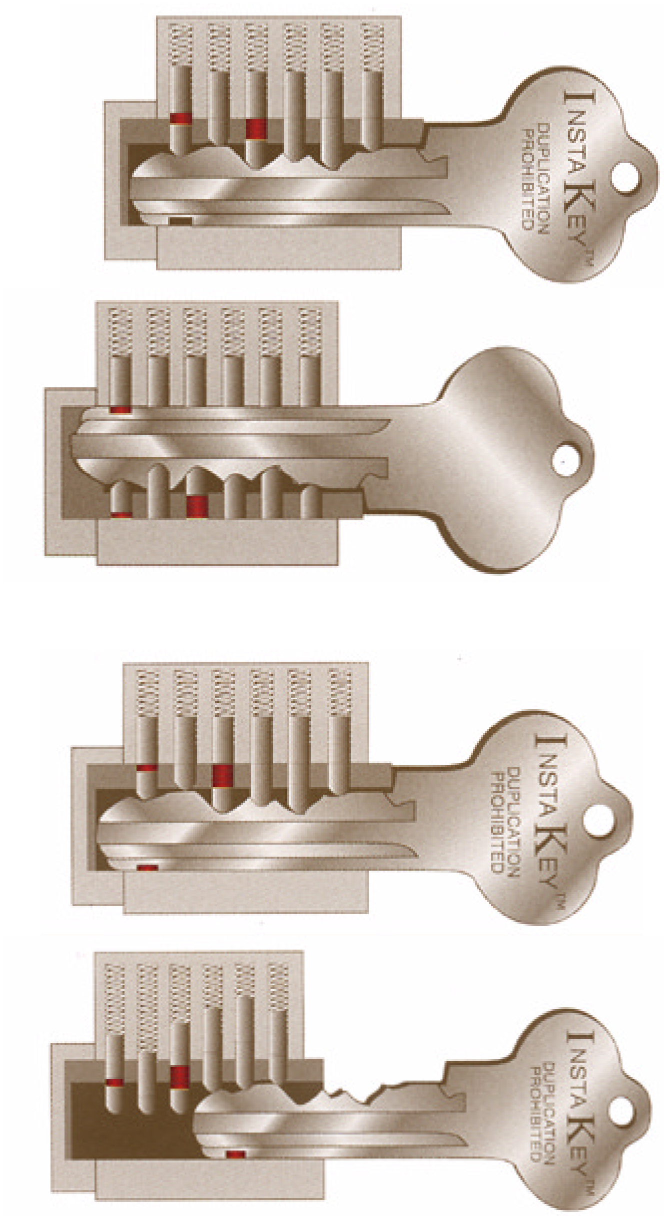


Figure LSS+3147 Instakey system allows for instant reprogramming of a cylinder, up to twelve times. In the programming sequence, the step key is first inserted for the specific chamber and pin stack that is to be altered.The key is turned, causing the next pin segment to be sliced. The key is then rotated back to home position. At this point, the sliced pin segment is carried in the notch at the base of the blade. Upon removal of the key, the .025" segment will drop out of the lock.

The Instakey programmable cylinder is utilized in many large facilities as well as by Medeco Bi-axial customers. The lock can present security and decoding issues if encountered in the

extrapolation process. See **chapter 22** for a detailed discussion of this technology. It is possible to sever one or more programmable pin segments within each chamber while probing a pin stack, which can lead to false positive indications of the depth of the TMK. Only three chambers are utilized for reprogramming, but they can be in any position. Little torque is required to slice a pin, and it does not need to be removed from the lock to cause problems. Generally, the Instakey name will appear on the face of a cylinder if the technology is employed, so caution is advised when working on these cylinders.

31_4.10.6.3.1 Security Issues Regarding Instakey

There are a number of security issues with regard to Instakey cylinders that relate specifically to the extrapolation process. These are summarized below.

Severing of programmable pin: Little torque is required to slice one or more segments within a pin stack.

False positive: If a programmable pin is sliced within a pin stack, then another shear line is created. This can be decoded as the top level master key. The problem becomes compounded if every depth is probed, because up to four additional shear lines may be created.

Key interchange: If a lock is sampled for the TMK and pin segments are sliced, then serious key interchange, incidental master keys creation, and cross keying issues will be the result.

Pick resistance: The pick resistance of a cylinder will be reduced if multiple shear lines are created.

Covert operation discovery: If a covert operation to decode a lock is undertaken and pins are inadvertantly severed, then there would be evidence of tampering with the lock by unauthorized individuals.

31_4.10.6.4 Schlage Everest

The Schlage Everest is a popular cylinder for use in master key systems where increased security against key duplication is required. Operatives may encounter different Everest keyways, and

would have difficulty extrapolating master keys within these systems without the capability of replicating blanks and accessing the check-pin. Thus, information regarding bypass of these cylinders is presented in this section. This lock is also utilized as an example of the capabilities of the Easy entrie profile milling machine in simulating blanks for restricted keyways or special designs that would make access to blank keys difficult.

This mechanism employs a unique patented keyway that incorporates an undercut area that must mate with a corresponding channel along the longitudinal section of the key wards. This blank is only available from Schlage, but may be simulated with the Easy entrie profile milling machine, or through modification of other non-patented blanks. See the detailed description of the procedure for bypassing the undercut portion of the keyway in **Chapter 8**.

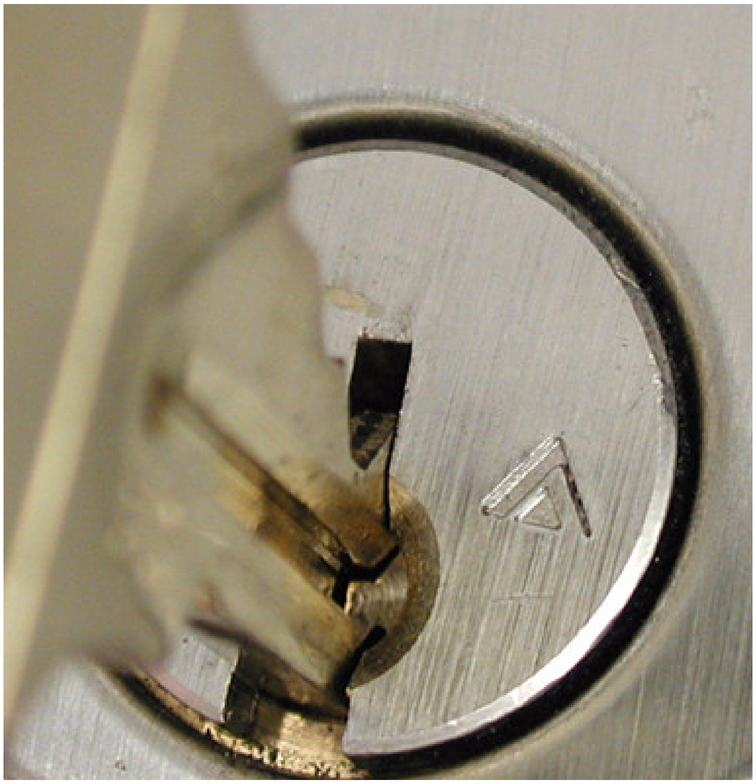
The reader is cautioned that replication of the exact Schlage profile and integrated undercut channel constitutes an infringement of their patent. The reader should consult with legal counsel prior to producing exact replicas of keys for this or any other patented cylinder.

As described in **chapter 8**, a digital image of the keyway of any Everest cylinder may be imported into the PC software of the Easy entrie. It will allow a key to be produced that ignores the undercut. The profile of the key, once obtained, can be stored for later generation for a specific keyway. When the proper blank is cut with the correct bitting, the Peterson ET-1 can be utilized to lift the check-pin. See **chapter 29** for an explanation of picking of this lock. The photographs show a key that has been produced for the Everest cylinder. Note the Peterson ET-1 that is inserted within the undercut next to the key to allow rotation of the plug. To produce this blank, the author, while using the draw mode within the Easy entrie software, actually created a profile that ignored the channel, normally present on OEM Schlage blanks. The undercut portion of the keyway is bypassed so that a precise indent is created to allow its passage by the key warding.



Figure LSS+3148 The Schlage Everest cylinder utilizes a patented check-pin system and undercut keyway. A blank has been produced with the Easy entrie profile milling machine that effectively eliminates the requirement that a corresponding channel on the key must pass the undercut in the keyway. Compare

the Easy entrie blank with the OEM Schlage Everest blank on the right. The channel has been removed during the "drawing" portion of the profile creation process. A blank for the cylinder (top) was produced entirely from a digital image of the keyway, shown below. Once the finished blank was cut on a standard key machine, it is inserted into the keyway together with the Peterson ET-1 tyne to raise the check-pin. The lock is opened without any difficulty, as if operated with a factory original key.



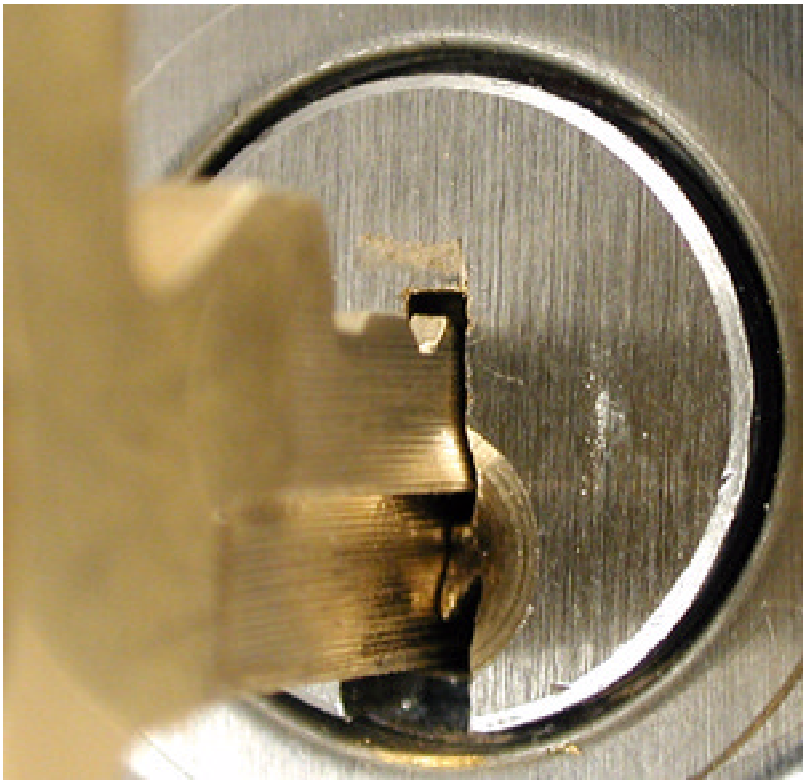


Figure LSS+3149 The Schlage Everest keyway, showing the patented undercut design. This feature normally requires the integration of a corresponding channel along the side of the key. However, the system can be bypassed by specially milling a blank and inserting a tyne into the undercut to raise the check-pin. A factory original blank is inserted into the cylinder (left). Note the undercut and how it must ride in the channel. The simulated profile (left) is created with an indent to physically bypass the undercut.

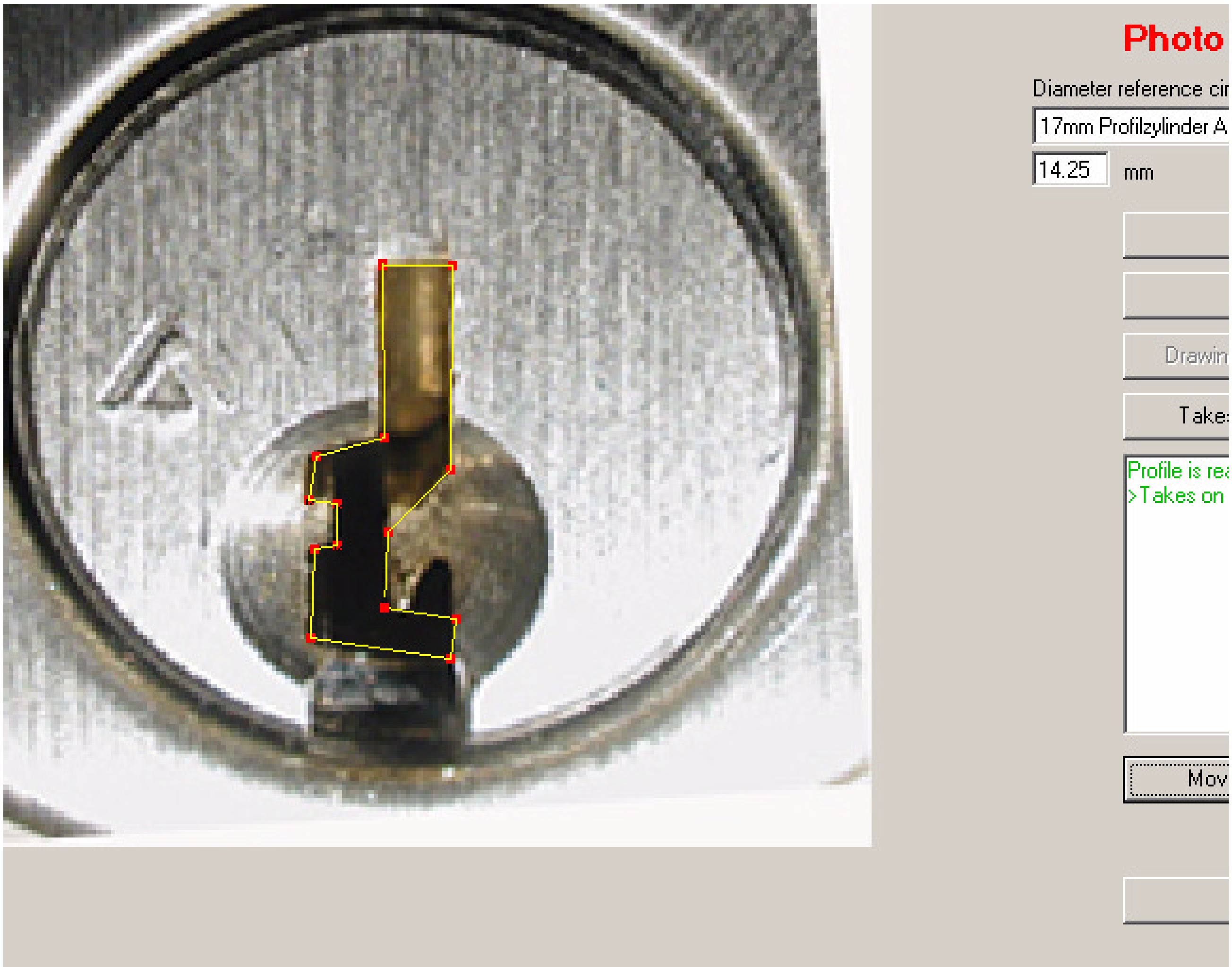


Figure LSS+3150 The Easy entrie is capable of simulating restricted profiles for the Schlage Everest and other conventional locks. Note how the keyway is "drawn" to bypass the undercut portion for the check-pin. This menu, from the special PC software, allows a profile to be created that will bypass the ward pattern of most keyways.

31_4.10.7 Obtaining Blanks for Target Locks

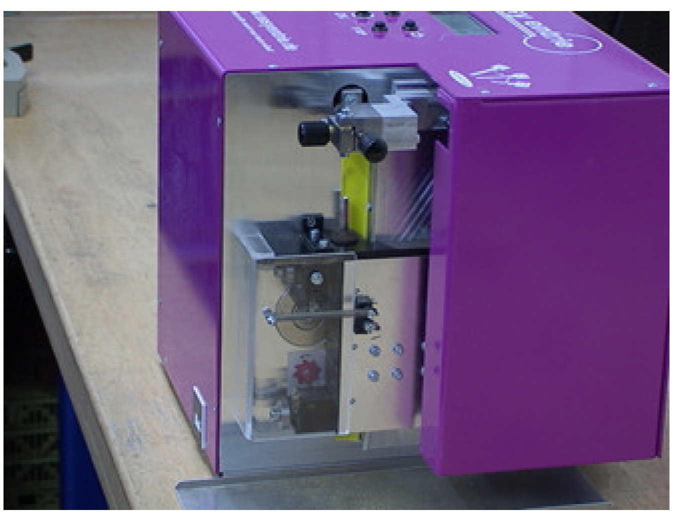
The extrapolation process requires the operative to be in possession of a sufficient number of blank keys to allow sampling of each chamber in order to ascertain the depth of each lower pin segment. This process may become more complicated under certain conditions:

- **Restricted blanks are utilized that are unavailable through normal channels;**

Only a bitted change key is available for the target lock;

- **A manufacturer or keyway cannot be readily identified, or no intelligence is available about the lock. Typically in this scenario, a target cylinder is identified that must be decoded. Blanks are only available from the manufacturer, and are not accessible to the operative on-site;**
- **There is no source for blanks to fit the particular keyway;**
- **Sectional keyways may be employed that are not readily available;**
- **A sufficient number of blanks cannot be obtained;**
- **Foreign locks may be involved for which blanks are not available or cannot be obtained within the required timeframe;**
- **Special blanks are utilized that contain unique sidebar millings, protrusions, or other obstructions that will prevent their use within the target keyway;**
- **Patented or legally protected(351) profiles are only available from the manufacturer;**

The production of blanks may require the use of profile milling machines that are described in **chapter 8.** The use of the Easy entrie machine will be discussed in the context of the compromise of master key systems in this section because of its suitability for such purpose. Additionally, the capabilities of other types of cutters may also be required if secondary mechanisms are employed, such as sliders, protrusions, detents, steel bearings, side millings or other physical obstructions which must be replicated.



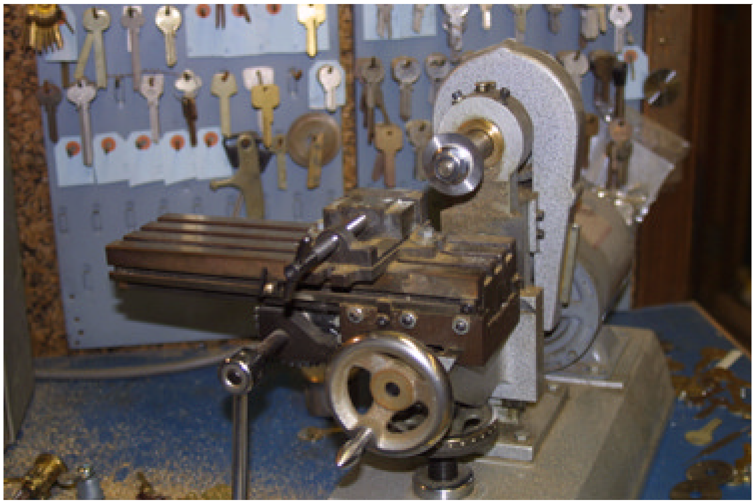
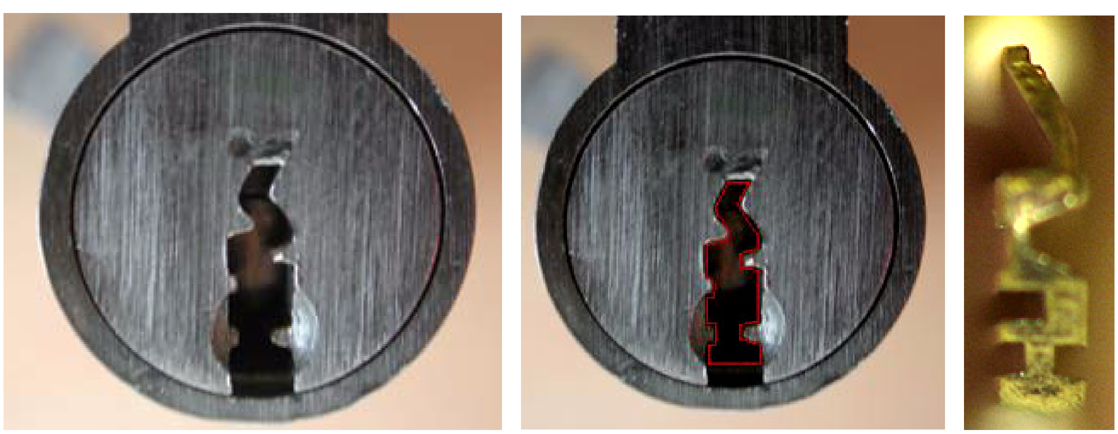


Figure LSS+3144 The Easy entrie and Keyway King profile milling machines can be utilized to generate or create blanks, even for restricted keyways.

The Easy entrie profile milling machine can allow the generation of blank keys from a variety of sources:

- **Sample of blank key;**
- **Sample of a cut key;**
- **Digital image of keyway;**
- **Digital image of end-view of the profile of a key obtained from a blank or cut key;**
- **Impression of a keyway;**
- **Feeler sample of a source key, from which a silicone impression is produced and photographed;**



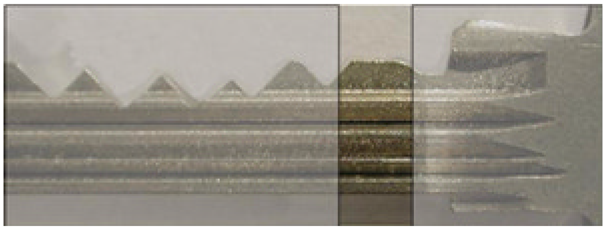


Figure LSS+3143 The Easy entrie profile milling machine can reproduce blanks from a variety of sources. In the photographs, a keyway from a European profile lock is shown, with the pattern traced in the software provided with the Easy entrie. A blank can also be generated from a photograph of the tip of the key. From a cut key, a section can be measured that provides a sample of the complete bitting surface. Any portion of the cut key can be measured to produce the blank. In the photograph (right) the portion of the key that shows the first cut from the shoulder is utilized to produce a blank.

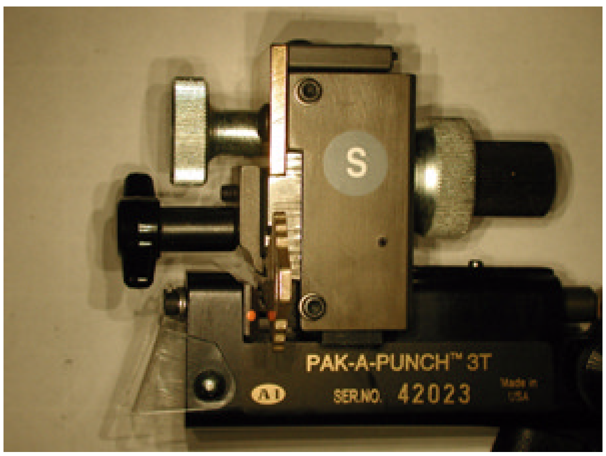
The Keyway King, distributed by DiMark Manufacturing, requires a great deal more skill to generate a blank but has the capability for precise milling of different sections of the key. The Keyway King is a milling machine that allows cutting on three axis, as shown in the accompanying video in **Chapter 8.** Unlike the Easy entrie, the Keyway King has no capability to automatically generate a blank from a source key, nor can it replicate a profile from a photograph. The advantage that the Keyway King provides is the ability to utilize many different cutting wheels to create different profiles. The Easy entrie cannot accomplish this because it measures a very small portion of the longitudinal cross section of the key and then replicates that measurement across its entire surface. If side millings or other unique configurations must be reproduced, then other specialized cutters can be utilized in conjunction with the Easy entrie to accomplish the task, so long as the millings are consistent across the entire surface of the key. The DiMark product has no computer interface capability, and thus does not have the capability of accurately repeating a process where multiple blanks must be created for the same profile. However, individual actions can be repeated with the same milling setup. In other words, several blanks can be milled in sequence for one particular cut before the settings are changed.

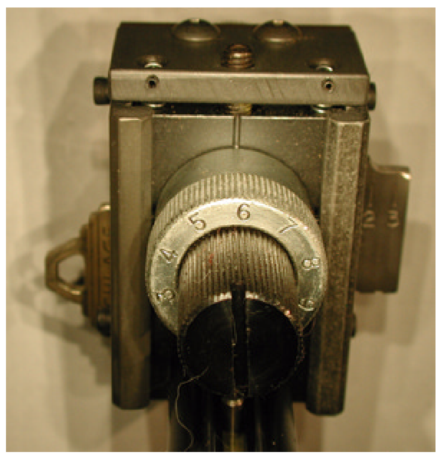
31_4.10.8 Cutting Keys During the Extrapolation Process

Operations may require that system keys be cut in the field for the target lock. In such an instance, there are a number of different alternatives available for key cutters. Two of the most versatile portable devices are the **Pack-A-Punch** and the **HPC 1200**

Punch.

The Pack-A-Punch is available for certain manufacturers and keyways as well as for most automotive locks. The tool can be carried in a jacket pocket and is completely self contained. Different dies are utilized for specific manufacturers. A key blank is inserted into the tool and then advanced and cut for each space. The bitting depth can be rapidly selected with a knob that denotes each depth increment, and the punch then makes the cut. The key is moved laterally across the punch; each position is shown on the right or left side of the cutter. If the Pack-A-Punch is utilized in conjunction with the Easy entrie machine, care must be taken to properly index the special blank because there is no bottom shoulder stop, which is required for the key to be properly referenced to the cutting die.





31_5.0 Electronic Sensing, Measurement, and Capture of Position, Pressure, Polarity, or Presence of Components or Data

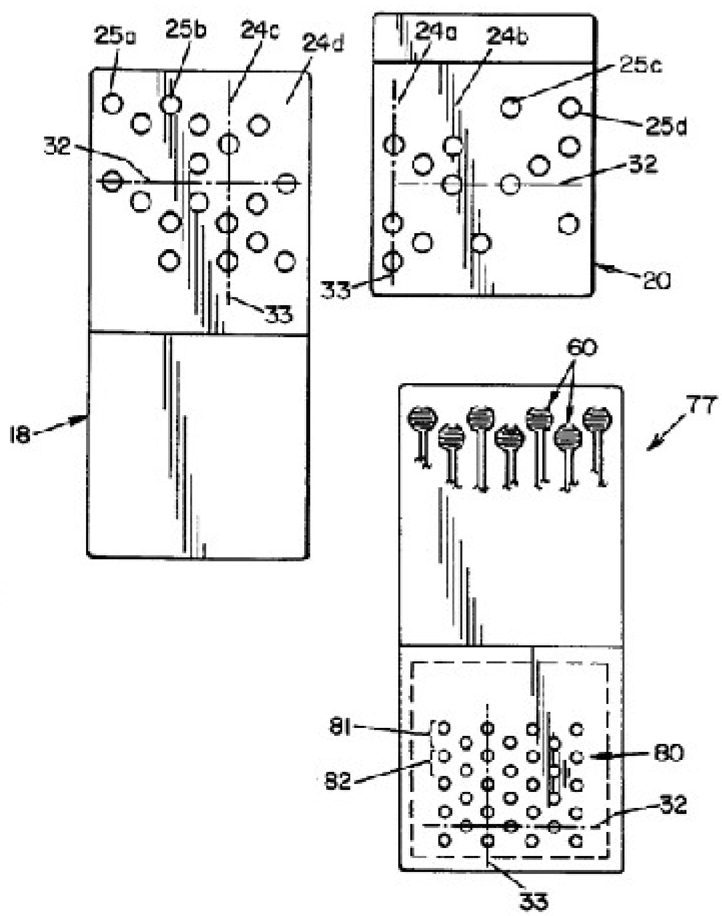
Depending upon the design of the lock, there are several tools and techniques that can be used to sense, measure, and capture the position, pressure, polarity, or presence of active locking components or internally stored data. Primary techniques to provide information about active locking elements include:

- **Pressure-sensitive resistive materials;**

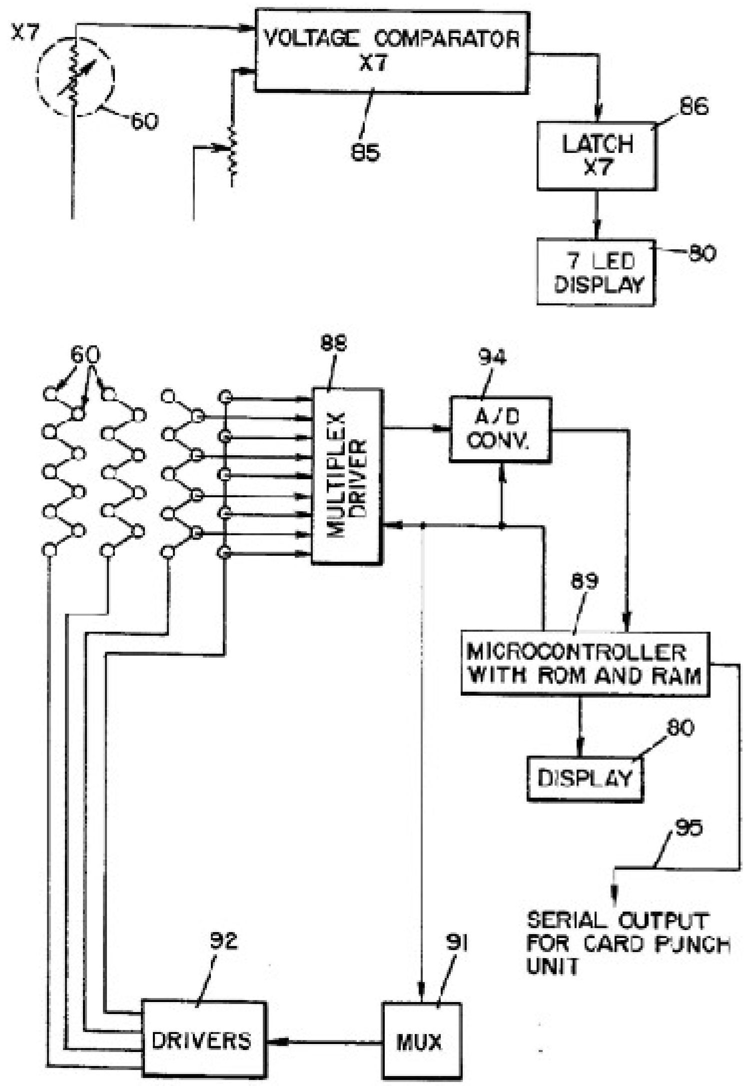
- **Hall-effect sensor for magnetic locks;**
- **Reading the lock;**
- **Decoding the information contained in a code source;**
- **Infrared decoders;**
- **RF decoders;**
- **Vibration at resonant frequency of active locking component.**

31_5.1 Conductive Ink Decoding Systems

The author received a patent in 1994 (**5355701(352)**) for a conductive ink resistor decoding device, used with Ving pin tumbler card locks. This system could sense the position and relative pressure of a pin tumbler within a pin tumbler array.



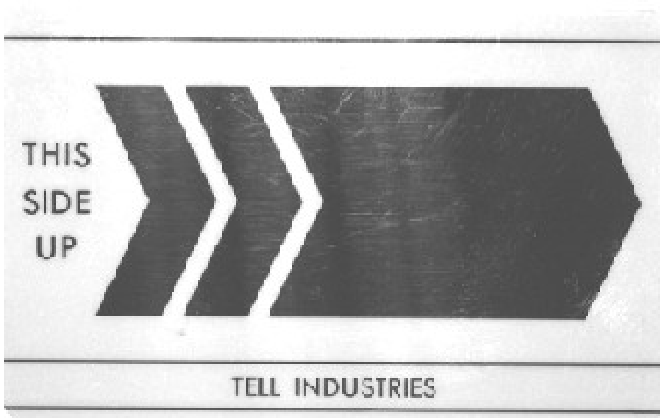
A matrix of conductive resistors matching the spacing of each pin chamber is produced on a plastic card that is interfaced to a small computer and light-emitting diode array. When the card is inserted into the lock, the pressure of each pin is sensed through a change in resistance. The display provides an instant picture of the combination of pins from which a key can be generated.

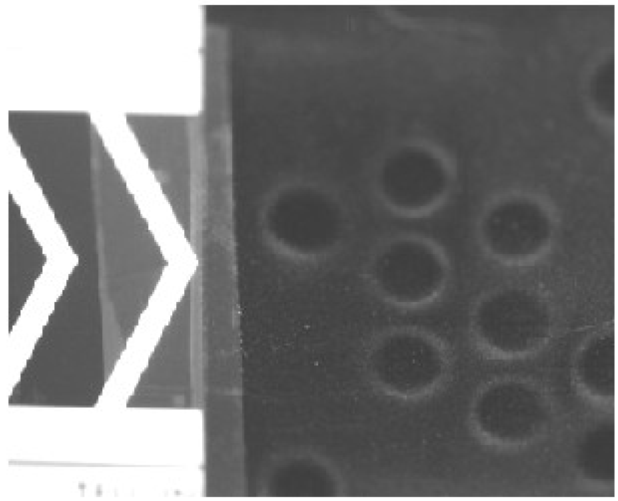


31_5.2 Magnetic Signature Capture

Some magnetic key, card, and disc locks are susceptible to decoding, with different materials and techniques. These devices

rely upon two distinct and different principles to provide security: one is based upon the physical law that like poles of a magnet will repel; the other utilizes tiny magnetized particles to store information.





A variety of materials and devices are used for decoding magnetic information. The 3M Company produces a magnetic-sensitive fluid that is encapsulated in a plastic carrier. Other manufacturers offer fluids containing iron oxide and magnetic sprays. Fine magnetic particles found in copier toner may also be used to read the location of magnetic spots. They are deposited over the target area, then the particles can be lifted with cellophane tape. NCR invented a magnetic paper that could be used in the same manner as the 3M material, except that it would retain the image after removal from the magnetic field.

31_5.2.1 Magnetic Pins or Rotating Discs

In one type of arrangement, magnetic pins or rotating discs are positioned to create a shear line, either directly or through the use of a sidebar. The pins or discs are repulsed from or attracted to a break point based upon the coding of a key or card having corresponding magnets or magnetic spots. The Evva and Miwa locks utilize these principles and were described in Chapter 19. In order to decode these devices, the position and polarity of the magnets must be determined (see patent (**4229959(353)**). The Ikon and Evva mechanisms are extremely difficult to decode due to the use of rotating discs and gates. Analysis of information from these locks will yield no useable indication of the location of any of the gates.

Hall-effect sensors contained within a tiny integrated circuit may be inserted into a magnetic array to provide information as to location and polarity of each magnet. So also, magnetic film, spray, or carbon particles can accomplish the same result. The author developed a sophisticated technique for capturing information as to the number, position, and polarity of magnets within a card lock at the request of a government agency. This technique is briefly described below.

The process involves the insertion of sensing material into the lock for about one second in order to record the presence of magnetic fields and the signature of the key or card. The material is withdrawn and read with a film that visually indicates where magnetic spots are located. Then, a sensitive Hall-effect probe is utilized to determine the polarity of each magnetized spot.

31_5.2.2 Magnetic Stripe Technology

In another type of lock, a magnetic stripe is incorporated onto the surface of a plastic card. Information is encoded onto this ferrous material to provide data to the microprocessor within the lock. It is the same technology as utilized in the credit card industry. Generally, up to 240 bits of information is written on the stripe in the form of magnetic flux reversals. ISO standard 4909 provides an international reference for encoding data and sets card size, thickness, and schemes for writing the information. Generally, three separate tracks can be created and written. In the case of credit cards, tracks one and two are utilized for account information. Track three is reserved for ATM transactions where new information must be written to the card in order to reflect the latest transaction. Lock manufacturers similarly encode these channels.

The encoding of cards is a simple process requiring a record head much like those found in tape recorders. These heads can be purchased at many electronics stores; the circuitry to encode magnetic tracks is relatively simple to construct. Card locks using magnetic stripe technology can be compromised by decoding and duplicating the data on the card or by reading the corresponding information contained in memory within the lock. Inexpensive card readers can be constructed or purchased that are capable of deciphering the data on most magnetic tracks. Likewise, it is reported that Weigand systems can be duplicated and compromised by reading the position of wires within a card

and simulating the data stream created by wire segments.

31_5.2.3 Solid-State Memory

Many of the electronic locks contain removable memory circuits that can be decoded with an EPROM (erasable programmable read-only memory), or EEPROM (electrically erasable programmable read-only memory) reader. A logic analyzer or storage oscilloscope can be used to examine the data contents of memory that remains active and in place on the printed circuit board.

It is also possible to determine the location within a memory device of passwords unique to a lock or lock system. Once the information is derived, it can be used to create a key, card, or other device to bypass the lock. The author conducted one investigation involving an Israeli safe used in thousands of hotel rooms in Las Vegas, Nevada. The 24-byte code that comprised the security bypass card for all of the safes in the hotel was compromised in less than ten minutes. A card was then encoded using a laptop computer that would open any safe in the hotel.

31_5.3 Infrared Decoders

Some locks utilize infrared as a transmission medium for the transfer of data between an encoding device and a receiver. Resembling a television remote control encoder, they head of the key has an IR transmitter built into it that transmits the data to the lock. In certain cases, the data stream between transmitter and receiver can be intercepted and decoded. Once this information is captured, it can be analyzed quickly and reproduced.

31_5.4 Radio Frequency (RF) Decoders

Many automobiles, security, and access control systems utilize RF as the mode to transfer information between user and the lock. These are quite easy to intercept, decode, and simulate because they use common frequencies and the encoding scheme can be fairly standard.

31_5.5 Other Decoding Systems

Many other types of electronic systems can be intercepted, measured, and decoded. Anti-theft systems in stores and

libraries, for example, generally rely upon the creation of a harmonic frequency through the introduction of RF into a tuned circuit sensor that is contained in the item to be protected. These systems can be compromised in many ways.

VATS decoders that measure the resistance of the pellet contained within the head of certain automotive keys require nothing more than an ohm meter to determine its resistance. Some proximity detectors may also be subject to compromise by planting a sensor near the receiver to determine the characteristics of the card or other device.

31_5.6 Resonant Frequency of Active Locking Component

In certain locks, it may be possible to determine the precise characteristics of an active locking component by the introduction of audio frequencies. Such energy can cause a pin tumbler or fence to vibrate at a specific frequency, which can then be correlated to the length of the pin or position of the fence (in a combination lock).

31_6.0 Optical Viewing

Internal components may be observed and decoded through the use of a variety of precision optical technologies. The three primary devices for acquiring images from the surface or inside of locks and safes are the **otoscope**, **ophthalmoscope**, and **borescope**.

These instruments can provide sharp, high-resolution images that can be viewed, photographed, or observed with a video monitor. Color and monochrome video camera heads are easily attached to facilitate decoding. Borescopes utilize relay lenses, or fiber optic links, to transmit images from sensors measuring as little as .3 mm. Charge coupled device (CCD) cameras are also available that may be inserted directly into the lock to provide a video image of internal components.

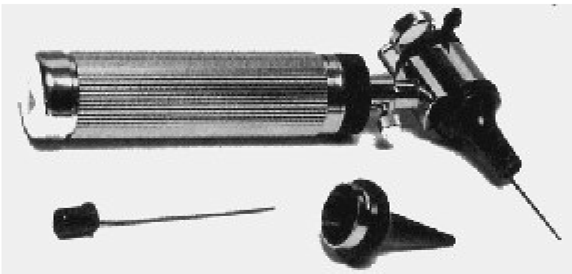
Otoscopes and ophthalmoscopes are inexpensive and simple in design as compared to borescopes. They provide for the surface viewing and magnification of components and allow for the adjustment of diopters and focus to compensate for individual visual acuity. Several factors will dictate which device is best suited to provide optimum imaging. These include:

- **Diameter of the aperture through which the view is to be made;**
- **Distance from the entry point to the active locking component;**
- **Clearance dimensions within the lock or safe;**
- **Required resolution;**
- **Viewing angle;**
- **Magnification requirements;**
- **Illumination requirements;**
- **Capability of video link;**
- **Digital capture requirements.**

Many locks can be decoded by viewing their wards, levers, wafers, pin tumblers, or wheel packs. Extrapolations can then be made from such observations. The information is then converted to code data resulting in the production of a key or derivation of the combination. Optical viewing devices are also used for conducting non-destructive forensic examinations. This section will describe the most common optical tools and their use. For detailed information including the decoding of safe locks, see **LSS+/^{x} CD/ROM.**

31_6.1 Otoscope

An otoscope is the least sophisticated optical viewing device. Typically, these are battery-operated magnifying and illuminating instruments designed specifically for small or difficult-to-view areas. The otoscope generally is provided with a magnifying lens, specula, and pin depressors to manipulate tumblers inside the lock. In 1963, a patent was granted to Rubens (**3087050(354)**) for a combination otoscope, light source, and pick holder.

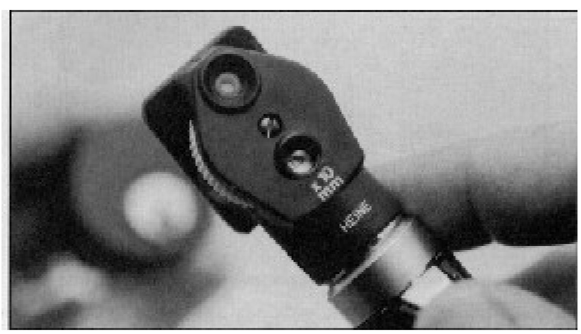




An otoscope head can be used with a borescope lens array. In this case, the otoscope provides a magnified view at a set distance from the lens. Any object that is outside of the depth of field will be out of focus. Generally, an auxiliary lens can be inserted for viewing objects farther away.

31_6.2 Ophthalmoscope

The ophthalmoscope is a necessary instrument in the fields of ophthalmology and optometry and is used to view the interior portion of the eye. It is equally useful for looking inside of locks.



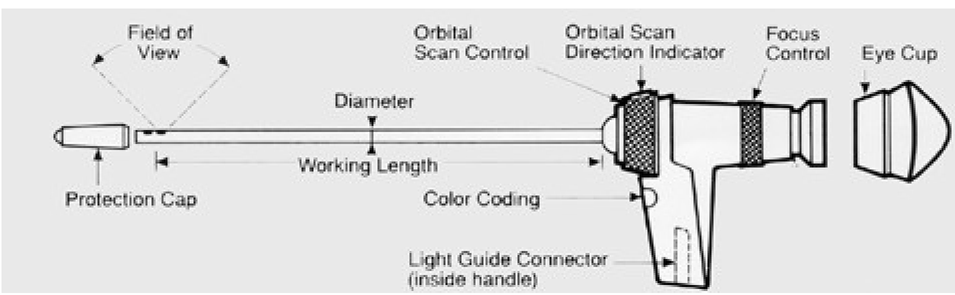
The device allows surface viewing and magnification of objects within a field of view of 5 mm to 250 mm, or approximately 32". Diopter adjustment is generally available. Usually a series of lenses may be selected for different focal lengths.

31_6.3 Borescope

Discussion of endoscope and borescope. Courtesy of Hans Mejlshede.

The borescope is the most sophisticated and expensive optical device available for lock and safe work and is an essential tool for the professional safe technician. Olympus is the leading supplier of relay lens and fiber optic viewing systems in the world. There are two types of borescopes: **rigid** and **flexible**. Each has certain characteristics and restrictions. Video and photographic attachments can be linked to the eyepiece of most borescopes to provide real-time images. This is especially valuable to the safe technician. Illumination of the target is provided by incandescent lighting, or transmitted via fiber optics from a portable light source.

Borescopes generally offer a very wide depth of field so that the target is always in focus. Angled views of up to 90° can be achieved, as can rotation of the target image. Illumination can be precisely adjusted for optimum contrast.

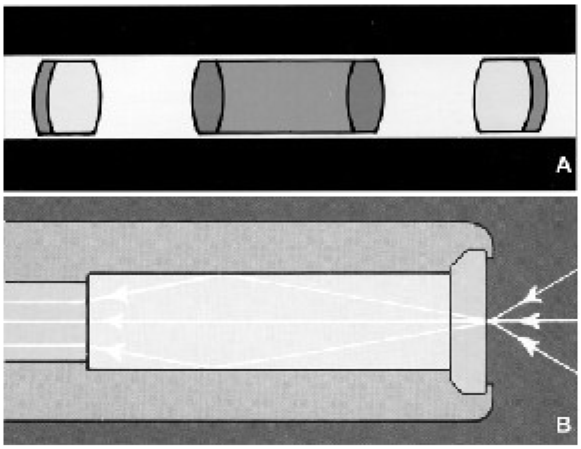


31_6.3.1 Rigid Borescope

A rigid borescope resembles a telescope in design. The imaging system relies upon three primary components: **objective, relay, and ocular.** The distal tip incorporates an objective lens that transmits an image onto the relay lens system. Different prisms can be used to provide varying directions of view. The image system is comprised of lenses and prisms. It will not tolerate any bending, which can prove a disadvantage in certain applications. The image resolution in the rigid scope is far superior to flexible units. The relay system, encapsulated within a long tube, transmits the image created at the objective to the ocular viewing lens and eyepiece. The images are actually relayed or recreated as they encounter each lens and prism. Auxiliary prisms are sometimes used to correct image orientation as they reach the eyepiece.

31_6.3.1.1 Lens Systems

There are three common lens systems used for relaying images: **thin lens relay, hybrid rod and thin lens relay, and selfoc/grin relay system.**



Thin Lens Relay

The convex thin lens is the simplest form of image relay and provides the greatest light loss or absorption during transmission. The system is comprised of a series of convex lenses that simply acquire and retransmit images down the chain.

Hybrid Rod and Thin Lens Relay System

This is a more sophisticated system and utilizes the convex lens in combination with cylindrical "rod lenses" with specially ground ends, for more efficient light transmission. The increased amount of glass provides greater resolution.

Selfoc System

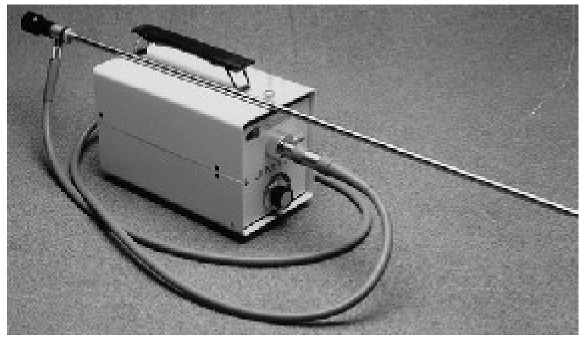
The Selfoc system is used on 1.2, 1.7, and 2.7 mm diameter borescopes. In this configuration, a glass rod forms one continuous cylinder. This is the most expensive system and is quite fragile.

31_6.3.1.2 Lenses and Image Quality

Image distortion depends upon the quality of the lenses within the optical instrument. Compound lenses are generally used in the more expensive borescopes for sharper definition. Two primary forms of image distortion result from the use of simple spherical

lenses: **chromatic** and **spherical**. Chromatic distortion refers to the characteristic of a lens that refracts light at different angles, depending upon wavelength. Short wavelengths (violet) are bent more; the longer ones (red) less. The result is color fringing within the image.

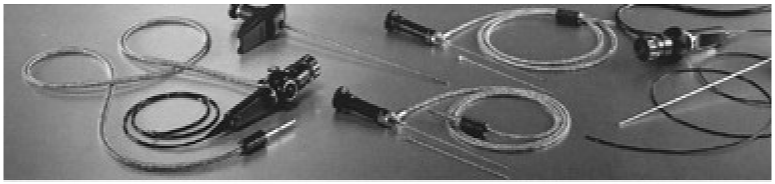


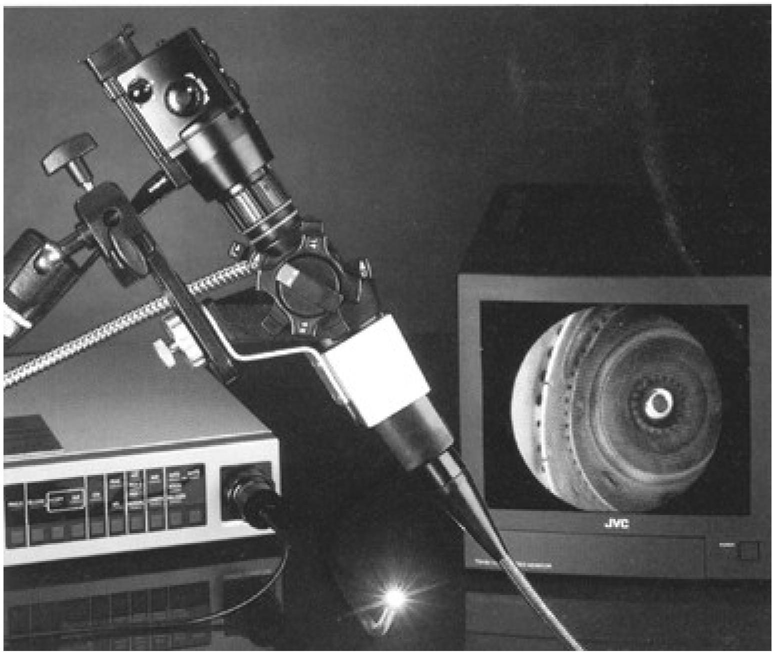


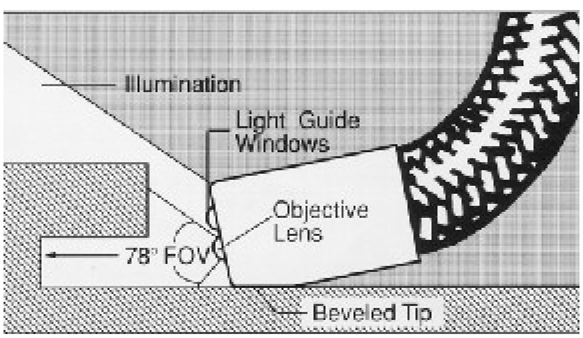
Spherical distortion occurs because the lens surface itself is shaped as a sphere rather than parabolic. This results in the lack of a single focusing point. In such cases, light rays are refracted to different degrees depending upon the point where they enter the lens, other than at the axis. To correct these errors, compound lenses are utilized. They consist of both concave and convex elements that have different refractive indexes. They cancel distortion without altering the transmission properties of the lens.

31_6.3.2 Flexible Borescope

Differing from a rigid borescope (where images are relayed by lens elements contained in the array), a flexible fiber optic guide is used to transmit images in this configuration. The resolution is not nearly as good in these systems, but allows viewing of targets in difficult locations up to ninety feet away. The tip can be controlled to observe different areas of the target. The Olympus series of flexible scopes can be used for covert operations that require the capture of images through walls, ceilings, and under doors.







31_6.3.3 Lighting Sources

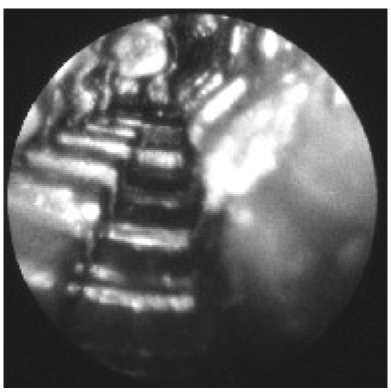
Incandescent lamps or fiber optic routing of light is used to illuminate the area or object being viewed. Optical fibers are preferred because they can provide lighting with high output that is adjustable and remote from the probe. A separate light-generating source is interfaced in the borescope, usually with a fiber optic pack that surrounds the tip of the probe. Halogen lights are often used to provide brilliant white illumination.

31_6.3.4 Using a Borescope for Decoding and Opening Locks

Borescopes have excellent resolution and can be used to observe active elements within a lock. The dimension, location, coding, and alignment of such components can be observed and calculated. Decoding of wafer, lever, and combination locks can be accomplished using regular and micro-borescopes. Micro-borescopes can penetrate pin tumbler and other locks that have keyways with ward clearance of .5 mm or more.

31_6.3.4.1 Decoding Wafer Locks Using Borescopes

Although it is technical overkill, most wafer locks can be decoded with a borescope. It will be remembered that the **overall** outer dimensions of most wafers do not vary. Differs are created by the relative vertical position of the void area within each wafer (where the key enters). The amount of bitting material that is present between the top of the open area and the top or bottom edge of the wafer determines the depth code.



Exploded view.

With an understanding of this principle, it is a simple matter to observe each tumbler and the relative position of the internal open areas, with respect to the top or bottom edge of each wafer. Since there are generally no more than six depths, the coding is simple to calculate. In the case of some General Motors sidebar locks, the depth code is imprinted on the face of each wafer, as well.

31_6.3.4.2 Decoding and Manipulating Lever

Locks Using Borescopes

Using two primary techniques, lever locks may be decoded, analyzed, and opened with a borescope. In addition, the number of levers, their characteristics, and any special security enhancements can often be determined.

31_6.3.4.2.1 Observing Fence-Gate Relationship

The levers can be individually manipulated by picking while observing the position of each gate and fence. In this instance, a viewing hole is often present through which the probe can be inserted. Otherwise, a hole can be drilled to accomplish the same purpose. Once a direct view is available at the point where the fence enters the gate of each lever, it is a simple matter to lift the levers for proper alignment.

31_6.3.4.2.2 Extrapolating Information from Bellies of Levers

The bellies can be viewed and analyzed for contact marks that occur where the bitting surface of the key interacts to lift each lever. Once decoded, the depth of each lever can be extrapolated and then transferred to a key. In locks where bellies are not uniform, the width of the interaction mark will be different, based upon the amount of lift required to bring the fence and gate into alignment. The ability to decode a lever depends in part upon how much the lock is used and the resultant wear. If very pronounced, then the width of the marks will be noticeably different for each depth.

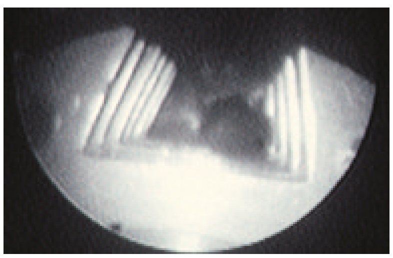
Uniform bellies, as are present in the Chubb 3G110, can be a great deal more difficult to decode. This is because the width and placement of the marking will change. A detailed knowledge of each lock is required to successfully decode these mechanisms. Tryout keys can also be used with lever locks having fewer differs because of the lack of tolerance. In England for example, many locksmiths carry sets of keys that will open all lever locks within the country.

31_6.3.4.3 Penetration of Safes and Vaults with Borescopes

There are many ways to effect an opening of a safe or vault. Other than manipulation, drilling is the primary technique. Once

the decision to drill has been made, the craftsman must decide where to drill and for what purpose. The primary reason to drill **any** lock is to gain access to the wheel or lever pack and to observe the interaction of the gate and fence. When a view of this interaction is achieved, moving the components into alignment can open the lock. This presumes that relockers have not been fired.

Critical components may be viewed by drilling anywhere that allows the wheel pack, levers, relockers, or active locking components to be observed. The borescope is generally the preferred instrument, where components are inaccessible to other forms of optical aids or surface viewing. They may probe into remote areas up to 30″ away and are ideal for safes, vaults, and lever locks.



Although covered in later chapters regarding safe penetration techniques, a brief description of the drilling process as relates to the use of a borescope will be presented here.

A small hole, generally between ¼″ to ½″ is made into the body of the safe at one of several preferred locations. A drill point template is generally required, as the placement of the hole must be quite precise to obtain the proper view. There are complicating factors to this process relating to the use of security glass attached to relockers and the penetration of barrier materials. Special compounds are also employed to frustrate penetration. These are discussed in **Chapter 5.** Barrier material, generally having a Rockwell hardness rating of up to 90, is usually positioned so as to cover the lock. This makes drilling more difficult and time consuming.

A pane of Herculite glass is generally placed in front of critical locking components in high-security safes in order to protect against penetration by drilling. The theory is that if the drill point touches the Herculite, the glass will shatter, releasing tensioned relockers. There are methods to circumvent glass that are discussed in later chapters. One other problem

involving the use of Herculite deserves mention. In some older safes, manufacturers had a practice of painting the glass. This technique was discontinued when it was discovered that the paint acted as a cohesive material to hold the panel together after penetration.

Notwithstanding the difficulties that may be encountered, a borescope requires that a small hole be precisely positioned to provide a view of the wheel pack or levers and their interaction with the fence. In the case of combination locks, a hole may be made anywhere within a 360° field around the wheel pack, so long as the outer edge of each wheel can be observed. Lever locks require more precision to provide a direct view of the point where the fence enters the gates.

To open a combination lock with a borescope, the probe is inserted and each wheel is rotated until the gate is observed. The **relative position** of the wheel is correlated to the number that is indexed on the dial. Each wheel is rotated, in the left-right-left or right-left-right sequence as if the combination were being dialed. All wheels must be aligned so that the fence **would** retract if the wheels were properly positioned with respect to the drop in position of the fence. Once this occurs, it is a simple matter to extrapolate the difference between the observed and actual drop in point.

The observation of the wheel pack can be achieved from the front, side, or back of the lock. Often, a hole is drilled at the rear of the safe; the change-key hole at the back of the lock is used as the viewing aperture. Security glass may be avoided by drilling a scope hole at the edge of the door in front of the glass.

31_7.0 Obtaining Key Codes Using Photographic Techniques

A target key, if available, can be photographed with high-resolution film that is indexed for precise measurement. From the print, it can be reproduced and decoded. If keys are visible for a few seconds, they can also be photographed through covert means. The author has successfully utilized the Tessina (Swiss) 35 mm double-lens-reflex handheld camera for this function, as well as standard format 35 mm with long lenses. Video is more difficult to obtain useable images due to the relatively low (30 dpi) resolution. Target keys can also be

overlaid on photographic paper and briefly exposed to light to obtain a 1:1 contact print. They can also be reproduced on a copy machine.

31_7.1 Photographic Techniques

The code information of keys can be derived through three primary photographic techniques: **covert**, **macro**, and **exposure overlay**.

31_7.1.1 Covert Photography

Keys sometimes can be photographed covertly if the proper circumstances either exist or can be created. Depending upon the following factors, covert photographs may be taken of target keys that are carried, worn, or left open to view.

Covert photography is used where direct access to the target key is not possible. For example, the master key carried by a maid in a hotel may need to be obtained. A series of photographs may be shot as she walks down the hall. The pictures may then be examined and the size of the key correlated with a known sample. One case that the author reviewed involved the surreptitious capture of the master code for a VingCard lock by hotel burglars in Europe. The thieves were able to photograph a VingCard plastic key and determine the matrix of holes that comprised the system master key. It will be recalled that these plastic cards have a series of holes punched randomly. It is a very simple matter to correlate the photograph with the generation of an actual card. In this particular case, thieves were able to compromise a number of hotels in Belgium and Holland before being caught.

Factors that will affect the acquisition of an image:

- **Size, design, and intricacy of the key;**
- **Type of locking system and complexity;**
- **Whether certain aspects of the bitting is not visible, such as sidebar data on an ASSA key that can only be viewed from one surface;**
- **Design of the bitting surface: ramps and valleys, square-cut, or dimple;**
- **Differences or spacing between each cut;**
- **Difference between the depth of each tumbler position;**

- **Angle and perspective of view;**
- **Contrast of bitting surface;**
- **Distance from the camera;**
- **Lens, focal length, and iris opening;**
- **Image capture format: film, video, radioactive imaging;**
- **Film format: size, DIN, resolution in lines per millimeter;**
- **color, monochrome, or infrared;**
- **Lighting;**
- **Reflection of light from the key;**
- **Background surface and color and the contrast thus created.**

31_7.1.2 Macro Photography

A macro photograph can be taken of the key with a precision ruler, providing a 1:1 guide for printing the image. It is then a simple matter to enlarge the photograph or extrapolate the depth of each cut.

31_7.1.3 Exposure Overlay

A very simple means to obtain a precise 1:1 image of a target key is to contact overlay the key on a piece of photograph paper or film in the dark, then briefly expose it to light. The image may be retained for a long period within a dark container and developed later. The resulting image may be translated to a hard metal blank.

31_8.0 Pressure-Responsive Materials

Pressure-responsive materials may be utilized for producing a direct impression of a target key or for decoding the active elements. Electronic and pressure-sensitive resistive materials can also be used to decode a lock.

31_8.1 Duplication of Keys

Target keys may be physically copied through the use of pressure-responsive materials. These include plasticine, clay, modeling clay (Fimo is recommended), metal foil, silicone material, soap, or even human skin. They may all be utilized to

obtain an impression of a key for later duplication. In an emergency, a key can be firmly depressed against the soft skin of the wrist. This will leave an impression that can then be dusted with talc and lifted with cellophane tape.

31_8.2 Decoding Active Components with Pressure-Responsive Materials

As detailed in **Chapter 26**, many materials may be used to decode the position and dimensions of active locking components within a warded, wafer, disc, lever, and pin tumbler mechanism. The proper and effective use of plasticine, carbon, wax, cellophane, metal foil, clay, and carbon paper rely upon basic impressioning theory, detailed in **Chapter 30.** Each of these materials is used to produce an imprint in order to obtain an image of the key or to extrapolate its measurements.

31_8.2.1 Newton Plasticine System

Martin Newton (UK) has developed a plasticine impressioning and decoding system for lever locks. A collection of several different keys is provided within a kit. Each is cut to lift one lever within the lever pack, allowing decoding. A special blank is also provided, upon which plasticine is overlaid. Once coated with the material, the blank is inserted into the lock and turned against the levers. The depth of each belly is defined as an impression, allowing a key to be generated (see **Chapter 30).**

Plasticine reading kits are available for the following locks:

- **Union 5-lever Black, Yellow, and BS3621**
- **Ingersoll M50**
- **Yale Titan and PM550**
- **ERA Invincible 5-lever, Viscount 5-lever, and Endurance 5-lever**
- **Securefast 5-lever**
- **Chubb Upgrader 5-lever**
- **Gibbons 5-lever**
- **Squire Defiant padlock**

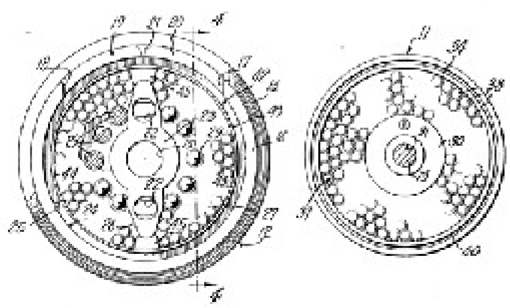
31_8.2.2 Falle Metal Foil System

The Falle metal foil impressioning and decoding system utilizes a

thin layer of metal to define the position and length of each pin tumbler. This technique is quite effective and can result in a precise image of the key that can then be decoded. See **Chapter 30** for a detailed description of this system.

31_9.0 Radiographic Imaging

Computers have changed conventional methods of radiographic imaging. Now, both radiography and radioscopy may be utilized for bypass and covert entry. X-ray, gamma ray, and other radiation technology have been successfully used by Russian, American, and other foreign intelligence agencies to determine the position of the wheel pack within a combination lock and to examine pin tumblers in a cylinder. Several patents have been issued for techniques to prevent the gathering of such information, generally through the use of lead masks.



Traditional x-ray methods utilize photographic film for the detection and recording of images. The electronic version, radioscopy, uses x-ray sensitive detectors to produce an image on a CRT or liquid crystal display. Radioscopy is a relatively new procedure and is used in industry for non-destructive testing. Standardization efforts began in 1988 by the ASTM, and the use of the technique is expected to increase. Presently, the primary users of radioscopy are industry, medicine, and aerospace. As equipment becomes more sophisticated, the application for covert entry will expand.

The technique can allow the examination of almost any object, including electronic components, ceramics, composites, plastics, and other non-metallic materials. Radioscopy can save cost, time, and labor, and eliminates the need for films and chemicals. It is obviously a more environmentally friendly process. One of the most important benefits of the imaging process is the ability to manipulate the photographed part or component, using

sophisticated software. It is possible to obtain different views and perspective when using such programs.

Once the data is collected in digital format, the results can be processed for detailed enhancement and analysis. Most importantly, radioscopy can provide a real-time examination of active locking components. There are now portable x-ray units produced by SAIC and others that can be used to derive real-time information about a lock, explosive, or other mechanical device. The second generation of these devices provides an enhanced image, displayed on a liquid crystal array or computer CRT.



There are inherent difficulties involved in the use of such technology. These relate to the fact that radiography relies upon a **difference** in the density and composition of metals or other materials in order to provide useable images. Minimal changes in density mean that it is impossible to distinguish between different components. Effectiveness is limited by many factors. These include:

- **Thickness, density, and composition of the outer surface that protects the lock;**
- **Composition of the individual locking components;**
- **Difference in composition and density of protective surfaces, barrier materials, and other enclosures in comparison to the active locking components to be measured;**
- **Ability to obtain an image based upon the position of the lock and the enclosure. This relates to the distance between the target and radiation source, as well as the capability of placing the lock within the focal length of the instrumentation.**

Typically, the use of x-ray to determine the position of each gate in a combination lock requires that the dial cover be removed. Film or a detector array is placed in front of the

wheel pack, and a gamma source is located at the rear of the safe. In practice, a small hole is drilled and radiation is directed through the hole to shadow the wheels by moving the area of exposure. Shadowing can be compared to the use of a borescope or focused light beam that is swept across the active locking components.

Two critical difficulties can be encountered with shadowing. If polymer components are utilized as an obscurant, such as delrin or nylon, the image will be almost impossible to read. Additionally, the use of protective hard plate may block the radiation source. Even if polymer wheels or other patented techniques are not in use, a great deal of skill is required to interpret the image information. It is reported that the Russians have been able to read a delrin wheel pack through digitization and enhancement techniques. Ultrasound and florescent penetrants have also been successfully utilized for covert entry.

31_10.0 Interception of Information Transfer

The newest lock technology involves the transmission, receipt, and validation of a data stream between key and lock. Described elsewhere in this text, these locks utilize keys containing passive transducers that receive, modulate, and echo data back to the host. The technology is now popular in automobiles, access control systems, and certain high-security programmable locks. Depending upon design, shielding, and environment, such data may be intercepted and decoded. Chubb, Medeco, Ford Motor Company, and many others are utilizing this technology.

Other systems utilize both infrared and radio frequency energy to transmit code information to validate the user. RF is easily detected several feet away; IR poses more of a problem. Interception is dependent upon frequency, ambient light, transmission angle, and power. IR systems are in use by Abloy, Marlok, and others.

Proximity sensors that are incorporated within access control and anti-theft inventory systems use passive devices that modulate or modify data and radiate it back to a source. They may also utilize schemes that repeat signals at overtones or multiples of original frequencies. This information can be captured, decoded, and simulated.

CHAPTER THIRTY-TWO: FORCED ENTRY

Destructive Entry: Tools and Techniques

Master Exhibit Summary

Figure 32-36 Sigma two-man battering ram
Figure 32-37 Sigma battering ram
Figure 32-38 Sigma hinge removal tool
Figure 32-39 Broco portable thermic lance
Figure 32-40 Broco thermic lance
Figure 32-41 Marks from a dent puller
Figure 32-42 Shove-knife
Figure LSS+3201 Sigma Baby ram
Figure LSS+3202 Explosive Wall Breaching System
Figure LSS+3203 Sigma Firecracker ram
Figure LSS+3204 Sigma Mitts
Figure LSS+3205 Sigma Ripper
Figure LSS+3206 Power actuated tool

Figure LSS+3207 External - Right hand inward opening timber door with standard Yale type lock; Internal - Left hand inward opening steel gate in confined area armed with single deadlock. Courtesy Ian Bauchop.

Figure LSS+3208 External - Left hand outward opening solid timber door with two locks; Internal - Left hand inward opening steel grille. Confined space with one deadlock and two sliding bolts

Figure LSS+3209 Internal concertina mild steel window grilles behind 6 mm float glass casement window

Figure LSS+3210 Right hand inward opening solid timber door with multipoint locking system

Figure LSS+3211 External - Right hand outward opening steel gate, slightly recessed with single lock and cover plate down lock side on two rising butt hinges; Internal - Right hand inward opening timber door

Figure LSS+3212 External - Steel cage protecting front door with right hand outward opening single lock with now cover plate. External steel grilles protection windows; Internal - Inward opening solid timber door

Figure LSS+3213 Right hand inward opening flush solid timber door with one visible lock

Figure LSS+3214 Internal view of LSS+3213 detailing timber braces and additional deadlock and night chain

Figure LSS+3215 Right hand inward opening solid timber door with four individual locks. Attack made with chain saw on hinge side

Figure LSS+3216 External - Right hand opening steel gate with single lock, full cover plate and rising butt hinges; Internal - Right hand outward opening solid timber door, locks unseen

Figure LSS+3217 External - Right hand outward opening steel gate, single lock, no cover plate and standard butt hinges; Internal - Right hand inward opening solid timber door, one lock visible

Figure LSS+3218 External - Right hand outward opening timber and glass door with single lock; Internal - Right hand opening timber and glass paneled door with two locks

Figure LSS+3219 Recessed Left hand inward opening solid timber door with multipoint locking system, set in steel frame plus additional top lock

Figure LSS+3220 External - Flush with building right hand outward opening steel paneled gate with steel mesh and full cover plate; Internal - Standard timber door with glass panel

Figure LSS+3221 Left hand outward opening recessed solid timber fire door with steel panel

Figure LSS+3222 External - Heavy duty right hand outward opening steel gate proud of building line with single lock and no cover plate; Internal - Right hand inward opening timber door, locks unseen

Figure LSS+3223 External - Recessed right hand outward opening steel gate with three standard butt hinges and no cover strip; Internal - Right hand inward opening timber paneled door with two locks visible

Figure LSS+3224 A sigma forced entry team shows the technique for breaching a door.

Figure LSS+3225 MSC Lock Force tool is similar to that produced by SIGMA
Figure LSS+3226 There are various dies for the MSC LOCK FORCE tool to fit different profiles
Figure LSS+3227 The use of the MSC LOCK FORCE tool is straightforward

Figure LSS+3228 The BROCO thermic lance is a small self contained package
Figure LSS+3229 The BROCO control nozzle and chemical self starter for the thermic lance
Figure LSS+3230 The KIBB security lock and strike system makes bypass difficult
Figure LSS+3231 An attack on a file cabinet safe with a variety of tools.

Figure LSS+3232 A hole saw can be used to ream out the entire plug.
Figure LSS+3233 A new shear line is created by drilling the plug.
Figure LSS+3234 The mounting for the cylinder is cast and can be fractured, allowing removal of the lock.

Figure LSS+3235 Knob locks should not be used as the sole protection on exterior doors.

Figure LSS+3236 Rim locks must be mounted properly to increase their resistance to attack.

Figure LSS+3237 Cylinders can be pried loose if not mounted properly.
Figure LSS+3238 The cylinder was pounded through the mounting.
Figure LSS+3239 A pipe wrench can be utilized to twist loose a key-in-knob or cylinder lock.

Figure LSS+3240 The ease by which a cylinder can be removed by shearing the setscrew.

Cylinders can be forcibly removed by applying torque and destroying internal setscrews. The setscrews can also be removed during business hours to allow the cylinder to be unscrewed at a later time. Courtesy of Don Shiles.

A wrench attack on cylinders can be very effective. Courtesy of Don Shiles.

Figure LSS+3241 A diagram showing the principle of jamb spreading.
Figure LSS+3242, examples of burglary tools found at the scene of a safe job.

Cylinders can be forcibly removed by applying torque and destroying internal setscrews. The setscrews can also be removed during business hours to allow the cylinder to be unscrewed at a later time. Courtesy of Don Shiles.
Figure LSS+3243, a special drill bit for removing plugs, called a rotary pick.
Figure LSS+3244 A lock can be drilled by raising all drivers above shear line.
Figure LSS+3245 A lock can be drilled to create a new shear line.
Figure LSS+3246 A lock can be drilled and then shimmed with a fine wire.

Figure LSS+3247 Peterson Manufacturing IC removal tool
Figure LSS+3248 The Stealth Lock Systems tool to open Medeco cam locks

Sigma analysis of the Kibb interlocking strike plate, with Ian Bauchop.

Demonstration of different forced entry techniques on doors utilizing the Kibb interlocking strike plate design.

A wrench attack on cylinders can be very effective. Courtesy of Don Shiles.

Forensic evidence of forced entry. Courtesy of Hans Mejlshede.

Opening a padlock by bouncing the locking dog. Courtesy of Don Shiles.

A discussion of covert entry by Harry Sher

A discussion of GSA containers and covert entry, by Harry Sher

A discussion of surreptitious entry and government containers, by Harry Sher

The use of the nose puller, courtesy of Harry Sher.

LSS201: MSC Lock Force tool, courtesy of MSC

LSS201: Forced entry tools produced by Sigma. Courtesy of Ian Bauchop.

LSS202: Broco Thermic lance description and use, by Tom Joos.

LSS301: Abus decoder, by John Falle

LSS301: European lever lock decoder, by John Falle

LSS301: Ford Galaxy decoding system, by John Falle

LSS302: Medeco lock decoding system, by John Falle

LSS302: Universal pin lock decoder, by John Falle

LSS302: European lever lock pick, by John Falle

LSS302: Axira lock decoding system, by John Falle

LSS302: BMW lock decoder system, by John Falle

LSS303: Pin and cam system for CISA and other European locks, by John Falle

LSS303: BiLock decoder system, by John Falle

LSS303: Abloy decoder system, by John Falle

LSS303: Universal pin and cam system, by John Falle

LSS304: Universal belly reader system, by John Falle

LSS203: Demonstration of the use of a loid, by MSC

32_1.0 Introduction

This chapter surveys methods of destructive entry for locks, enclosures, and premises. Penetration of safes and vaults is covered in **Chapter 35**. The manipulation of safes is detailed in **Chapter 36** as are the methods of covert entry. Integral to our discussion is the characteristics of materials under stress as detailed in **Chapter 5**. The chemistry and physics of metallurgy will determine how a security device can be compromised by force. The focus of this chapter is premised upon the use of tools and techniques by two disparate classes of users: authorized, and criminal. Tools employed by government security services, military units, and rescue services are described. Unfortunately, professional criminals utilize many of the same devices in the business of burglary and espionage.

Whereas the more sophisticated thefts are covert in nature, almost ninety percent of all burglaries are based upon forced-entry. Although this statistic would seem to indicate that the amateur and semi-professional burglar resort to the more basic forms of forced-entry to steal his goods, this is not necessarily the case. There are certain distinctions between the different types of burglars. Generally, they can be described as belonging to one of three categories: amateur, semi-professional, and professional. The semi-pro steals regularly and targets residences and businesses that are easily compromised. The professionals earn their living from thefts. They are knowledgeable about locks and security systems, safes and vaults, and other security hardware. More important to our discussion, the professional can afford the latest tools and technologies. Opportunities are created with such implements. He will look for property of substantial value and assess the difficulty and risks involved.

Destructive entry shall refer to any process that causes any

damage or indication of compromise of a security system, container, or device. Covert and surreptitious entry can be considered the opposite of destructive entry. The United States government in Federal Specification AA-F-358G, issued March 7, 1989, defines **Covert entry** as “a method of entry which would leave evidence, but would not be detectable by a user during normal use, but would be detectable during inspection by a qualified person.” **Surreptitious entry** was further defined as “a method of entry, such as lock manipulation or radiological attack on the combination lock, which would not be detectable during normal use, or during inspection by a qualified person.”

A discussion of covert entry by Harry Sher

A discussion of GSA containers and covert entry, by Harry Sher

A discussion of surreptitious entry and government containers, by Harry Sher

There are many methods by which a lock and anything to which it is attached can be forcibly compromised. Today, a variety of tools, both off-the-shelf and custom, can be utilized to effect entry. This chapter will describe the more specialized tools and techniques rather than to reiterate common attacks. Destructive entry procedures, for our discussion, will be classified in terms of **tools** and their use, the **application of energy**, and **devices** subject to attack. Application of energy means the use of some form of force, energy, or temperature to directly or indirectly displace, distort, bend, break, shear, twist, expand, compress, contract, or move the critical component of a security system, to allow compromise or bypass. **Tools** shall refer to any implement that is employed to effect the compromise of a security system or device. This includes locks, barrier material, enclosures, or perimeter protection. **Devices subject to attack** shall refer to locks, barrier material, enclosures or other thing that protect or secures an entry, area, or enclosure.

32_2.0 Application of Energy or Force

The application of energy to effect the compromise of a security device is dependent upon the design of that device and surrounding materials. It is axiomatic that energy is applied in order to reverse, distort, break, or bypass the fundamental mechanical configuration that makes such designs secure. Materials utilized in locks, safes, and security devices are designed to withstand many different kinds of stresses that can

result in the alteration of molecular structure. Most testing procedures reproduce the stresses associated with different forms of attack and measure a material's resistance to such forces. ASTM, ISO, UL, BSI, and other standards organizations have developed extensive criteria and protocols for such testing. International regimes for certifying locks, security devices, and materials are defined in **Chapter 37**.

32_2.1 Specific Forces

Tools are utilized as the vehicle to deliver and focus energy upon a specific target. The fundamental forms of force and stress, applied through direct or indirect means, include:

- **Shearing, cutting, and chopping requires the application of pressure to the material between two edges, much like a scissors. Drilling is included within the definition. Example: padlock shackles may be cut when two shearing blades are positioned within a tensile loading device having a compression load capability;**

- **Tension, stretching, or pulling. This technique requires that the component be stressed past its tensile strength. In the case of cylinders, the plug is forcibly withdrawn. Padlocks are especially vulnerable to forms of attack that create such stress;**

- **Torsion or twisting generally requires that a blade type tool be inserted into the keyway until the lock opens;**

- **Opposing forces applied simultaneously include Prying, Bending Ripping, and Wedging;**

- **Compression requires pressure to be applied to a material in order to weaken or sever it;**

- **Breaking will cause an alteration or fracturing of a material through the application of temperature or some sort of force;**

- **Impact or blows, including dropping. Explosives or shock is applied to the device. The weight of the security device can also be exploited when dropped on its face or sides;**
- **Temperature extremes can be utilized to alter the molecular structure of a material. High temperatures can be generated by a thermic lance, torch, electric arc welder, lasers, and chemicals. Super-cooling agents such as freon and liquid nitrogen are utilized to freeze materials;**
- **Acids and other chemicals can be applied to virtually any material to dissolve, disintegrate, or destroy the molecular structure.**

32_2.2 The Results of the Application of Force

Force and energy are applied to a material to secure a specific change in structure. This will be dependent upon the mechanical design of the security device, metallurgy, and security rating. The desired result will ultimately include one or more alterations:

- **Displacement of components;**
- **Vaporization, disintegration, burning, or melting;**
- **Shattering, brittleness, or loss of temper;**
- **Breaking;**
- **Movement of components;**
- **Distortion, warping, bending, or alteration;**
- **Expansion;**
- **Change in molecular structure.**

32_2.2.1 Displacement of Components

Locks may be attacked in an effort to displace internal components. For example, a pin tumbler mechanism may be drilled at shear line in order to move and destroy pins so that the plug is free to rotate.

32_2.2.2 Vaporization, Burning, or Melting

Heat can be utilized to melt, soften, or vaporize barrier materials. Torches and thermic lances will generate sufficient temperatures to destroy the molecular structure of any material.

32_2.2.3 Shattering, Brittleness, or Loss of Temper

Extreme heat and cold can be utilized to alter the properties of a given material in order to cause brittleness or loss of temper. If a metal is superheated then rapidly cooled, it can be fractured or shattered. A common technique when penetrating hardplate is to drill until the material is red-hot, then repeatedly strike the metal with a sharp punch to break or fracture the surface. This provides a place for the tip of the drill bit to engage.

A similar procedure was utilized to forcibly enter the old cannonball safe. The circumference of the door was superheated around the outer groove. Cold water was then poured on the hot metal, which would cause it to harden. A special hatchet was then pushed into the channel. Repeated blows to the hatchet would be struck with a heavy hammer as it was moved completely around the door until it broke open.

32_2.2.4 Breaking

Creating sufficient stress on barrier or supporting materials to cause fracture may break critical components.

32_2.2.5 Movement of Components

Active locking components may be physically moved by certain procedures involving the application of energy or force.

32_2.2.6 Distortion, Warping, Bending, or Alteration

Distorting, warping, bending, or altering the mechanical configuration of active components may compromise locks or security devices. Perhaps the simplest example is the spreading of an aluminum door frame in order to provide clearance between the strike and strike plate.

32_2.2.7 Expansion

The expansion of materials may provide sufficient clearance to access active locking elements and to bypass their proper operation.

32_2.2.8 Change in Molecular Structure

A change in molecular structure can sufficiently weaken the barrier material so that it no longer presents an obstacle to bypass. Chemicals, heat, cold, electric charge, and induced energy may all effect such a change.

32_3.0 Tools

LSS201: Forced entry tools produced by Sigma. Courtesy of Ian Bauchop.

The definition of a "tool", in the context of destructive or forced-entry, is often elusive because many common implements can be used for such purposes. Burglars are quite adaptable and inventive in such regard. Our discussion shall examine and survey those tools that have been designed to apply different kinds of force described in the previous section. There are many tools specifically produced for locksmiths, military, and law enforcement in order to effect a forced-entry. Others, which are commercially available to the consumer, may be readily adapted to such tasks.

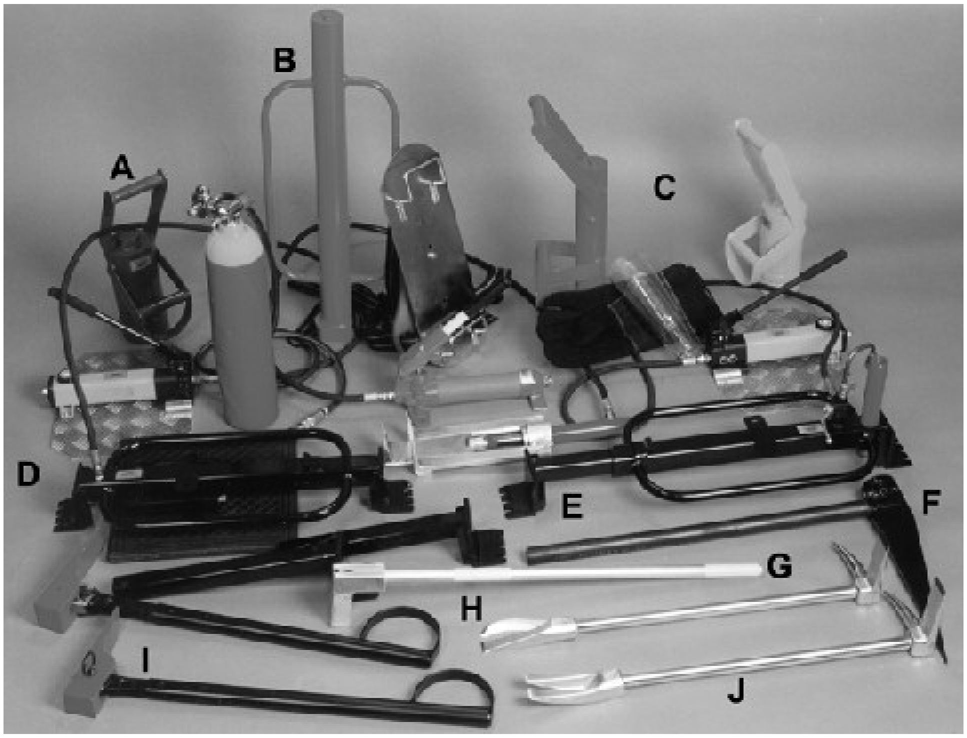




Figure LSS+3224 A sigma forced entry team shows the technique for breaching a door.

Many tools are utilized to forcibly enter or bypass a lock or security device. The more common of these include:

- **Bolt cutters;**
- **Channel-lock pliers;**
- **Chisel;**
- **Crowbar;**
- **Cylinder wrench;**
- **Disc cutters;**
- **Drill-rigs, including vacuum, magnetic, and snap-on;**
- **Drills;**
- **Drills made or coated with carbon, chromium, tungsten, and carbides;**
- **Duckbill tool;**
- **Grinding wheels and grinders;**
- **Hole-saws;**
- **Jamb-spreader;**
- **Jimmies in various lengths;**
- **K-Tool;**
- **Laser-cutter;**
- **Levers;**
- **Nail-puller;**
- **Piercer;**
- **Pry bar;**
- **Punches, ice pick, chisel, awl;**
- **Pulling-tools, including slam-hammers, dent pullers, and nose-pullers;**
- **Sledgehammer and dead-hammer;**
- **Wedges;**
- **Wrenches, including plumbers wrench.**

A destructive entry tool or device will act upon materials in different ways, depending upon its design and the resultant concentration of energy. The following discussion will detail the various methods that a tool or process employs to compromise the security of a device or enclosure.



Figure LSS+3231, an attack on a file cabinet safe with a variety of tools.

32_3.1 Shearing or Cutting

One of the favored modes of entry is to shear or cut the barrier or protective material. Shearing and cutting of materials can be accomplished in many ways to include:

- **Drilling**
-

- Cutting
- Sawing
- Filing
- Grinding

Tools that are capable of shearing or cutting generally require the application of pressure between two edges, simulating the action of a scissors. Drills are included within the definition because they perform their task by cutting.

32_3.1.1 Drilling

Drilling is probably the quickest and most effective way to compromise a security device. A thorough explanation of how a drill cuts metal is presented in **Chapter 5**. The use of drills to penetrate barrier materials in safes is described in **Chapter 35.** A drill is an extremely complex cutting device that requires precision design in order to work properly. They are engineered

to cut various materials based upon hardness rating. In order to penetrate hardplate and specially designed barriers, drills must be capable of operating at extremely high temperatures and pressure. They are made from or contain carbon steel, cobalt, chromium, tungsten, and diamond. Historically, locks, locking devices, and related mechanisms have been protected from drilling by the use of various barrier materials and other techniques. These include:

- **Layers or laminations of steel plates, or iron laced with hard studs to snap drill tips;**
- **Free-rotating hardened discs;**
- **Case-hardened plate;**
- **Insertion of beryllium and copper plates to act as a heat sink. Drilling is frustrated because heat must be generated at the drill tip in order to penetrate hard metals. Heat sinks quickly draw high temperatures away.**

The first drills that were capable of penetrating dense materials were invented at the end of the nineteenth century and were designed to function when red-hot. Since their introduction, a tremendous amount of engineering has produced improvements in metallurgy, speed, pressures, operating temperatures, and ability to cut different materials.

The **core drill** was popular for a brief period and was used in both the construction industry and by safe technicians. It was originally designed to make large holes through concrete. The drill bit was actually a tube, measuring from one to nine inches in diameter, with diamond or carbon chips embedded around the rim. The water or air-cooled tube was attached to an electric drill motor and operated at high speeds. Standard **high-speed drills** tipped with special materials are utilized to make precise holes in safes and lever locks. They are equally useful in the neutralization of pin tumbler locks, by creating a new shear line or allowing removal of the plug.

32_3.1.1.1 Drilling Pin Tumbler Cylinders

Situations dictate that a cylinder must be drilled when picking or impressioning is not possible. Several techniques are available for compromising a cylinder by drilling.

32_3.1.1.1.1 Rotary Pick

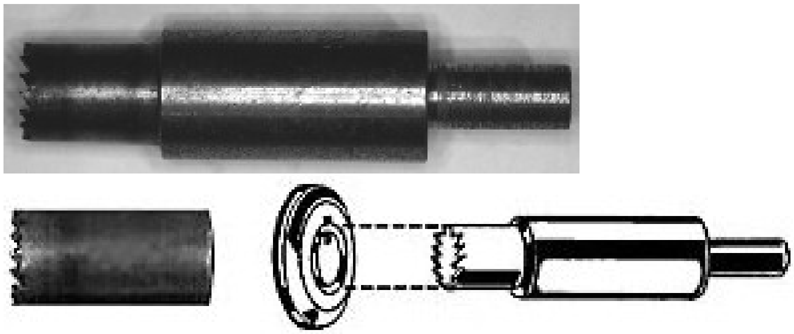


Figure LSS+3243 HPC produces a hole saw specifically designed for cylinders and axial locks.

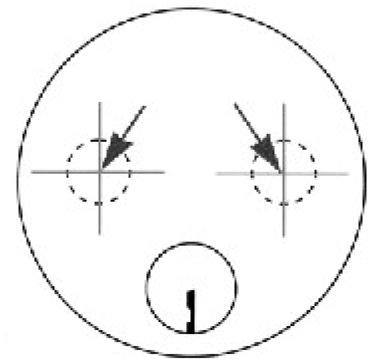


Figure LSS+3232 (ISP 35-3529)
A hole saw can be used to ream out the entire plug.

Referred to as a rotary pick, a large drill bit can destroy an entire plug. The drill is almost the same diameter as the plug and is utilized as a reamer to remove all metal that blocks rotation of the cam.

32_3.1.1.1.2 Retaining Screws

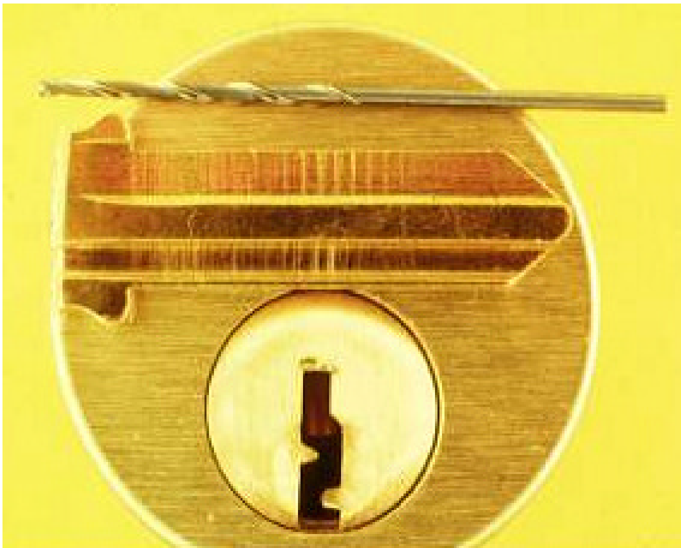
Cylinder drilling jigs are available that are designed to fit over a fully inserted key blank. The retaining screws on rim cylinders can be drilled; the cylinder is simply rotated counterclockwise and removed. Holes can also be made above and below some cylinders to allow manipulation of the bolt works.

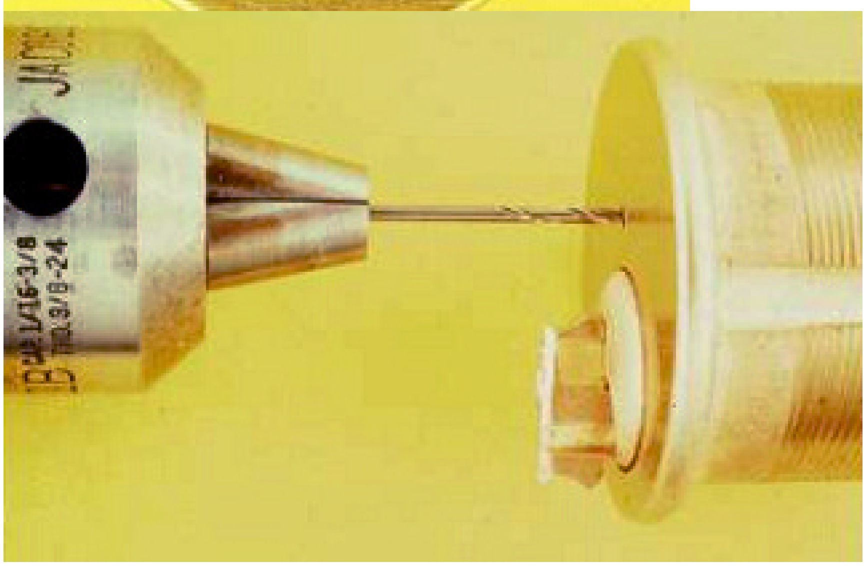


32_3.1.1.1.3 Shear Line

There are three primary means for drilling a cylinder in order to effect bypass.
Using a 3/16” or smaller bit, the face of the cylinder is penetrated immediately below the top of the plug. The bit is placed above the centerline of the keyway, as shown in the photograph below and even with the circumference of the plug to create a new shear line. The bit must be run across all pin chambers.

Another variation of this procedures requires that a key blank be inserted prior to drilling in order to engage all of the lower pins, and raise them to their highest point in the plug. This will engage all of the driver pins, placing them above the plug, or at shear line. A drill is then inserted just above shear line, which will create a new break point, by virtue of splitting each of the drivers. Once the cylinder has been penetrated and all pins have been cut, the key is removed. The plug is then rotated.





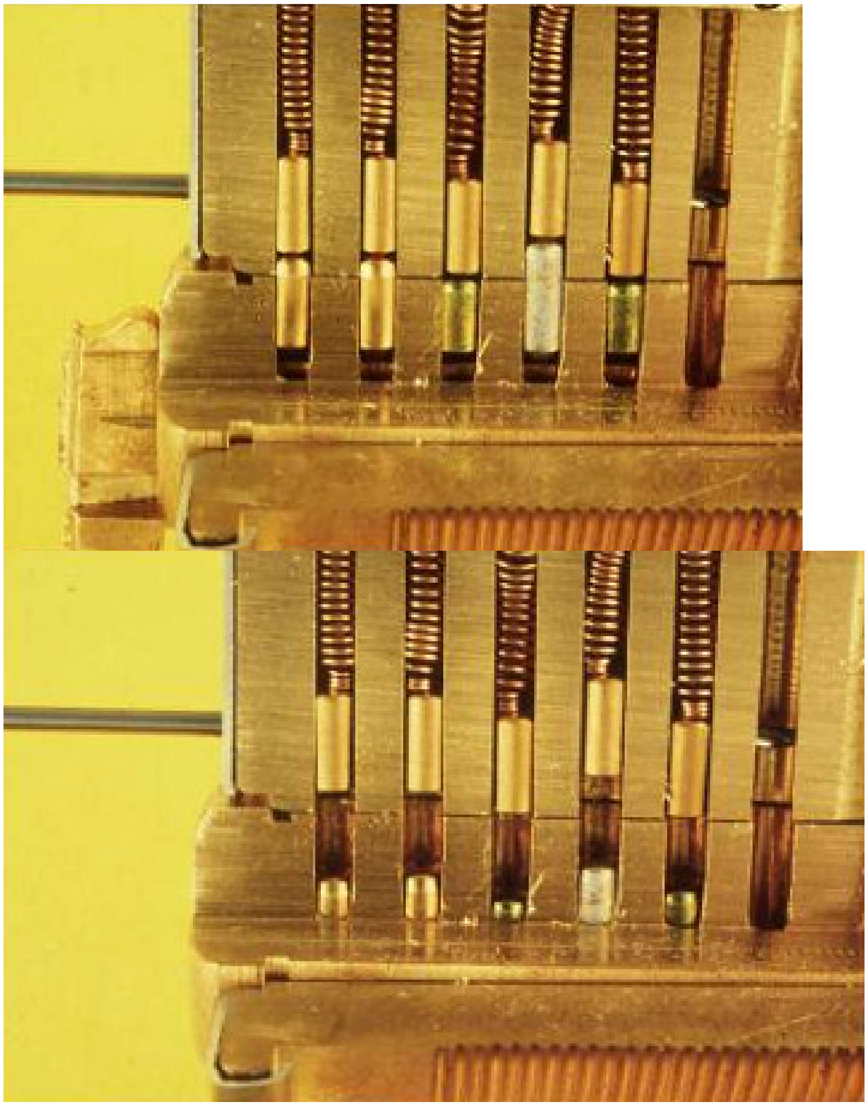
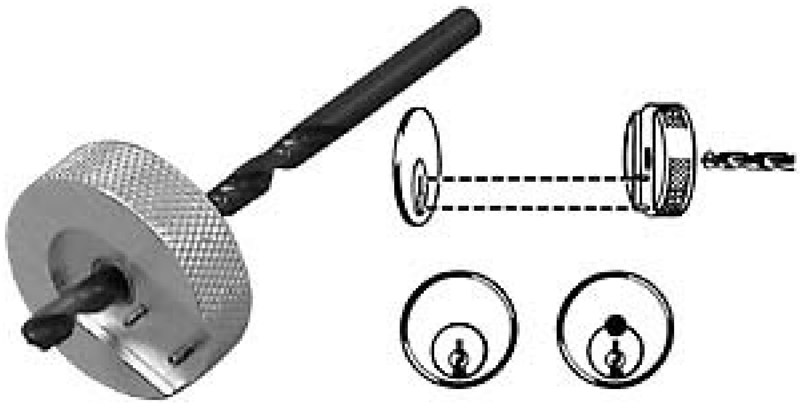


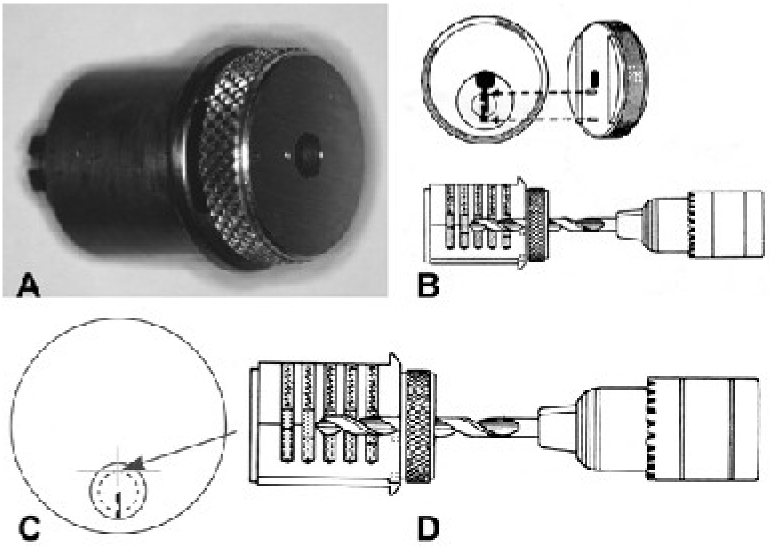
Figure LSS+3244 A blank key is inserted prior to drilling in order to raise all drivers to a position at or above shear line. Then a drill bit is run across all chambers. The blank is removed and the pins allowed to fall into the lower chamber, The plug can then be turned. Courtesy of Medeco.

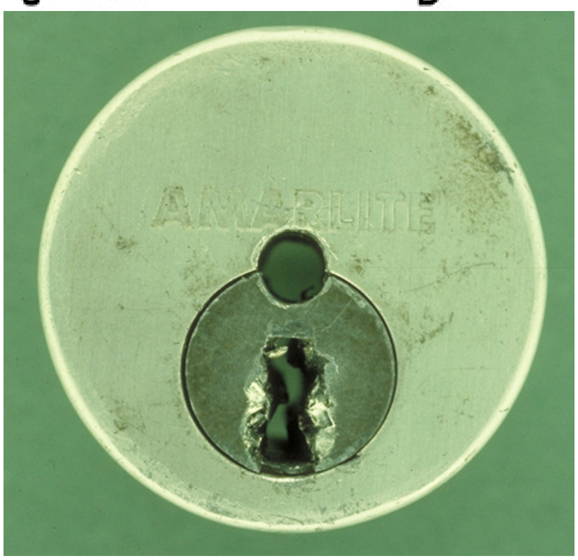
Another technique requires a very fine hole to be drilled precisely at shear line, just to the first pin chamber. A shim is inserted and fed through each break point between pins, as they are raised with a pick. This is the exact reverse procedure that is described elsewhere in this text for shimming open a lock from the rear of the plug.








A
B
C
D





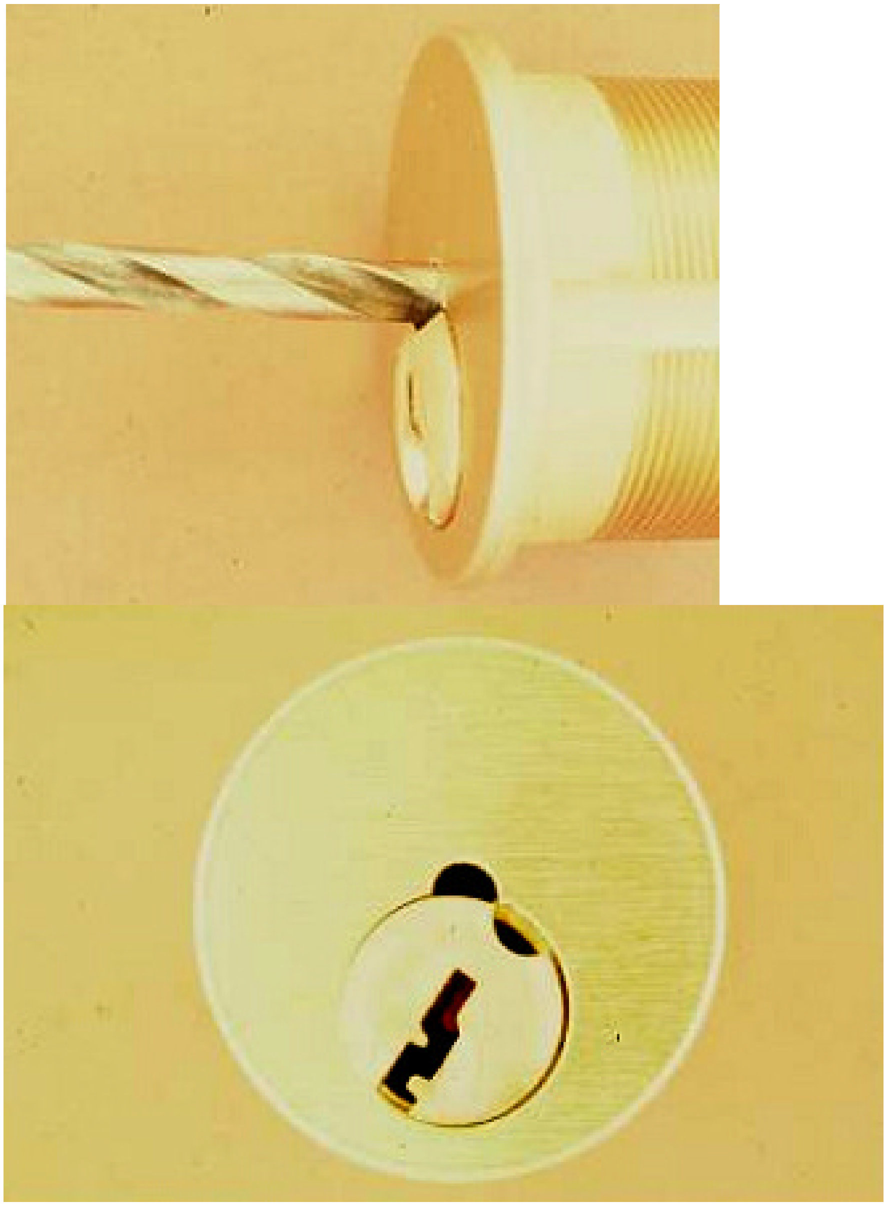
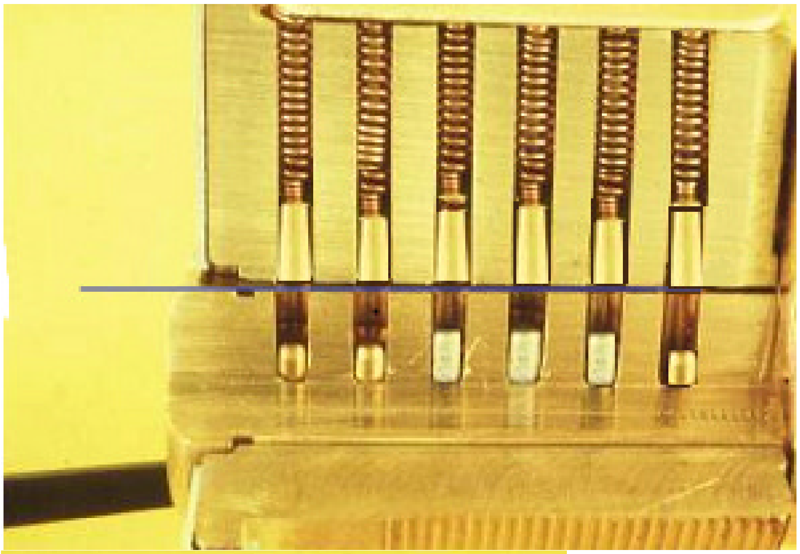


Figure LSS+3245 A lock can be drilled to create a new shear line. Courtesy of Medeco.

Figure LSS+3233 (ISP 33-3529 center, 34-3529 right). A new shear line is created by drilling the plug. A shim is inserted through a small hole drilled at shear line to the first pin chamber. The blue line indicates the shim, showing how the drivers are split from the lower pins, thereby allowing the plug to rotate. In such attacks, the hole may be repaired and an examination of the internal plug may be required. A pick (shown lower left) is utilized to raise each of the pins from front to back.





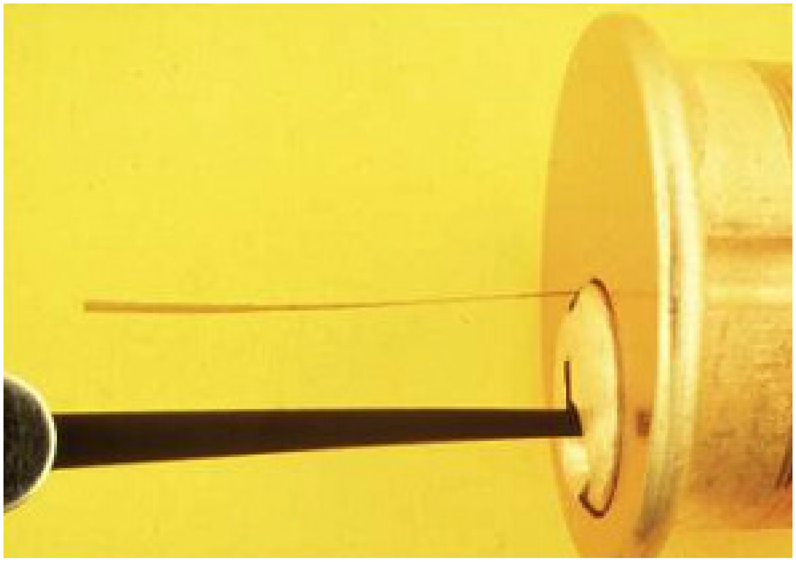


Figure LSS+3246 A lock can be drilled and then shimmed. Courtesy of Medeco.

The **HPC CDJ-1** is a tool to drill pin tumbler cylinders. The bit is maintained perpendicular to the face of the lock while drilling. As much of the broken pins and springs are removed as possible, then a screwdriver is utilized to rotate the cam. Other drills have been designed for opening axial pin tumbler locks, although they should not be used if the mechanism contains hardened pins or ball bearings in the keyway.

A patent was granted to Watts in 1999 for a technique involving raising all lower pins within a lock, then drilling of the plug (**5987946(355)**). A similar patent was issued to Randall in 2000 for a technique to open padlocks through the use of a drill (**6151936(356)**). A similar patent was granted to Smith in 1998 (**5713225(357)**).

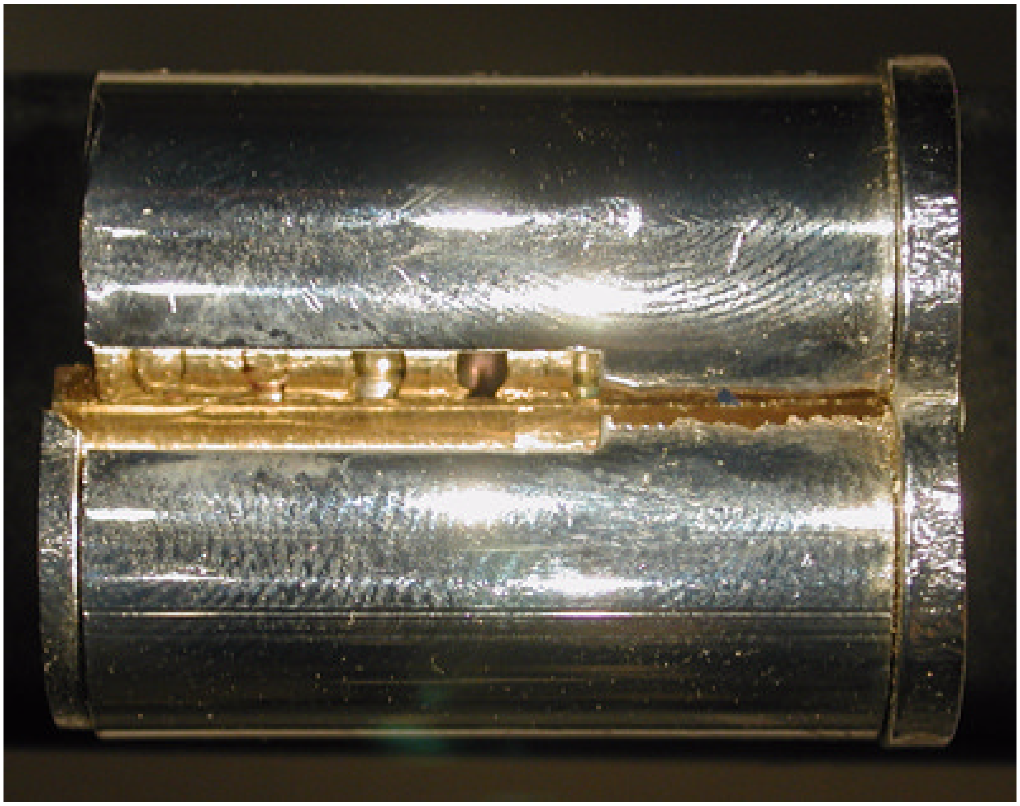
European profile locks are drilled at the bottom of the cylinder in order to destroy the pins at the shear line. Many of these locks incorporate hard pins and bearings to protect from this form of attack.

32_3.1.1.1.3.1 Removable Core Locks: Drilling the Control Lug

Peterson Manufacturing(358) produces a unique drill jig (IC-DJ) for removing the control lug from interchangeabe core locks. This procedure allows removal of the core without any damage to the shell. As shown in the photographs, the jig is utilized with a

key that acts as a guide for the drill points. All small format cores can be drilled.





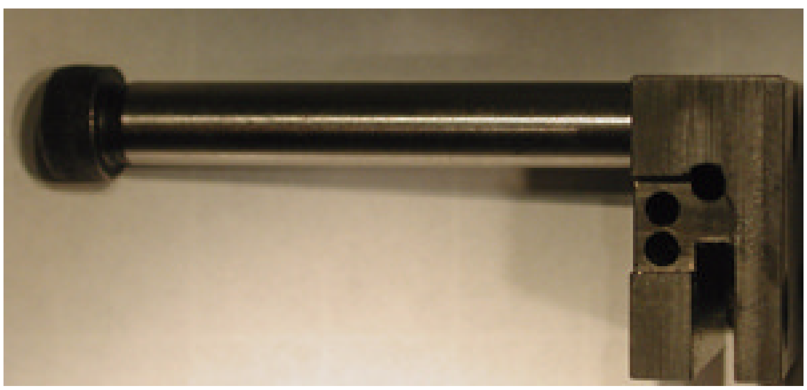
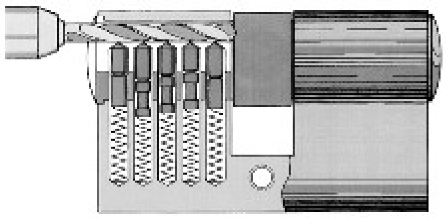


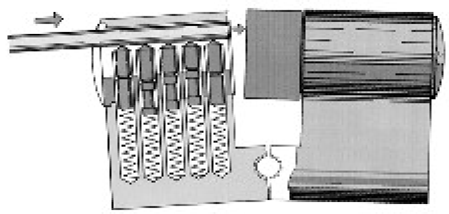
Figure LSS+3247 Peterson Manufacturing IC removal tool

32_3.1.1.1.4 Drilling to Break Apart the Lock

Profile cylinders can be drilled above the pins in order that a piercer or rod can be inserted. Their purpose is to exert force sufficient to shear the thin metal that connects the inner and outer cylinders. It is then a simple matter to move the inside lock out of the way. A two-piece breaker kit is available for removing plugs. The kit consists of a drill guide and hardened

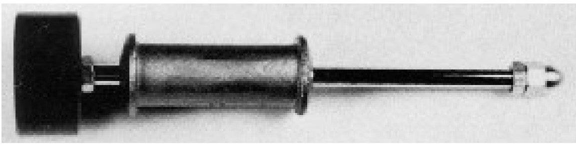
bit, together with a special handle. The plug is first drilled, then the cylinder is twisted and removed.





32_3.1.1.1.5 Dent-Puller or Slam Hammer

Cylinders are often drilled in order to insert a metal screw into the keyway. A slam-hammer, dent-puller, or other device is then utilized to violently withdraw the plug.



32_3.1.1.1.6 Hinge Screws and Pins

Hinge screws are often drilled as a common practice for entry to safe-deposit boxes.

32_3.1.1.1.7 Viewing Lever and Wheel Pack

Templates are available for many lever and combination locks to show precisely where to drill. This will provide a view of levers or tumblers, the location of relockers, and bolt works.

32_3.1.2 Cutting, Sawing, and Grinding

The operations of cutting and sawing utilize the same implements. A wide array of tools are available, both commercially and for the consumer. In addition, torches may be successfully employed as cutting devices.

32_3.1.2.1 Disc Cutter

The **disc cutter** is an extremely simple yet effective hand-carried device for penetrating almost any material. Abrasive grinding disks up to a foot or more in diameter are rotated at high speed

and engaged against the barrier material with pressure.

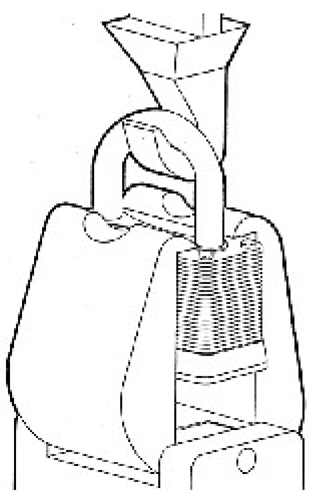
32_3.1.2.2 Laser and Water Cutters

Laser and water cutting tools are available that can sever many different materials. Lasers utilize focused coherent light beams to create extremely high temperatures in a very small area. Power consumption requirements limit the ability to produce a portable laser cutter. However, many manufacturers utilize industrial lasers to obtain .005" or better tolerance between doors and bodies of safes and vaults.

Water jets can also be successfully utilized to cut and penetrate metals. Essentially an abrasive process, a finely focused stream of water is directed in a cutting path.

32_3.2 Tension, Stretching, or Pulling

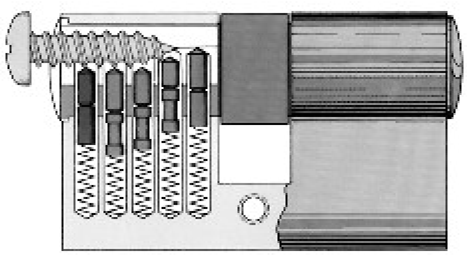
There are many techniques to pull cylinders and plugs from their housing. All rely upon the application of force that will overcome the tensile strength of the core materials. In the case of a pin tumbler cylinder, the pins must be sheared or the surrounding material must fail under stress in order for a plug to be released.



Extreme pulling force applied to a mortise cylinder may result in the shearing of retaining screws or stripping of threading on the lock body. Profile cylinders can be forcibly removed by breaking loose the retaining screw that holds the assembly within the security housing. The following tools and techniques are the most popular and direct methods for removing plugs and cylinders.

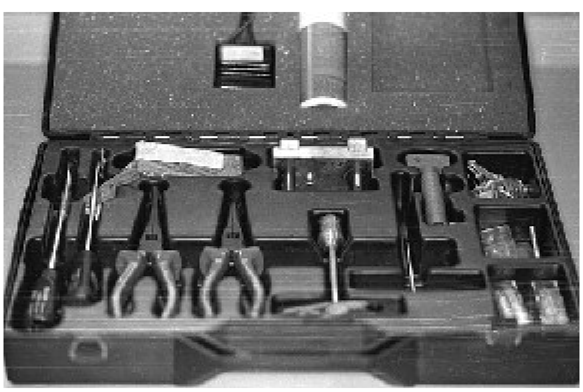
32_3.2.1 Nail-Puller

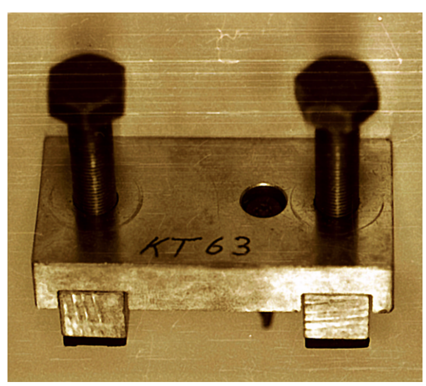
A plug within a cylinder or a profile lock can be torn loose without difficulty, if a metal screw is seated into the keyway and then withdrawn with sufficient force. A **nail puller** will provide sufficient leverage to remove the entire cylinder. In practice, a metal screw is first tapped into the keyway. A nail puller is then locked into place with the head of the screw, and located against the door frame. A block of wood may be utilized for additional leverage. Counterforce is then applied to rip the lock from its housing.



32_3.2.2 Dent-Puller

A dent-puller or nose-puller relies upon a similar operating principle to the slam-hammer, but accomplishes its task in a very different fashion. These devices, available from HPC, MBA, Lockmasters, and other vendors, provide a means to remove plugs, cylinders, and safe-deposit doors.

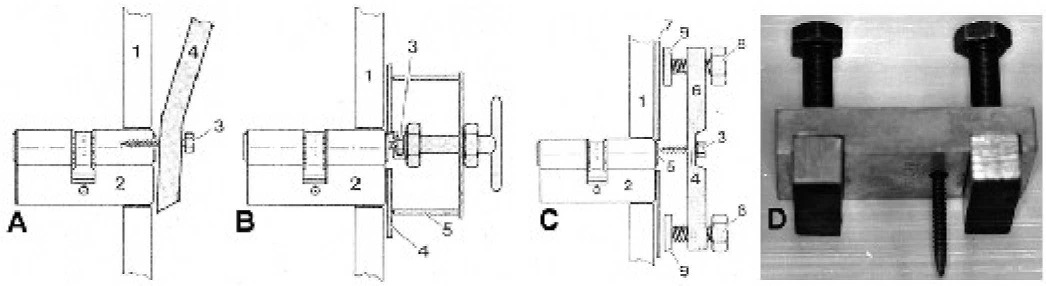




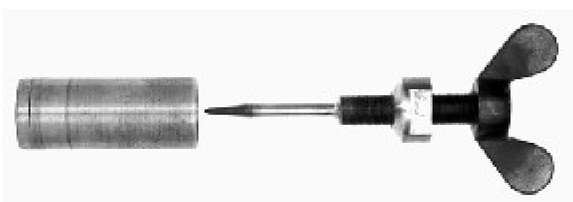
Exploded view 1, 2 3.

The underlying theory of operation relies upon the exertion of a pulling force that will exceed the tensile strength of the material to which it is attached. Like the slam hammer, the dent

puller requires that a metal screw be tapped into the target device. However, unlike the slam- hammer, slow and steady force is applied to accomplish removal, rather than a violent shock



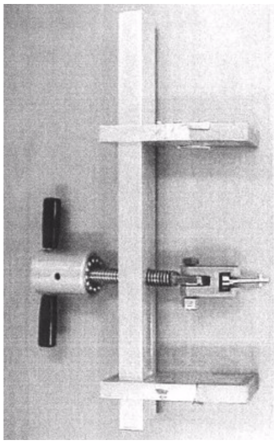
All of the dent and nose-pullers utilize a long threaded shaft that is isolated from the target with a block spacer. The active end of the device is attached to the target and a counterforce is applied by advancing a collar on the threaded shaft. As the collar is moved forward, the screw will be withdrawn an equal distance.



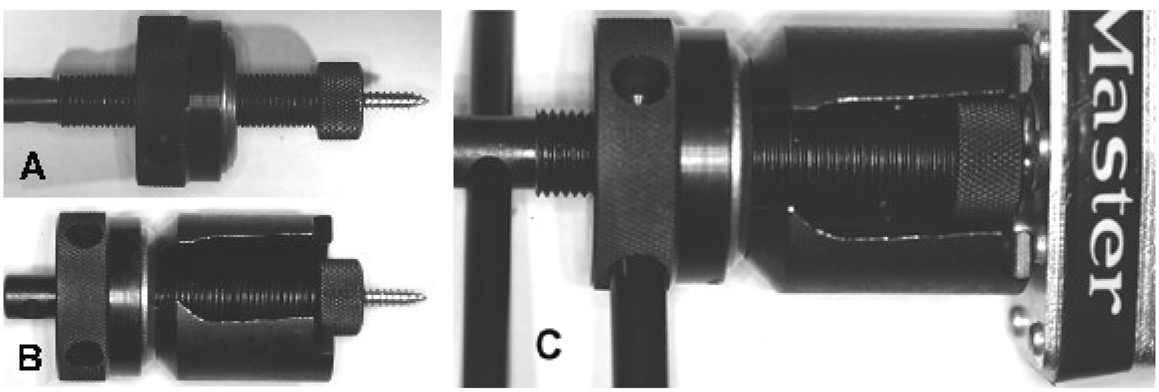
32_3.2.2.1 Safe-Deposit Nose and Door Removal







One of the primary uses of the nose-puller is to open safe-deposit boxes. Thus, a more thorough discussion of the practice is presented here. In the above photographs, over one hundred safe deposit boxes were opened in a successful burglary at the diamond exchange in Antwerp, Belgium. A tool was designed to be inserted into the lever lock portion of the door. The jig was then tightened against the supporting frame, causing the bolt to be warped to allow the box to open. The burglary, which occurred in February, 2003, netted seven thieves more than $100,000,000.



Nose pullers are typically used to open safe-deposit locks where the renter's key has been lost. Generally, a blank key is placed in the keyway to keep the nose from spinning, while a hole is made for a 10-32 machine screw, grade 5 or grade 8. If this is not possible, then a 1/8" hole is made to accept a #8 stainless steel sheet metal screw.

Once the screw is anchored firmly, the spacer block is attached, and the entire assembly tightened. The shaft is then slowly

retracted to extract the nose. Once access to the levers is obtained, they can be manipulated into alignment in order to withdraw the bolt. In certain cases, the door must also be pulled. Depending upon the design of the tool, one or more contact points will present pressure against the inside of the door, where the nose was originally positioned.

The use of the nose puller, courtesy of Harry Sher.

32_3.3 Pounding, Driving, Prying, Fracturing

Poorly designed hardware is subject to a variety of attacks from pounding, driving, prying, and fracturing components through the application of force. The photographs below demonstrate a number of weaknesses of much of the locking hardware in use today.



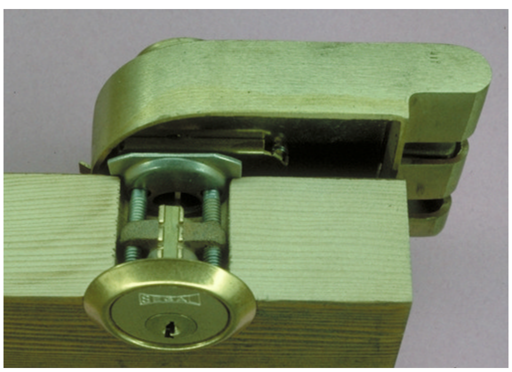
Figure LSS+3234 (ISP 14-3529 left, 15 right) The mounting for the cylinder is cast and

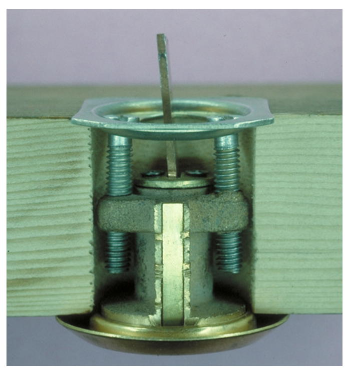
can be fractured, allowing removal of the lock.

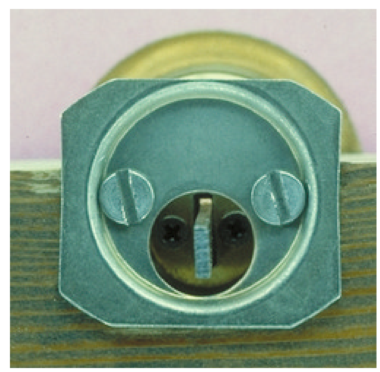




Figure LSS+3235 (ISP 16-3529 left, 17 right) Knob locks should not be used as the sole protection on exterior doors.







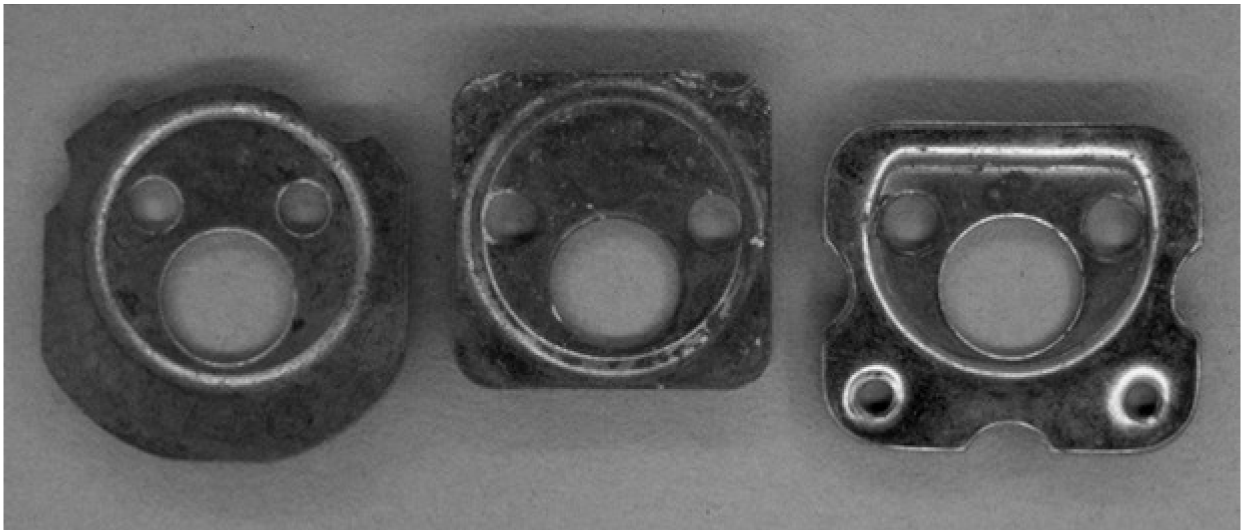


Figure LSS+3236 (ISP 22-3529 top left, 23 center, 24 right, 25 bottom). Rim locks must be mounted properly to increase their resistance to attack.



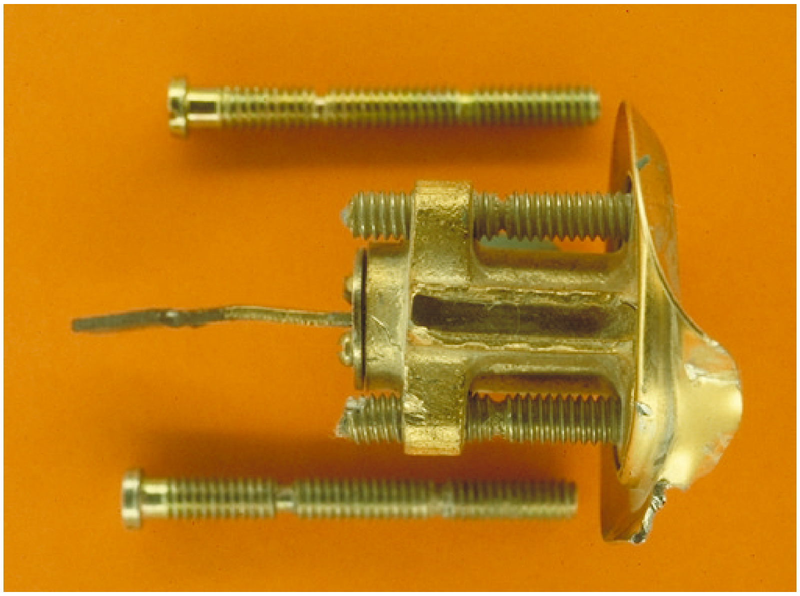


Figure LSS+3237 (ISP 26-3529 left, 27 right). Cylinders can be pried loose if not mounted properly.



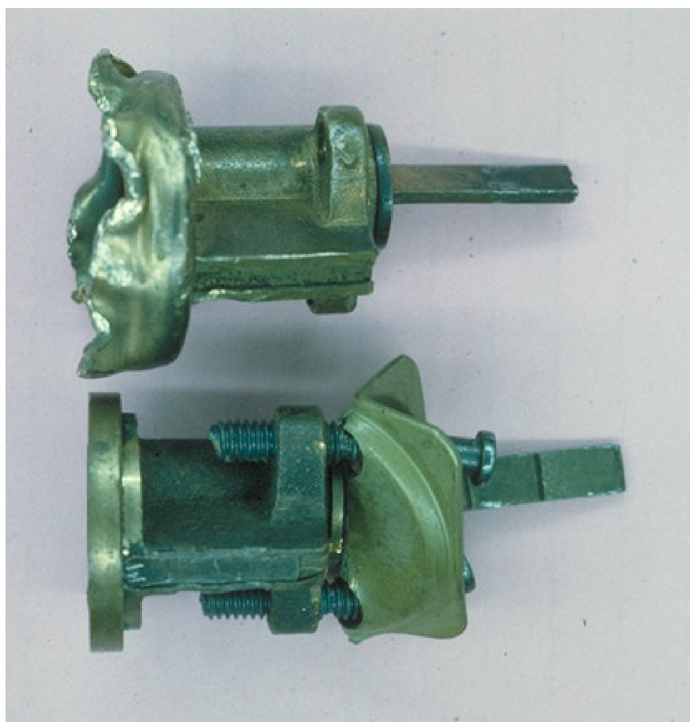


Figure LSS+3238 (ISP 28-3529 left, 29 right). In 28, the cylinder was

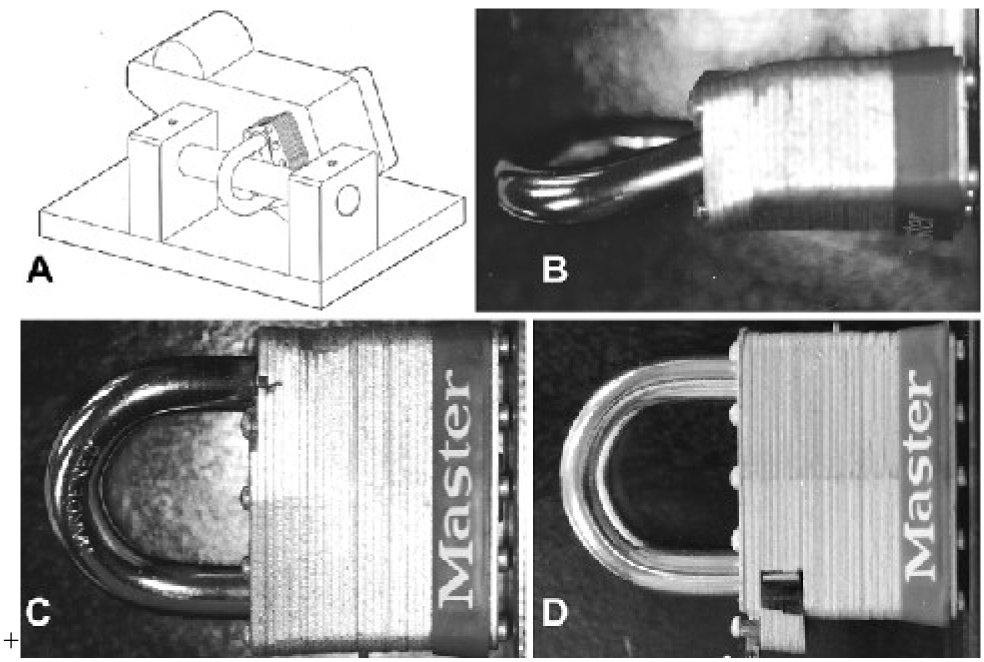
pounded through the mounting. In 29, another example of driving the cylinder through the door.

32_3.4 Bending

If a material can be repeatedly bent, it can be fatigued and fractured. Depending upon the design of the security device, it may be possible to bend or distort a locking component to allow bypass. Metal door frames are a classic example of bending to allow the bolt to pass. The design of most frames will cause the material to return to its original condition after the pressure is released.

32_3.5 Torsion or Twisting

Depending upon the physical design of a lock, locking mechanism, or housing, torsion or twisting force can be applied to break it.



32_3.5.1 Chain Wrench

A plumbers tool is quite effective in removing locks and doorknobs. Leverage is provided by a chain, linked to a mechanism that holds a pipe. In operation, it is placed around the lock and torque is applied. The chains will self-tighten and will shear the lock from its housing or anchor.

Another form of this tool can be made to remove guard rings from cylinder locks. A piece of pipe having a diameter just large enough to fit over the guard ring and cylinder is tightened with a bolt through its center. A rod is utilized to twist the end, thereby providing sufficient leverage to release the lock.

32_3.5.2 Wrench







Figure LSS+3239 (ISP 18-3529 left, 20 center, 21 right). A pipe wrench can be utilized to twist loose a key-in-knob or cylinder lock.

Flush-mounted guard rings are utilized to protect cylinders from being grabbed. Without them, a channel lock pliers, cylinder wrench, or a pipe wrench may be used to free a cylinder from its housing, once a foothold can be gained. These tools will generally adjust themselves to the lock; the cylinder is then twisted and turned. The result: setscrews will be sheared or broken, or the cylinder is ripped out of the jamb.

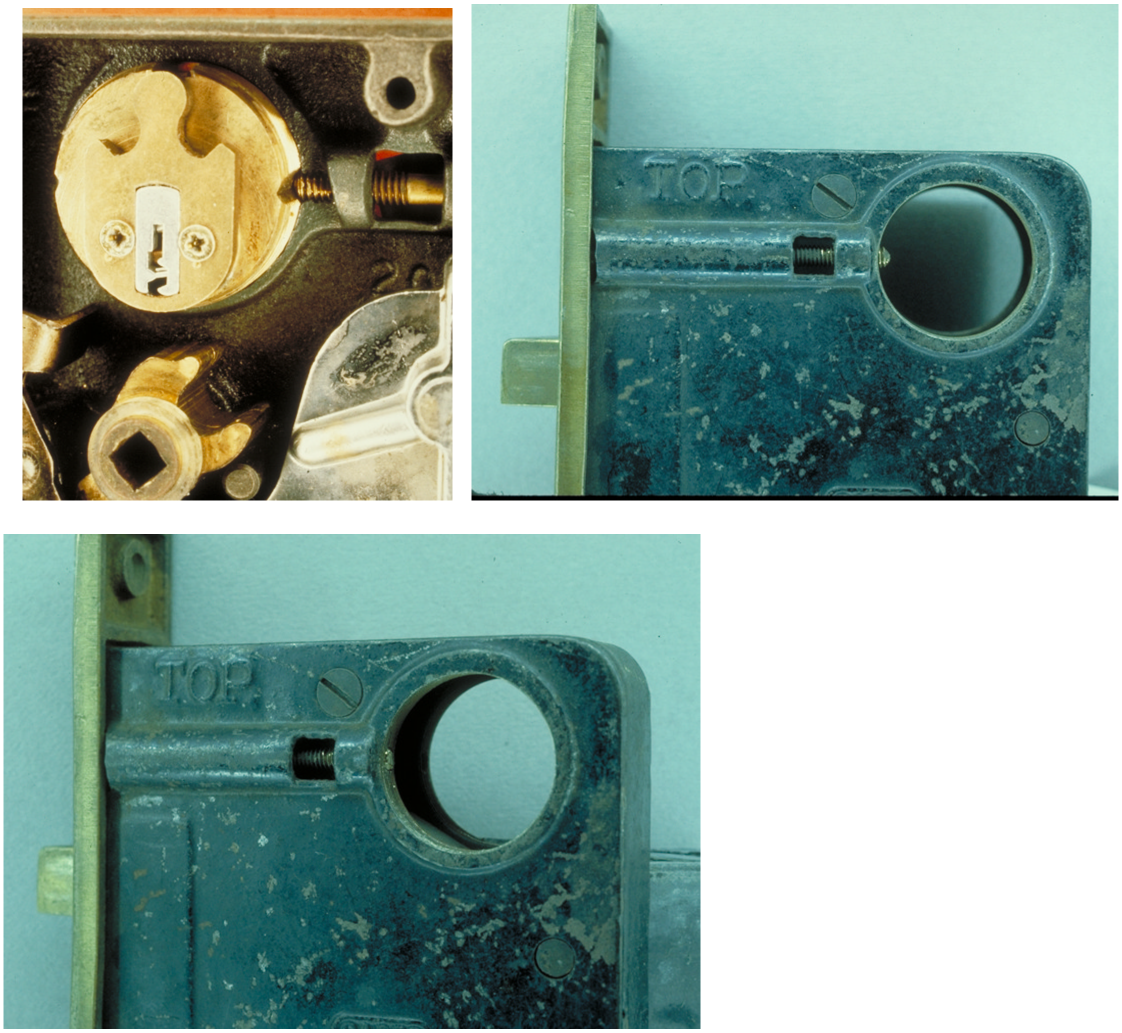


Figure LSS+3240 (ISP 11-3529 left, 12-3529 center, 13-3529 right). These series of photographs show the ease by which a cylinder can be removed by shearing the setscrew. There is little security in this arrangement. Courtesy of Illinois State Police, Bill Sherlock.

Cylinders can be forcibly removed by applying torque and destroying internal setscrews. The setscrews can also be removed during business hours to allow the cylinder to be unscrewed at a later time. Courtesy of Don Shiles.

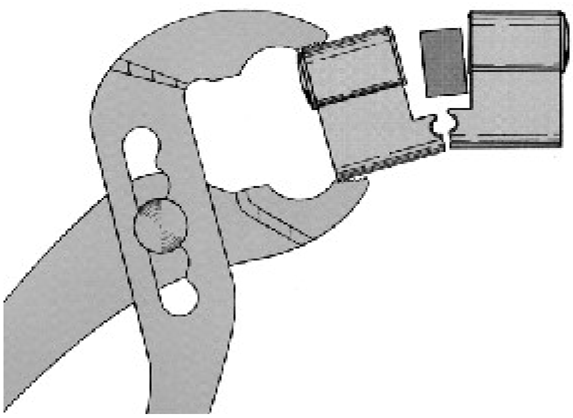
A wrench attack on cylinders can be very effective. Courtesy of Don Shiles.

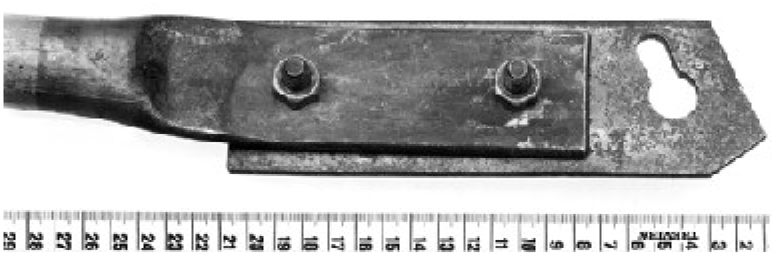
It is quite easy to wrench free a profile cylinder lock that protrudes from its housing. Once the outside half of the

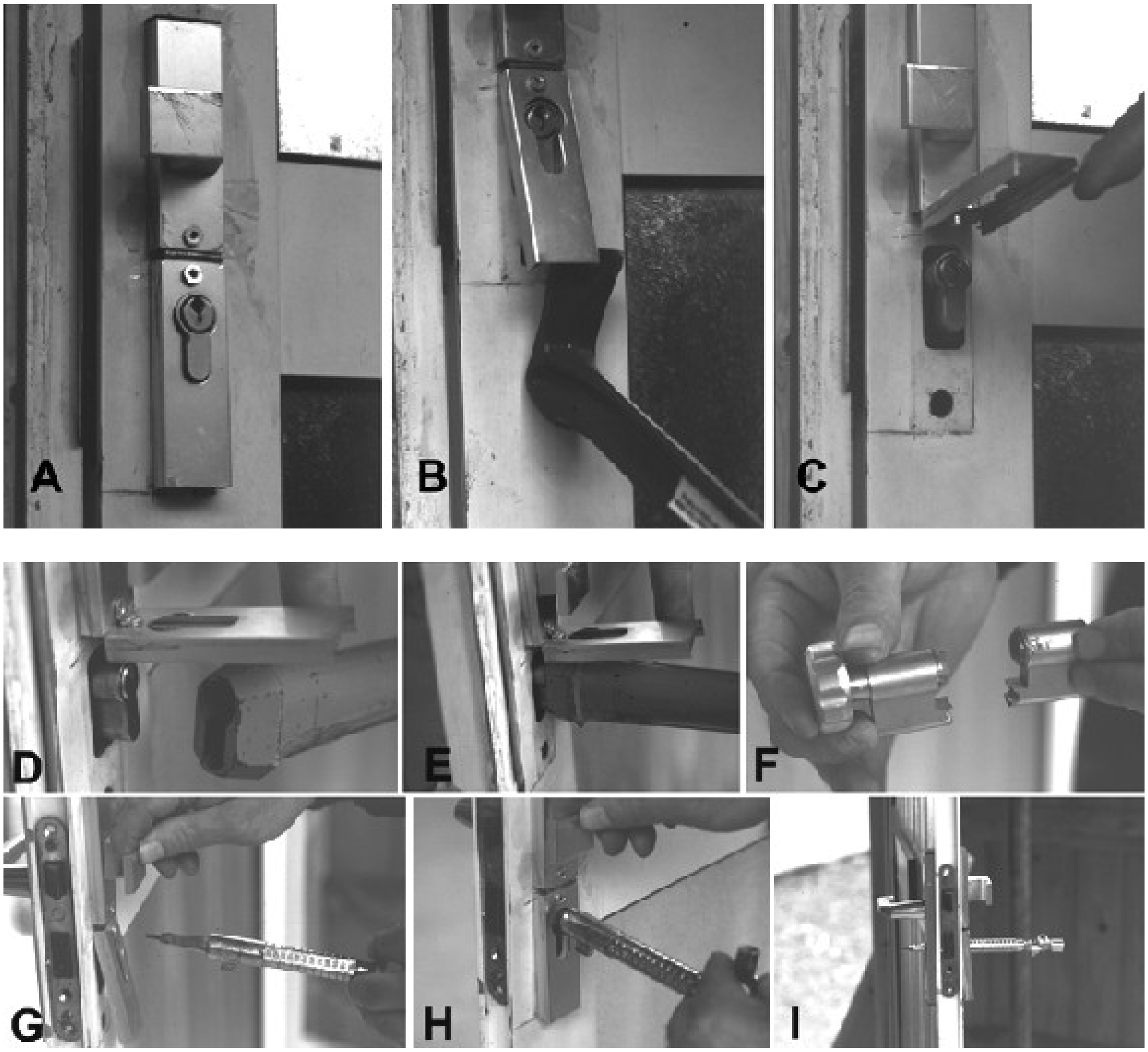
assembly has been removed, the bolt can be withdrawn with a wire hook, screwdriver, or other tool.

32_3.5.3 Profile Cylinder Removal Tool

Unless properly protected, a profile cylinder can be easily dislodged using a tool designed to provide torque or twisting force. This form of attack may be prevented by first cutting a groove into the cylinder, then installing a 2 mm thick hardened metal plate. Several companies produce tools for removing profile cylinders. Tools produced by Sigma (UK) and MSC (Germany) are shown below, together with demonstrations of their effectiveness. The tool that is produced by MSC is a multipurpose device, and can be utilized on a variety of lock configurations. It also allows the forced removal of the core.

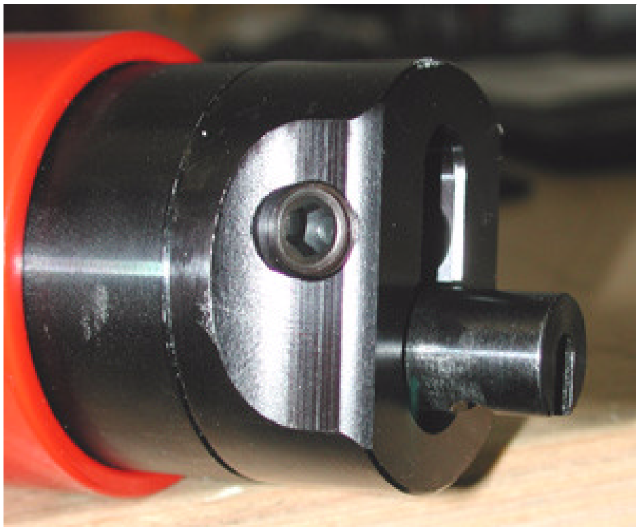






Exploded views 1, 2, 3.





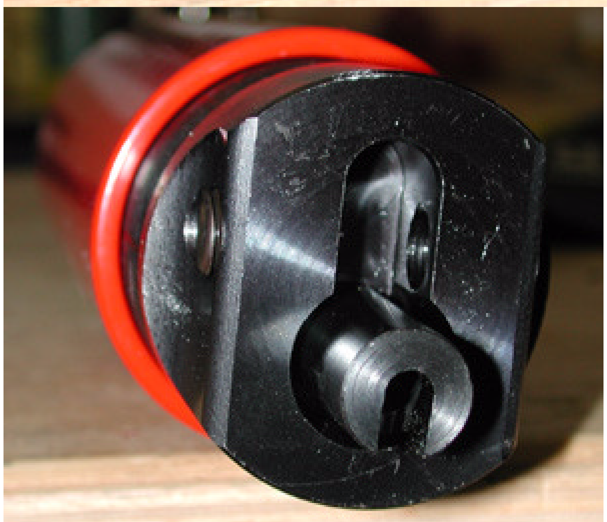




Figure LSS+3225 The MSC Lock Force tool can be used to remove profile cylinders from their housing.





Figure LSS+3226 MSC provides different dies to allow the Lock Force tool to be applied to different cylinder designs.

32_3.5.4 Core Removal Tool

LSS201: MSC Lock Force tool, courtesy of MSC

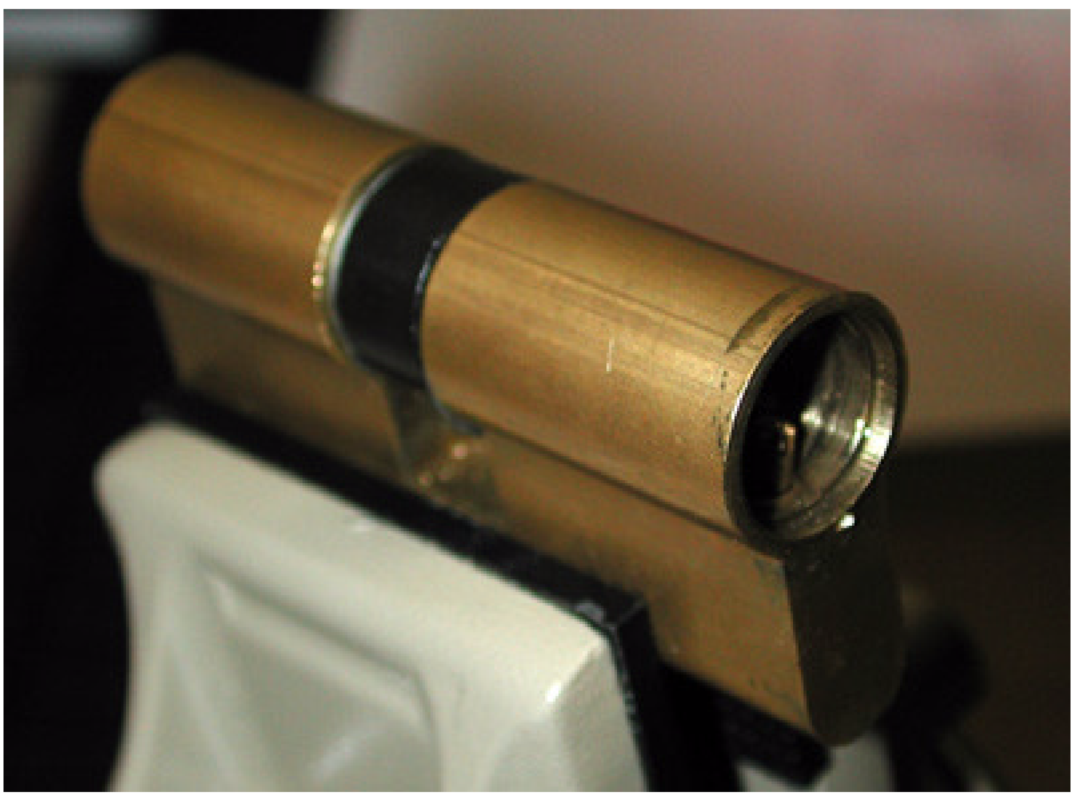
MSC in Hamburg, Germany produces a multifunction "Lock Force" tool for the removal of cylinders from their housing, and the extraction of cores through the application of reverse torque. The tool is actually a miniature dent puller, and is provided with attachments for several different profile designs.

The photographs show the extraction of a core from a profile cylinder. A special hardened screw is tapped into the keyway, then the tool is seated to the screw and reverse tension is applied. This causes shearing of the internal tumblers. A special collar is utilized to index the tool to the core. The tool can also be used as a slam hammer, as the sleeve is designed to move laterally along the internal shaft.













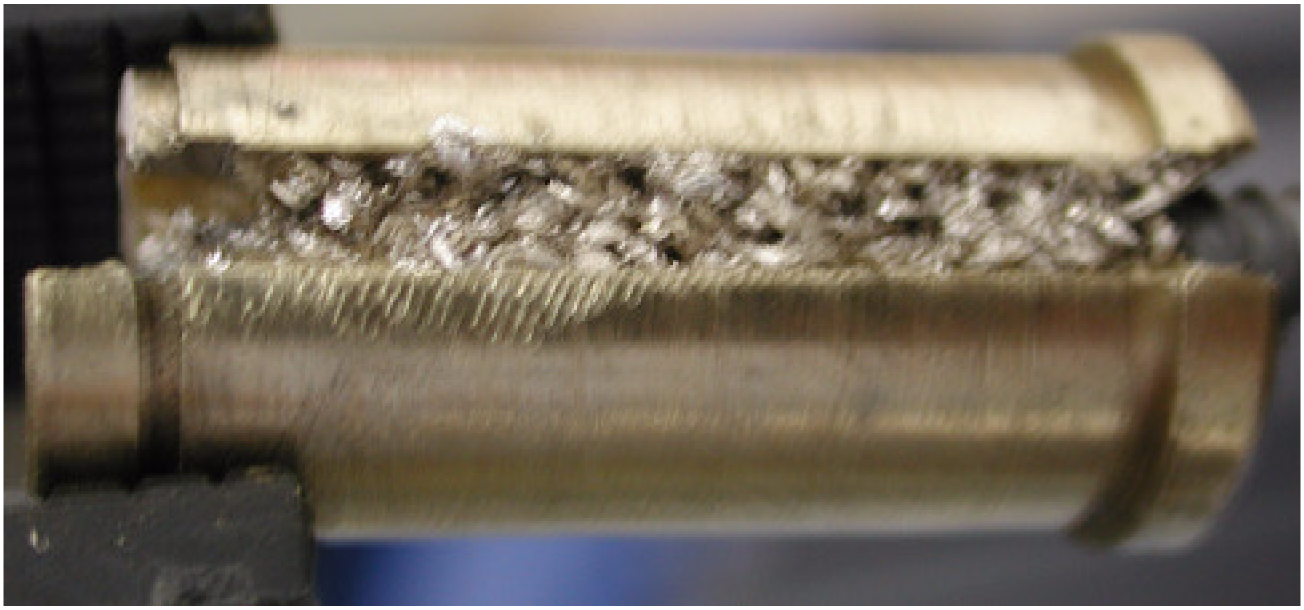
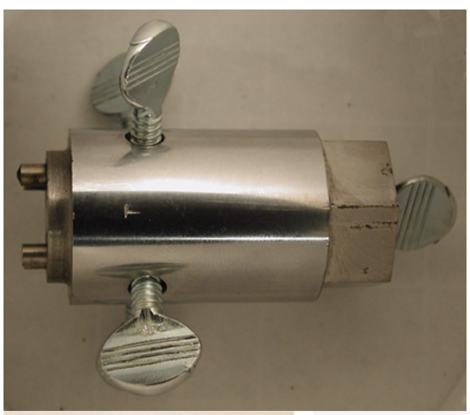
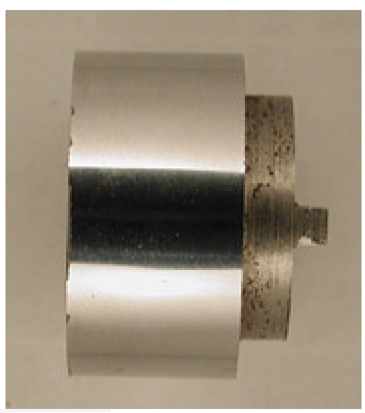


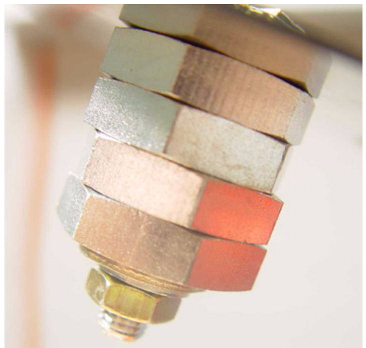
Figure LSS+3227 The MSC Lock Force tool is designed to remove a core from the shell.

32_3.5.5 Application of Torque to the Plug: Opening the Medeco Cam Lock





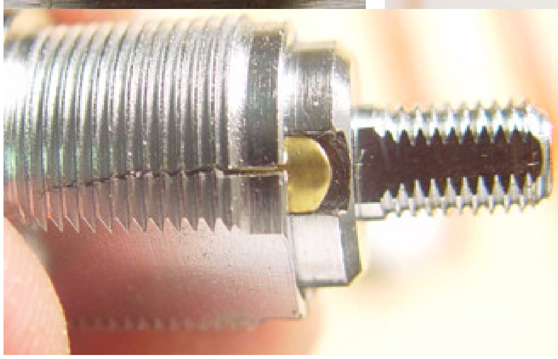
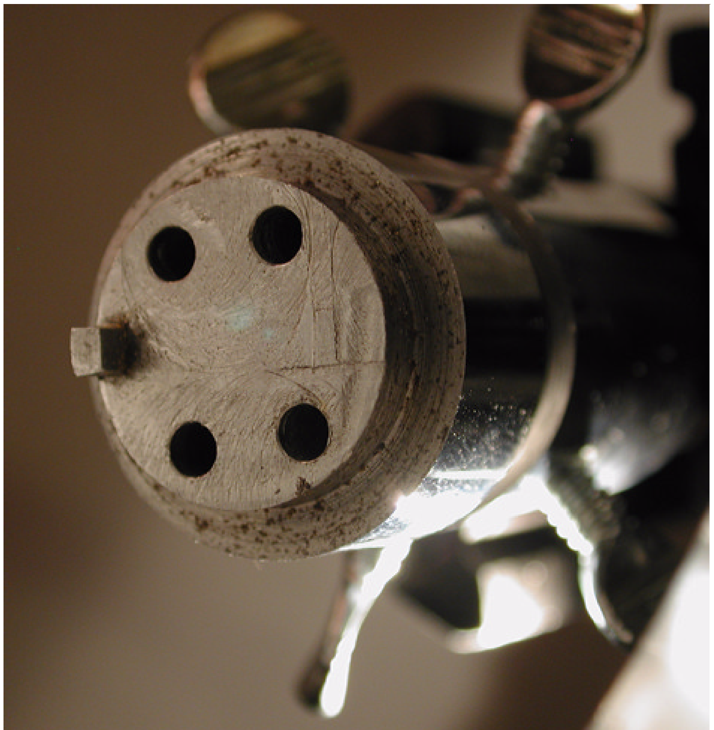
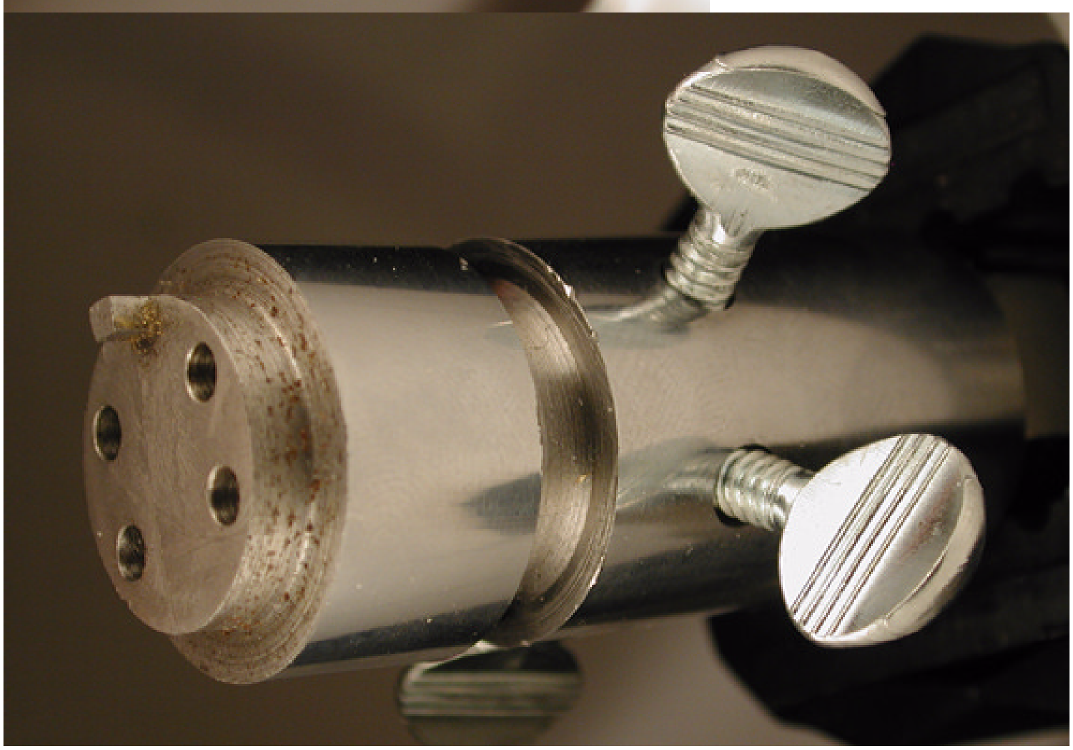


Figure LSS+3248 The Stealth Lock Systems bypass tool for Medeco cam locks is comprised of two pieces, as shown. The main body contains four hardened steel pins that link with the fact of the plug to allow the application of torque. The drill template (right) allows precise drill points to be marked on the lock. A dremel tool is utilized to create dimples that correspond to the holes in the steel template. The two pieces are linked together for ease in storage. The photographs (top right) show the back and front of the tool. The back view provides a drill template. The front shows the movable steel pins. The tool has a tendency to skip across the face of the cylinder. In the bottom row of photographs, torque was applied to a lock with nuts used for reinforcement. It can be seen that the tool allowed enough force to be linked to the shell that the housing was fractured.

A tool to open the Medeco cam lock has been introduced by **Stealth Lock Systems.** This device is a two-piece design that is utilized to mark and drill the face of the cylinder in order for the protruding pins from the tool to mate and connect with the lock. The drill points allow for the application of torque to force the plug to an unlocked condition. Although the tool will allow the cam lock to be compromised, it does so in a manner that requires replacement and effectively destroys the mechanism. This device is described in this text because of the prevalence of the Medeco cam lock and the relative ease with which it can be destroyed.





The device, which is really a sophisticated drill jig, is well made and relatively simple to use. It requires the use of the

following tools to effect an opening:

- **Dremel high speed rotary engine;**
- **1/8" shank diamond bit (small round head);**
- **1/8" drill bit;**
- **11/16" wrench.**

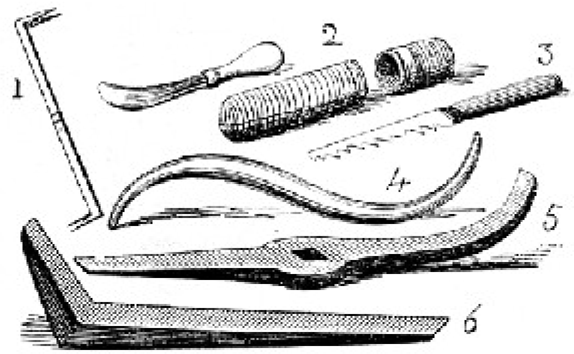
Opening a cylinder is a straightforward procedure:

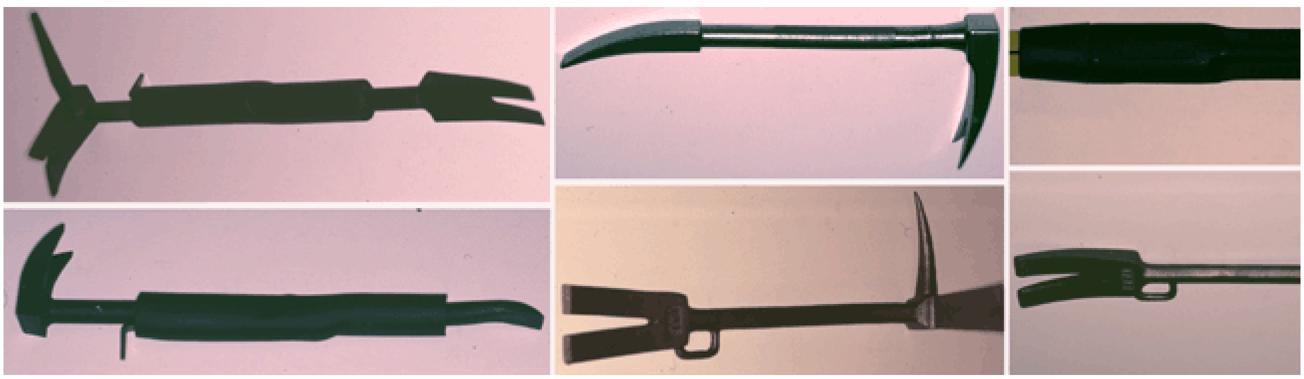
- **Separate the main tool from the drill template;**
- **Locate and properly seat the template to align it with the keyway;**
- **Insert the Dremel drill through two of the four holes of the template and use the drill to create reference marks on the face of the cylinder;**
- **Use the diamond bit to create concave depressions for each of the marks, so that the link pins can properly seat to the face of the lock;**
- **Replace the drill with the 1/8" bit and make holes no greater than 3/16" depth in each impression;**
- **Place the hardened steel pins in each hole in the tool, and link to the face of the cylinder. The thumbscrews are utilized to adjust the length of each of the pins so they firmly seat. Then apply sharp turning motions with a 13/16" wrench. The lock can be opened with the application of repeated rotations.**

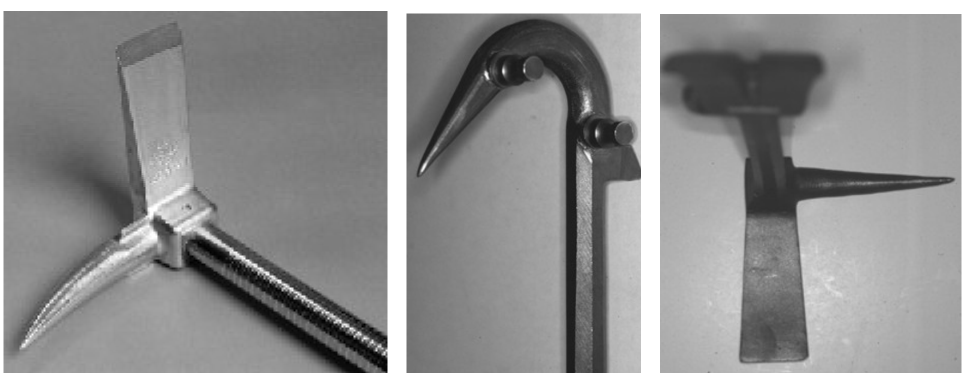
The manufacturer also produces tools to open the Tubar locks, and a line of picks for other mechanisms.

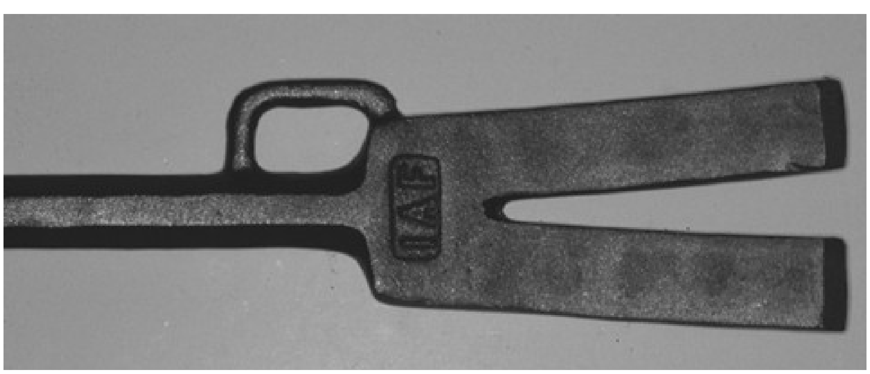
32_3.6 Opposing Forces Applied Simultaneously: Prying, Wedging, Peeling and Ripping

Many tools can be utilized to apply forces in opposing directions simultaneously in order to pry or wedge components from their normal position. Specific use is dictated by the design of the enclosure or security device.

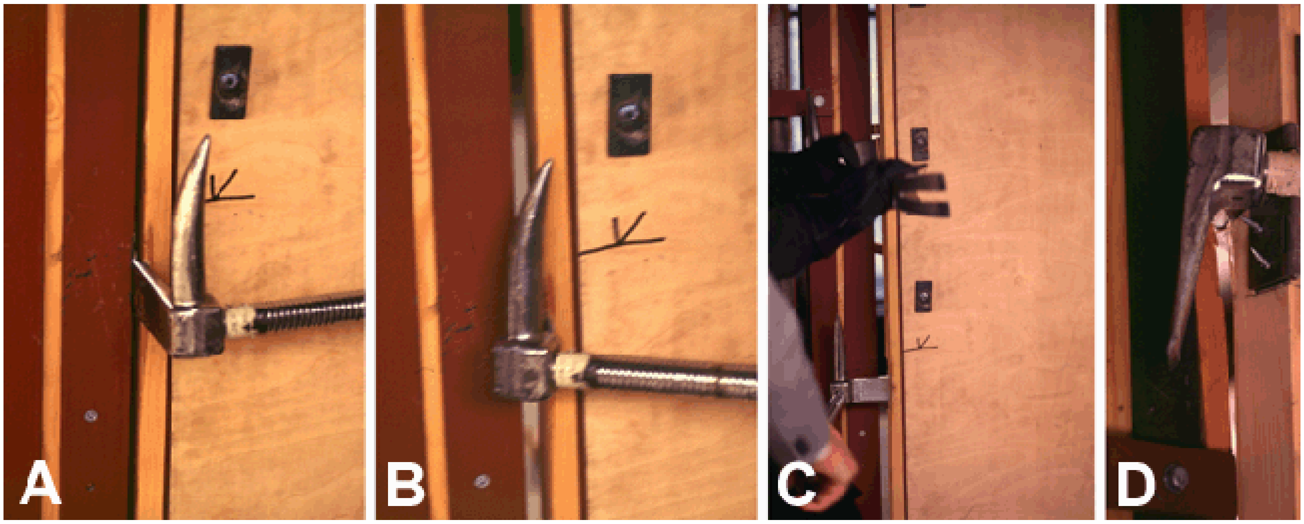








Exploded views 1, 2, 3, 4, 5, 6, 7, 8, 9.



Exploded view.

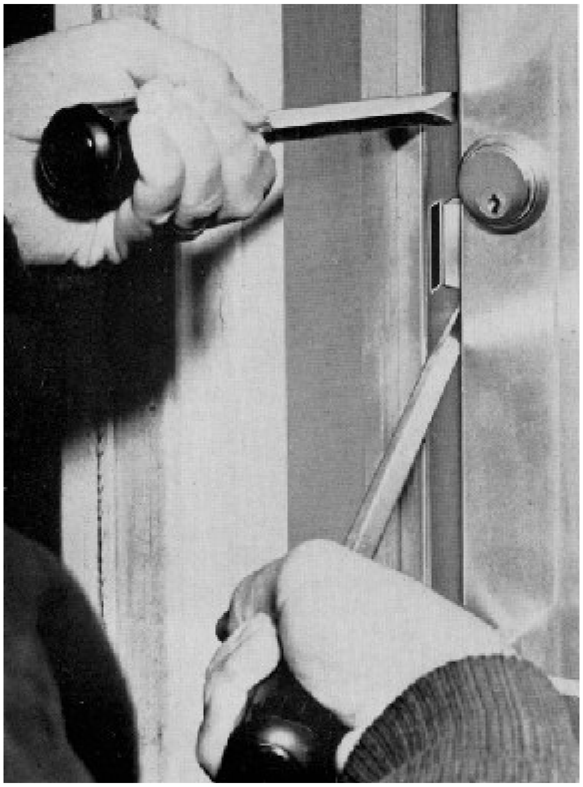
32_3.6.1 Peeling and Ripping

A technique known as **peeling** or **ripping** is popular for removing metal laminations that protect safes and vaults, generally fire safes with lightweight metal skins. The process is more thoroughly discussed in later chapters. It depends upon the use of a wedge or similar tool that will allow force to be exerted between layers of metal in order that they may be separated. The goal is to create or utilize a gap between active surfaces in order to exert force in two different directions. Length of the tool will directly affect leverage, which in turn controls the amount of force that can be presented to the metal surfaces.

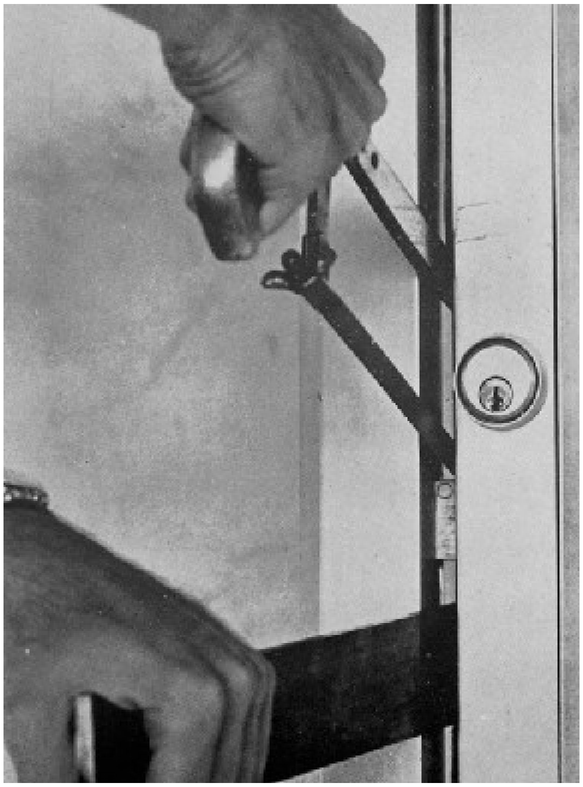
32_3.6.2 Prying and Wedging

32_3.6.2.1 Jamb Spreading or Peeling

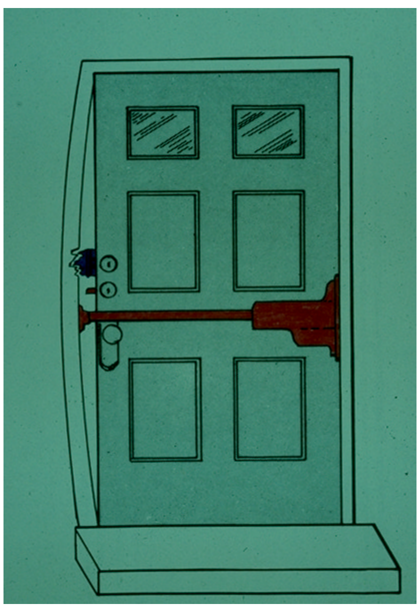
This is a technique to withdraw or displace the strike casing far enough to allow the bolt to clear the obstruction that block its movement.



Most bolt systems can be bypassed if enough of a gap is created between the lock and strike, thereby eliminating the obstruction to movement of the door. Although crowbars, pry bars and wedges may be utilized for the task, there are several hydraulic jamb spreaders available. They are capable of compromising almost any door frame with little effort.



The use of a hydraulic car jack with wood blocks is quite effective in spreading a jamb. One such device develops 4,000 pounds of pressure without any damage to the door frame. This type of spreader will not work on heavy metal frames, however.



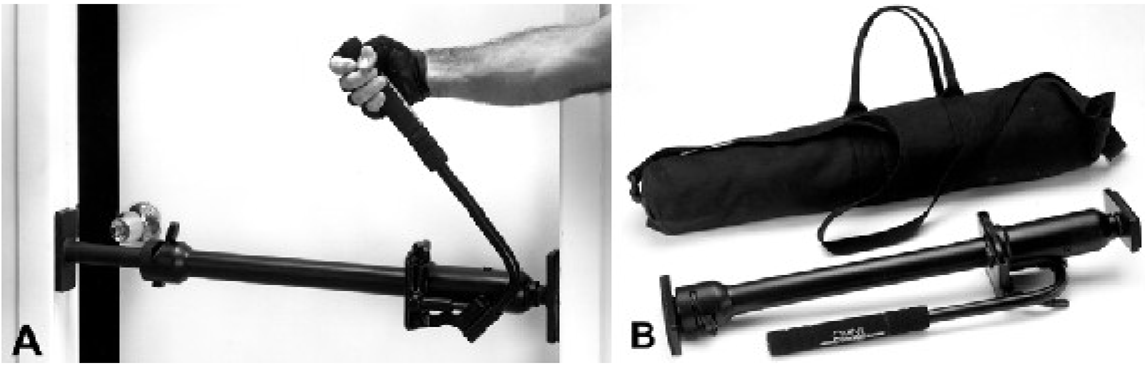
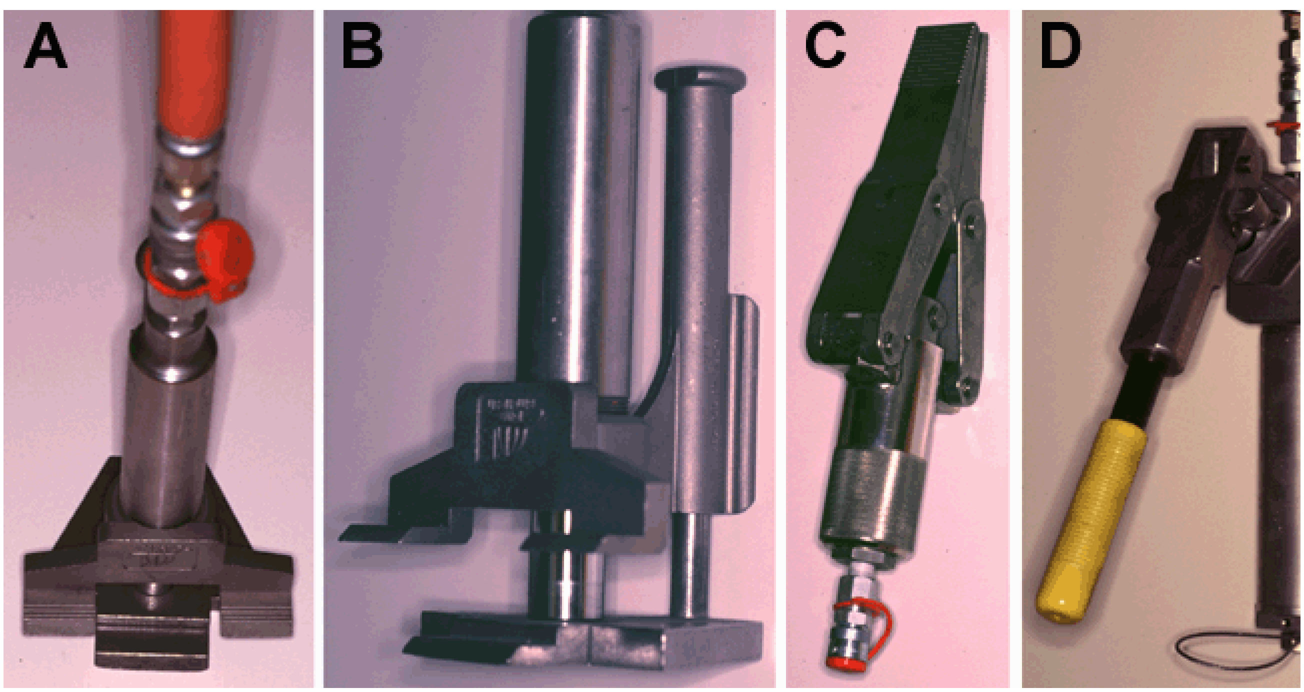
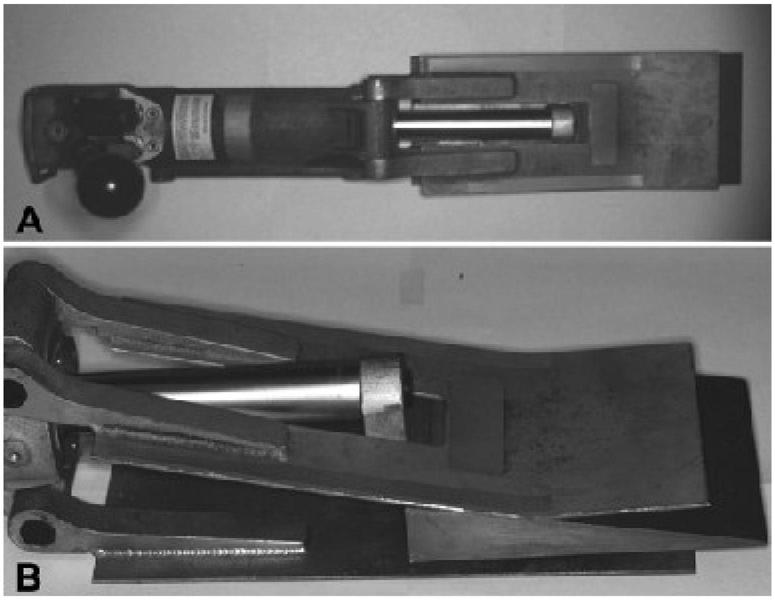


Figure LSS+3241 (ISP 39-3529) A diagram showing the principle of jamb spreading.

The **Hydra Force** and **Jaws of Life** are two other examples of jamb spreaders. Compressed hydraulic fluids or air pressure is developed by pumping and can be used to open a door within a few seconds. This type of spreader can develop 8,000-10,000 pounds of force.

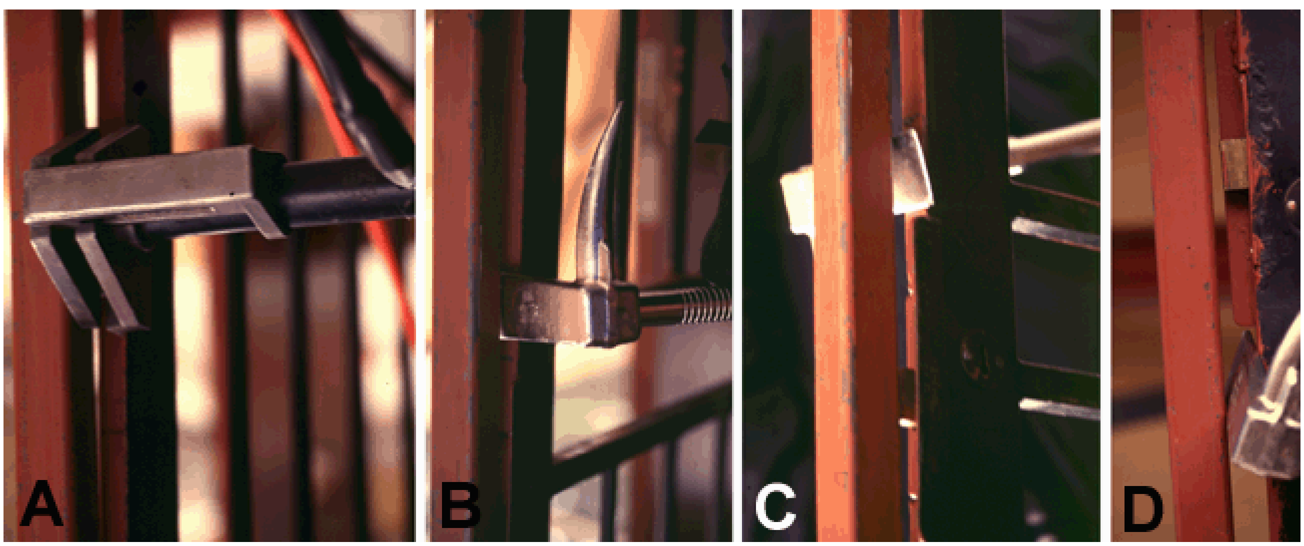


Exploded views 1, 2, 3, 4.



Exploded view 1, 2.

Sigma (UK) and Iowa American (U.S.) produce a series of hydraulic tools for rapid-entry teams, search and rescue, and paramilitary operations. Both of these companies are world leaders in the design of these tools. In the experience of the author, such devices can force open virtually any door within seconds.



Exploded views 1, 2, 3, 4, 5, 6.

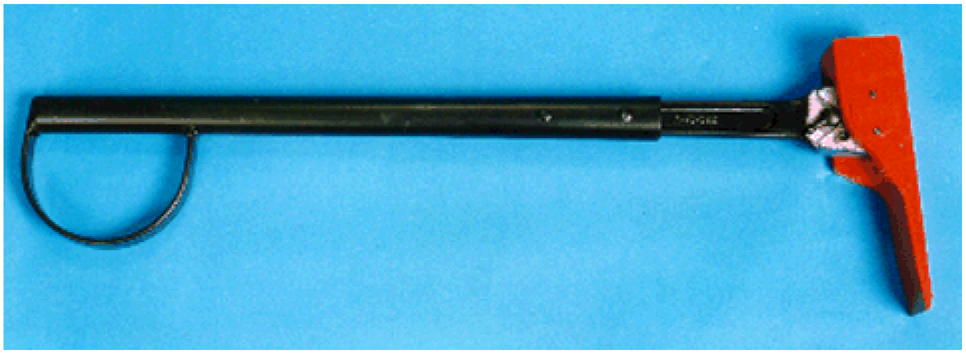
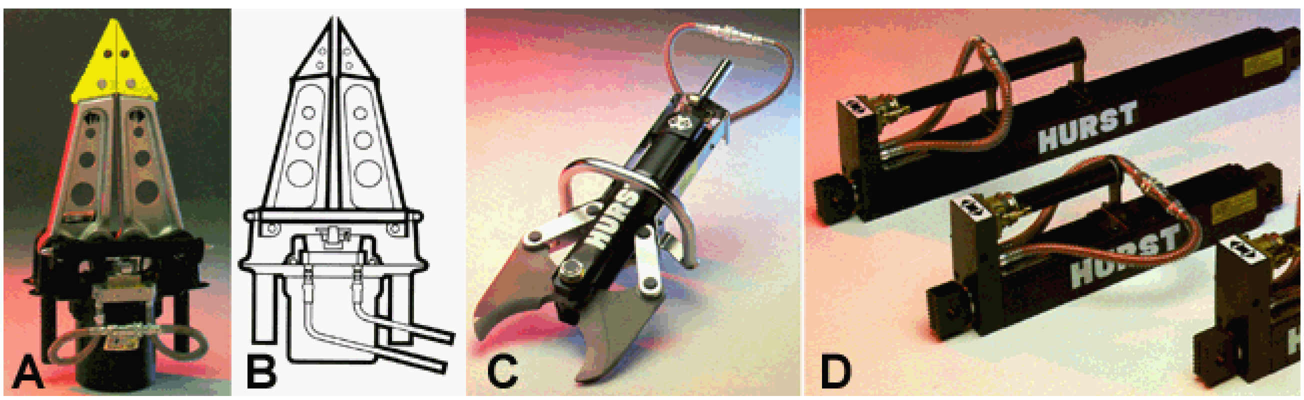
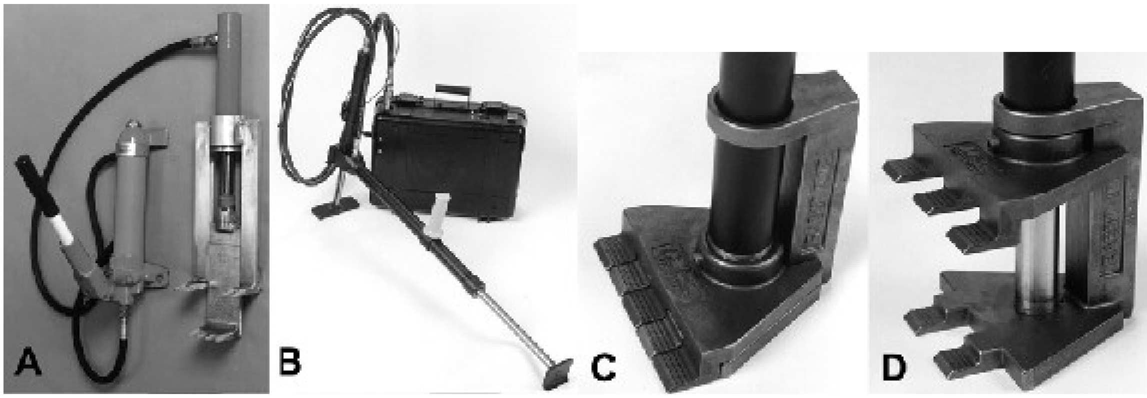


Figure LSS+3205 Sigma Ripper

These tools are placed into the jamb between the sides of the door frame. Once seated, they will cause spreading. They will exert pressure against the frame, often at five or more different points. If the door is nailed shut, a sharp wedge can be initially driven into the frame with a hammer.

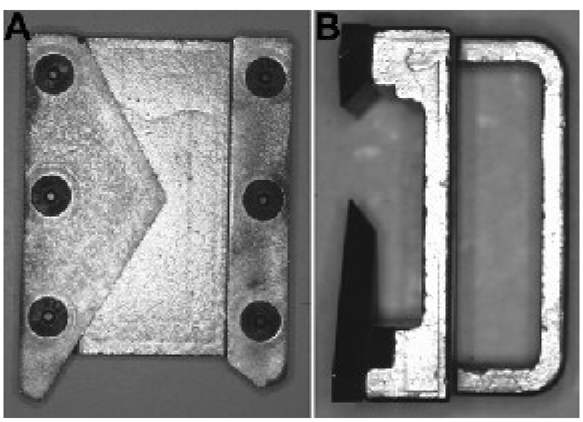


Safety precautions should be taken when using these devices because of the extreme hydraulic pressures that are generated and the potential for instant dislodging. Specifically, heavy gloves and goggles should always be utilized to protect against flying metal and fluids.



32_3.6.2.2 K-Tool

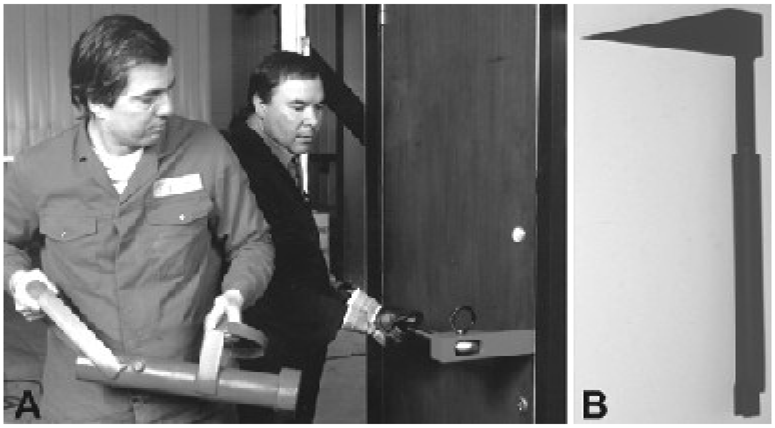
The **K-Tool** from Iowa American Company provides another means to remove a rim or mortise cylinder from its housing. This device, constructed in the form of a slotted box with an extremely sharp wedge, is initially forced around the lock to provide a firm grip. Its design will cause it to be locked onto the cylinder so that a pry bar or duckbill can be utilized to rip it loose from the door or frame.



Exploded view 1, 2.

32_3.6.2.3 Power Wedge (Duckbill)

Another form of wedge that employs leverage will create energy from a graduated angle upon impact. The **duckbill tool** is primarily used to compromise padlocks and cylinders and is configured as an L-shaped crowbar.

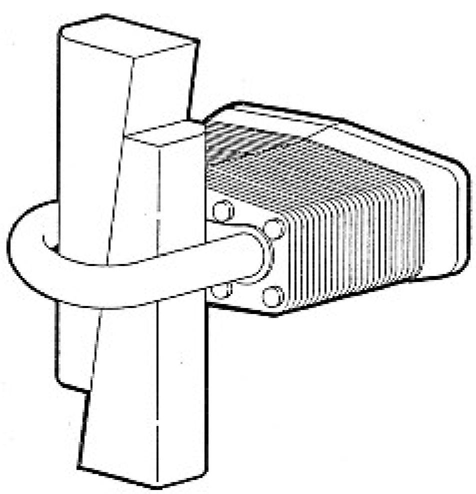


Exploded views 1.

To open a padlock, it is placed into a shackle then struck with a sledgehammer. The force thus created will cause the shackle to be pulled from its anchor. When used with a K-Tool, almost any cylinder can be ripped from its housing within seconds.

32_3.7 Breaking

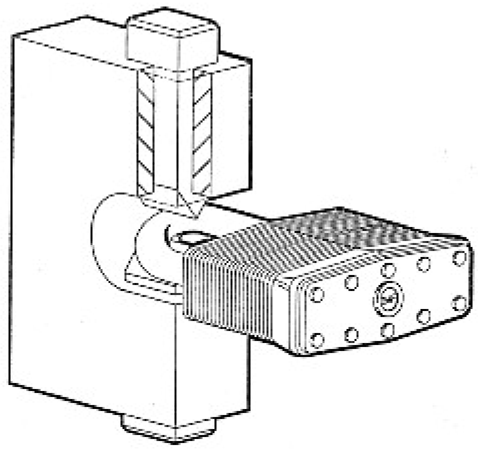
Locking components may be physically broken, fractured, or ripped apart using a variety of techniques described in this chapter. If the material and its molecular structure can be altered or destroyed, the security of the device can be bypassed.



32_3.8 Compression

Some materials and components can be subjected to extreme compression in order to alter or destroy their structure. Wire

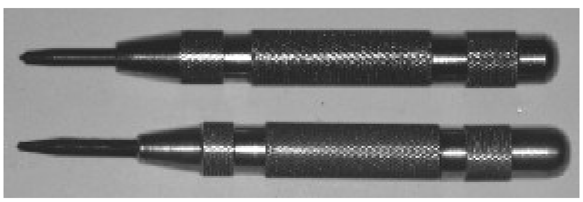
or bolt cutters, shears, and similar tools can be utilized to compress materials in order to reduce their strength.



32_3.9 Impact, Blows, and Shock

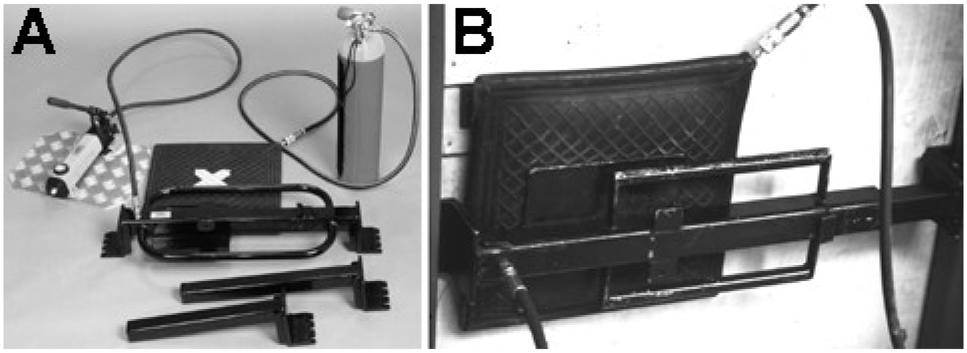
Safes, vaults, security devices, and barrier materials can be bypassed or destroyed when subjected to impact or blows caused by direct contact or concussion. Many tools and techniques are available for delivering and focusing such forces.



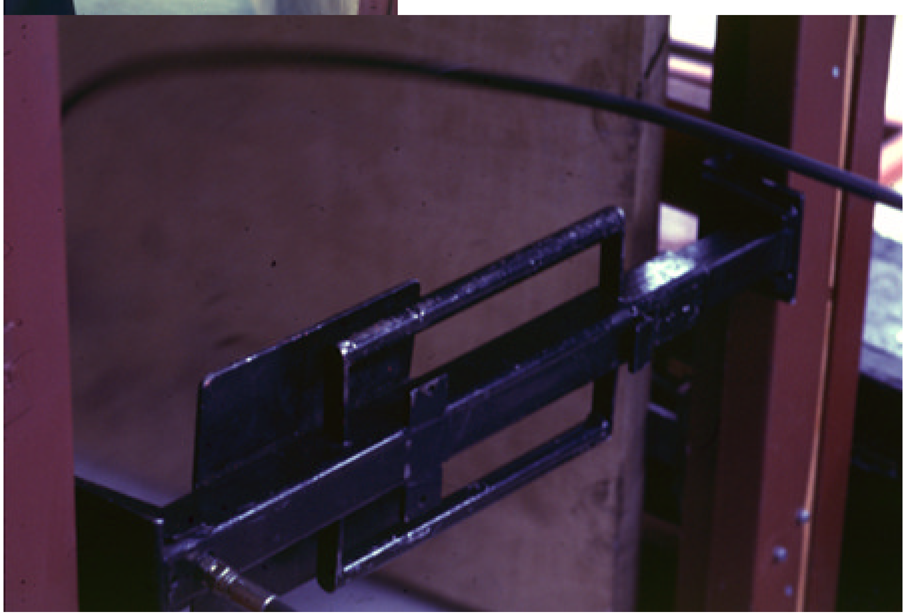


Exploded view.

In first-generation safes after the Industrial Revolution, it was a favorite practice to strike the metal sheets with a heavy hammer, causing deformation and the metal to pull away from the rivets. A lever or axe would be utilized to peel the face. Likewise, blows can be used to compromise a dead bolt locking arrangement. A well-known technique requires the placement of a bar at the top of a bolt, followed by the application of a downward force with a sledgehammer. This action will generally release the bolt from its housing.

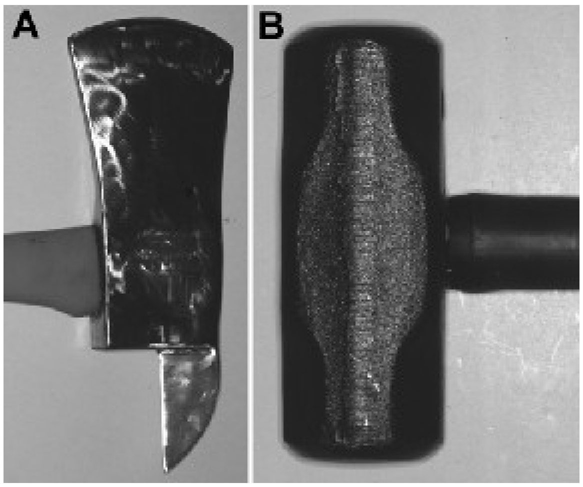

A
B





Exploded view 1, 2.

Sigma produces a highly effective air bag system to compromise almost any door in seconds. It utilizes a heavy rubber pouch that is placed between a metal frame and the door. A hydraulic assembly is secured into the door frame to provide structural support to the air bag. Once inflated, the bag will force the door inward and shear any bolts that are holding it in place.



Exploded views 1, 2.

32_3.9.1 Bouncing Locking Components

Inferior-quality padlocks can often be compromised by applying shock to the shackle assembly, using a rubber or wooden mallet. This will cause the dog to retract, allowing release of the shackle. Likewise, impact pick guns are used to bypass pin tumbler locks.

Opening a padlock by bouncing the locking dog. Courtesy of Don Shiles.

Another common technique involves the application of shock to the walls of small safes used in hotels that employ spring-loaded bolts. Sufficient energy can cause the bolts to momentarily retract, allowing the door to be opened.

32_3.9.2 Battering Ram Door Hammer

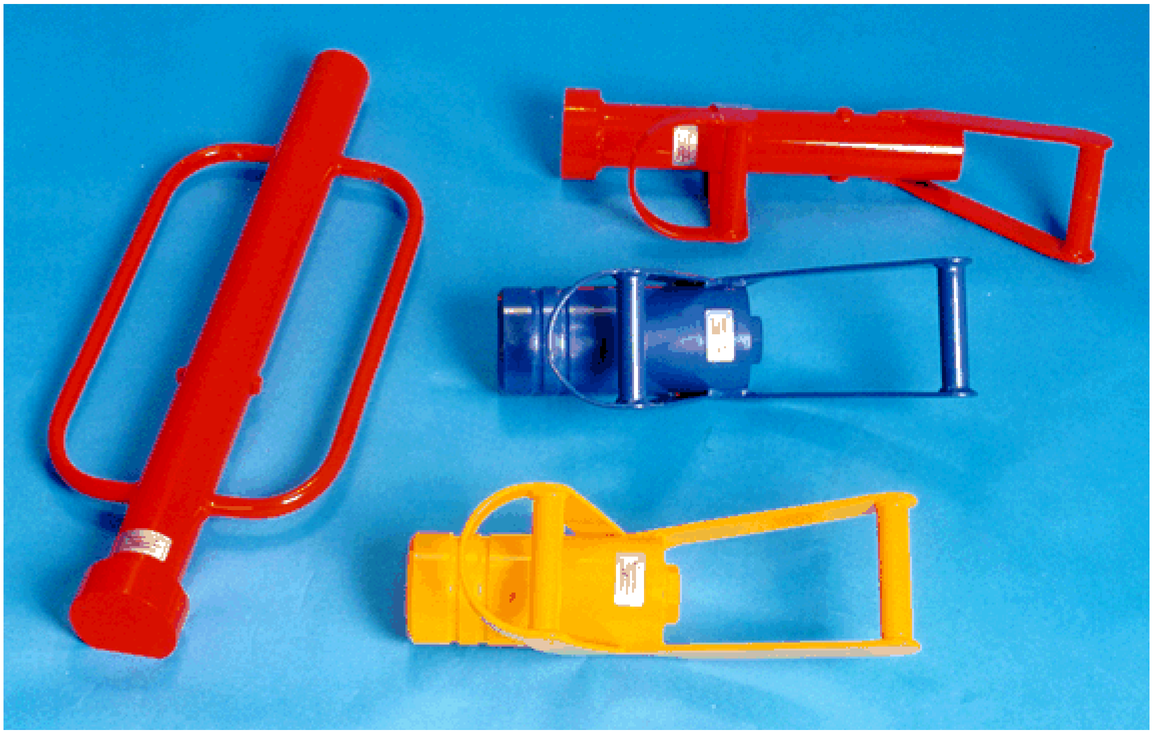
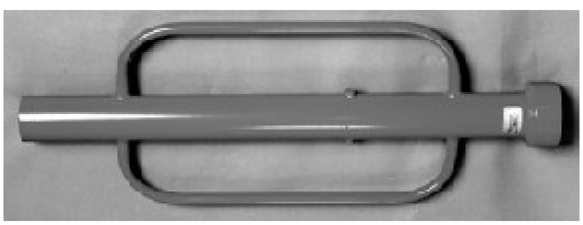


Figure LSS+3205 Sigma Ram Family

One and two-man battering ram door hammers have been developed for use by the military, security services, and rescue teams to effect rapid entry. These devices can generate a great deal of force through a combination of weight, physical design, and impact velocity. Interestingly, it appears that the first hydraulic ram was patented in the United States in 1851 (**7918(359)**).



Generally, these tools are made of steel and contain concrete. They can deliver up to 14,000 pounds of pressure. Once such device manufactured by Sigma (UK) offers eight times the force of a fourteen-pound sledgehammer. It can open almost any door in seconds. Iowa American produces similar tools.



Figure LSS+3201 Sigma Baby ram

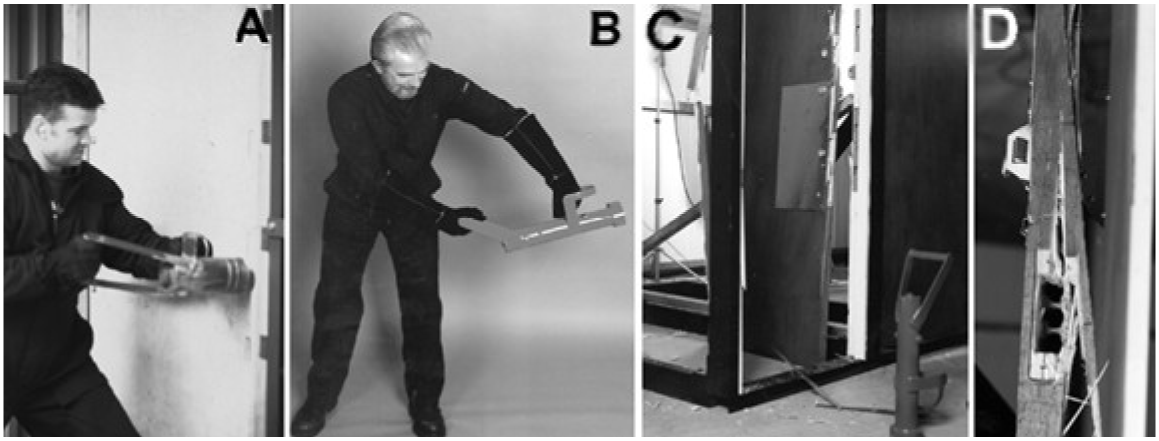


Figure LSS+3203 Sigma Firecracker ram



Figure LSS+3204 Sigma Mitts

In use, the ram is placed to hit a door on either the hinged or the locked side. Because of the tremendous capability to deliver focused energy, they are extremely destructive. Impact directed to the hinged side of the door may be preferable in order to insure officer safety.



Exploded view.

32_3.9.3 Slam-Hammer

The slam-hammer resembles a dent-puller and provides a means to exert a magnified pulling force to remove plugs, locks, safe dials, and other fixed components. The tool is quite simple in design and relies upon the multiplication of force by creating a momentum with a heavy sliding mass. The energy created by sliding the mass away from the target object will be transferred to that target object.

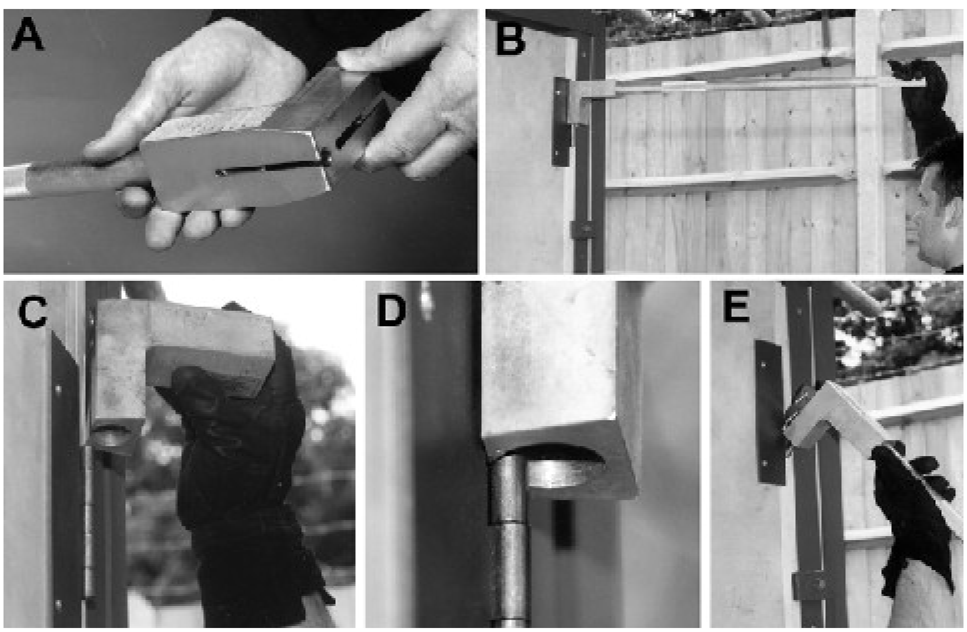
The tool is comprised of a long pipe that has a collar that is free to move over its entire length. The tip of the tool is designed to retain a metal screw that is tapped into the component to be removed. The round collar is quite heavy and is just slightly larger in diameter than the guide pipe. The weight of the collar, the length of the guide, and the speed at which the collar is withdrawn determines the amount of force that is applied to the lock. In operation, the front end of the slam-hammer is attached to the component to be removed through a self-tapping metal screw. The collar is moved to the tip of the device, then violently slid backwards. The counterforce or momentum that is generated when the collar **stops** at the end of the guide is transmitted to the lock or component.

32_3.9.4 Punching

Force may be delivered through punching, using a sharp-pointed rod, punch, spike, piercer, awl, or other cylindrical object. This is a popular technique to bypass bolt mechanisms and locks within safes. Access is first gained to the lock casing or bolt works by drilling a hole or knocking off the dial. The punch is then placed in a position to dislodge the lock by forcing the spindle forward. Shock, created by repeated blows with a hammer, will generally remove the lock case or bolt.

32_3.9.5 Chisel

A chisel with a sharp point is a favorite tool for bypassing hinges. In practice, the tool is used to spread the leaves and break a piece of the hinge. The sharp wedge is inserted and the hinge is pried loose from the door. Sigma produces a special tool to remove hinges. It is slid over the hinge assembly, then pried loose at an angle. **Hinge pins** can also be removed with a sharp chisel.



32_3.9.6 Shotgun Shells

Special shotgun shells have been developed to produce the equivalent of a shaped charge. These low-order explosives contain powdered metal or ceramics and will not ricochet.

32_3.9.7 Explosives

Explosives are chemicals that produce a large volume of gas almost instantly. The force that is created is measured in terms of violence rather than power. Explosives are rated in terms of **high** and **low order**; the classification denotes speed of reaction. The higher-order materials will produce gas more quickly. Explosives have been utilized for more than six centuries to open safes and vaults. Although today few safe penetrations are accomplished in this way, burglars sometimes turn to the techniques that were popular with older safes. In addition, SWAT teams can effectively employ plastic strips and placed charges to effect rapid entry.

The earliest use of explosives is claimed by the Chinese in the thirteenth century. A mixture of charcoal, saltpeter, and sulfur created gunpowder. This remained the principal propellant until just a few years ago. It is believed that explosives were not effectively applied to the task of opening locks and safes until the seventeenth century. See **Chapter 35** for methods of safe and vault penetration.

The early use of gunpowder in attacking safes was crude. As manufacturers refined their designs, so the safecracker became more sophisticated in his use of explosives. First, guncotton, then glycerol trinitrate was employed to open safes, beginning about the middle of the nineteenth century. In 1846, Sobrero was the first to produce a high-explosive liquid that caused a shock wave when ignited. **Nitro** would give safecrackers a new and powerful tool.

Until the middle of this century, dynamite has been the favorite explosive. In 1867, Nobel invented a stable form of the material, called Guhr dynamite, which was safe to handle. Gelignite, which is a combination of guncotton and nitro, was also developed by Nobel to compete with dynamite. Appearing as a dessert jelly, it was a favorite of safecrackers until about 1920.

32_3.9.7.1 Modern Explosives

Today, explosives can be safe to store, carry, and handle. Materials are available in many configurations and are offered in plastic, special shotgun slugs, compressed powder metal, or ceramics. An expert can place a shaped extruded charge to precisely f/ocus both force and damage. Explosives can be used

to blow apart hinges and locks and to make holes in doors or other barrier material.



Figure LSS+3202 Explosive Wall Breaching System

When hinges and locks are to be destroyed, the explosive is generally formed as a cord in the shape of a ring and wrapped around the obstruction to be removed. In the alternative, **thunder strips** may be placed over a door. These consist of soft, flexible foam containing 300 - 500 grains per foot of explosive. A slow blast applies pressure to the target material. Generally, an instant detonation firing system is employed.

See **Section 35_4.2.7** for an examination of the use of explosives in the penetration of safes and vaults. A comprehensive set of definitions of conventional explosives is provided at **Section 35_4.2.7.7.**

32_3.10 Application of Temperature Extremes

The application of temperature to surface material can be an extremely effective method of compromise. The object of such treatment is to alter the molecular structure of the target. This can cause a change in density, loss of temper, weakening, or distortion of the surface. It can also result in softening, brittleness, and shattering, or simply melt or vaporize barrier material.

32_3.10.1 High Temperature

High temperatures may be applied with a torch, thermic lance, or similar device. Chemicals may also be employed to induce an exothermic reaction. Thermite, for example, can develop high temperatures to melt barrier materials. Depending upon the technology and technique, heat may be directed to a very limited area as in the case of a thermic lance, or to a more general area with a torch.

To combat the effects of heat, most safe manufacturers place heat-sink material between layers of steel. Chubb, for example, utilizes a sandwich of copper and beryllium to draw heat away from the contact point of a torch. This technique is not particularly effective when a thermic lance is utilized.

32_3.10.1.1 Thermic Lance

The lance has a long and distinguished history, dating more than a century. Initially used in England, it has had limited acceptance in Europe and the United States as a tool for forcible entry although many daring safe burglaries have been accomplished with the lance. Today, the exothermic torch is used in the repair of heavy equipment, plant maintenance, construction, dredging and marine emergency services, and safe penetration. SWAT teams utilize the technology for rapid entry, damage control, and rescue operations. It is particularly well suited for deployment in prison riots, where bar stock and heavy steel doors must be rapidly penetrated.

The modern lance is small, portable, and safe. With training, it can provide a means to penetrate any material. The lance is more fully discussed in **Chapters 5** and **35**.

32_3.10.1.1.1 Broco Exothermic Lance

LSS202: Broco Thermic lance description and use, by Tom Joos.

Broco(360) is the leading manufacturer of the exothermic torch. Their primary market is mainly for underwater repairs and construction. They have received two patents (**4069407(361)** and **4182947(362)**) for a binary metallic system used in conjunction with an ionized gaseous core. This provides a continuous cutting action of high temperature, extreme power, and great intensity.

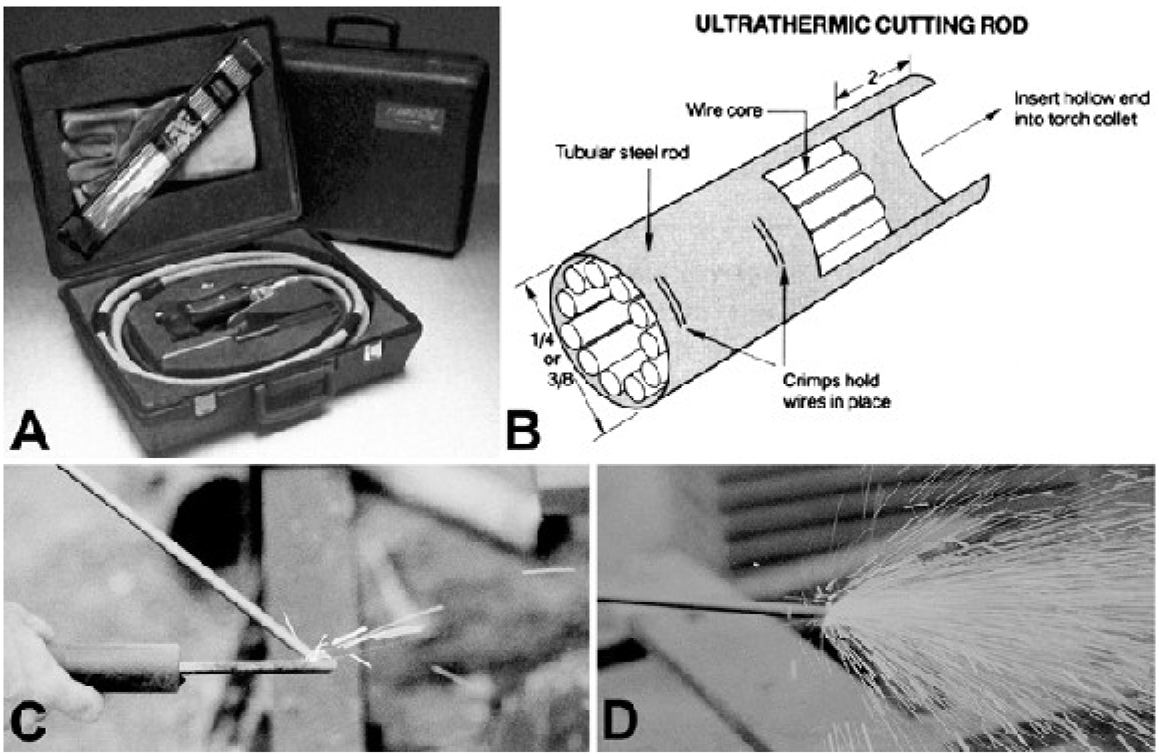




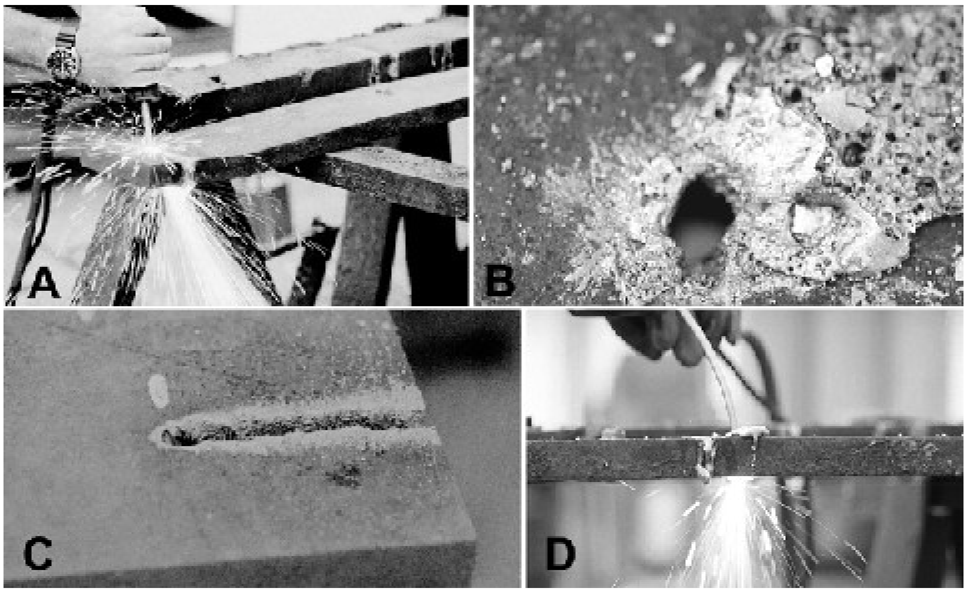
Figure LSS+3228 A smaller and newer version of the Broco thermic lance. This system utilizes a special oxygen bottle the newly designed trigger valve. The control valve can be utilized as shown, or connected via an extension hose to a separate oxygen source.



Figure LSS+3229 A close-up of the control valve with a rod inserted. The rod is inserted into a self-contained ignition system which requires no battery. It is pushed into the special capsule and will ignite.

The unique burning action of the Broco proprietary Ultra-thermic rods liquefies anything in its path, using the material itself as fuel. They will quickly cut or melt through almost any known material, including cast iron, steel, stainless steel, concrete, granite, nickel, titanium, and aluminum. The lance will even penetrate a spacecraft's heat-shield tiles and exotic metals. The Broco lance is completely self-contained and is ideal for

applications involving specialty gouging, piercing, or cutting. The Ultra-thermic rods burn in damp atmospheres, even when submerged in mud or water.



Prime Cut systems are safe and easy to operate because they do not require high amperage or potentially dangerous acetylene (or any other secondary fuel). The system produces little noise, smoke, or noxious gasses. Because the system cuts so quickly, there is minimal heat build-up. This enables the temper of the material to remain virtually unchanged. For detailed operating instructions and safety information, see the ***PRIME CUT Tactical Cutting Torch Kit PC/TAC and PC/MINI-TAC*** **OPERATING INSTRUCTION MANUAL.**

The lance is designed for simplicity of operation. It requires 12 volts DC for ignition and a single oxygen source with one regulator. The equipment is self-contained and portable and can be operated effectively by first-time users.

32_3.10.1.1.1.1 Lance and related components

The torch is straightforward in design and is fabricated from impact-resistant materials. It is engineered to be ergonomically efficient and to relieve operator fatigue. The system is provided with a flash arrester to eliminate flashbacks, and two collets to accommodate both ¼" and 3/8"diameter burning rods. All components are easy to remove and clean. The oxygen control lever is simple to work with in a gloved hand, allowing the

operator to "feather" the flow of oxygen during rod ignition and use.

32_3.10.1.1.1.2 Ultra-Thermic Rods

Broco's patented Ultra-thermic rods burn in excess of 10,000F at the tip and will cut, melt or liquefy virtually any known substance. The design of the rod incorporates a series of circular crimps to allow bending without restricting oxygen flow. This feature enables the operator to reach difficult or otherwise inaccessible places and ensures an even burn.

32_3.10.1.2 Oxyacetylene Torch

The Oxyacetylene torch has been utilized for cutting of metals and penetrating safes and vaults for over one hundred years. It relies upon the proper mixture of oxygen and acetylene to produce a flame of several thousand degrees.

32_3.10.2 Low Temperatures

Extremely low temperatures may also be utilized to alter the molecular structure of materials. Freon and liquid nitrogen have been successfully employed to make barrier materials brittle and subject to fracture upon impact. Supercooling of materials can be especially effective in the bypass of padlock shackles. Although some manufacturers add chrome and nickel or other materials as hardening agents, the less expensive locks are subject to the practice.

32_3.11 Other Forms of Attack

Acids and corrosive chemicals have been utilized to destroy barrier materials. Although difficult to work with, the application of acids can be quite effective in neutralizing security devices. Many solutions can be used to eat through metals, plastics, ceramics, and glass.

32_4.0 Evidence of Forced-Entry

This section provides information about tool mark evidence and the importance of proper procedures in collection, documentation, and analysis of materials (see **Chapters 24-27)**.

Forensic evidence of forced entry. Courtesy of Hans Mejlshede.

32_4.1 Tool Mark Evidence

Tools that have been used to commit a crime, found at the scene, or possessed by a suspect can often yield tool mark, trace, and many other forms of evidence in a criminal investigation. Tool marks can associate a suspect with a crime scene. This type of evidence can also provide an indication as to the type of tool that was used and the expertise of the perpetrator. It appears that the first substantive case involving the admissibility of tool mark evidence was decided by the Washington Supreme Court in 1930. That court held "the edge of one blade differs as greatly as the lines of one human hand differs from the lines of another." This landmark decision established the credibility and acceptability of tool mark evidence.

The surface and edges of any tool will always contain innumerable ridges and irregularities. These identifiable traits are unique to each tool and its surface material and are created both during the manufacturing process and because of wear. When the active portion of a wedge, crowbar, screwdriver, or similar surface forcibly encounters other materials, these traits may be transferred from one surface to another. Such tool marks can identify a particular tool just as reliably as the ridges and grooves of a spent bullet or fingerprint. When a tool contacts another surface and displaces material and creates any kind of mark, that impression can often be identified as having come from a particular instrument.

A tool mark can be described as an identifiable trait in the form of an imprint or impression that is created by an instrument, tool, or object upon a softer surface. Such traits are used to identify a suspect tool with a surface upon which contact has been made. Jimmy marks on a door frame, tool impressions on a cylinder, and drill tip marks on a safe all may provide information regarding the perpetrator.

Tool marks are generally associated with offenses related to burglary. It is not uncommon to develop such evidence in other criminal investigations, including possession of burglary tools, arson, rape, homicide, and espionage. It is critical that investigators focus on the **modus operandi** in order to determine possible tool mark indicia.

A tool can both transfer other evidence to the scene and carry away traces from anything to which it came in contact during the commission of the crime. Wood fragments, sawdust, safe insulation, metal filings or dust, explosive residue, splinters, paint flakes, oil, blood, or other contaminants or chemicals may be left behind, or be present on the tool or its surroundings (see **Chapter 25)**.

During a search, there is always an urge for investigators to attempt to match a tool with an obvious corresponding mark that is found at the scene. Valuable evidence can be lost by doing so. Foreign substances may adhere to cutting edges that may be contaminated and destroyed. Even more importantly, a mark and its characteristics may be altered, making a positive match difficult or impossible. Rigorous cross-examination can expose such mishandling and result in the suppression of vital evidence.

The examination of tool marks can yield the following conclusions:

- **The tool produced the mark;**
- **The tool did not produce the tool mark;**
- **There is not sufficient individual characteristics within the tool mark to conclusively determine whether the tool did or did not produce the mark.**

32_4.2 Burglar Tools



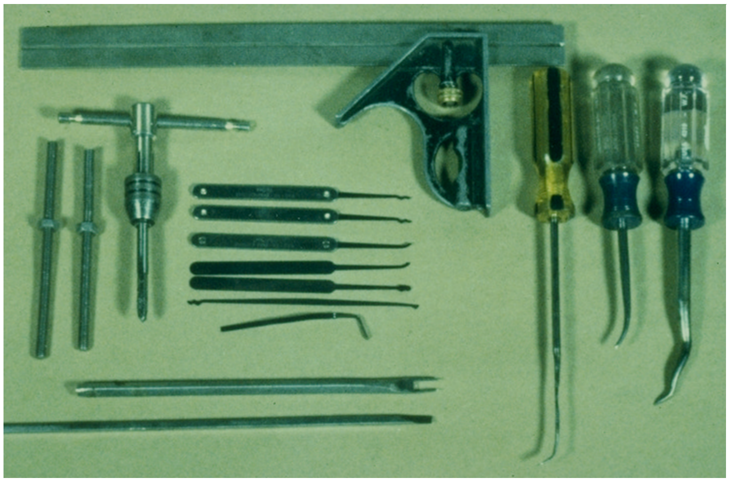


Figure LSS+3242, examples of burglary tools found at the scene of a safe job. (Photo ID ISP 100-3563, left, and 101-3563, right).

Tools found at a crime or in the possession of a suspect may provide physical evidence to link the perpetrator to the scene. These implements may also constitute an offense in their mere possession. The possession of burglar tools is a crime in most jurisdictions. The definition is illusive and depends upon many factors. Generally, implements, instruments, devices, or explosives that meet the following criteria can be described as burglary tools:

- **Suitable, or adaptable, or peculiarly adapted for use in breaking and entering;**
- **Possessed with intent to commit a felony or theft;**
- **Possessed with the knowledge of its character.**

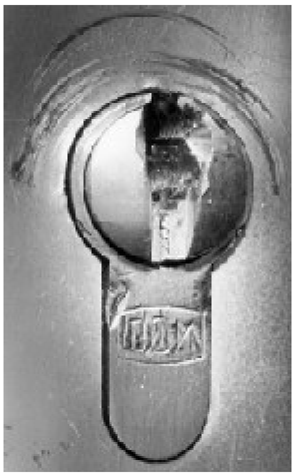
The government must prove the elements in such cases, based upon the use of the tools and circumstances of its seizure. In certain instances, the identification of a burglary tool is prima facie. Such would be the case involving a cutting torch, thermic lance, or sledgehammer. Intent becomes the critical factor; it is often inferred from all of the facts and circumstances.

32_4.3 Types of Marks

Imprints are generally divided into two primary groups: **impressions** and **striations**. In some circumstances, a tool may leave both types of marks.

Impressions are indentations created upon a softer material by a harder one. The marks resemble a mold that duplicates the identifying characteristics of an object. Impressions can be created by a sudden impact, such as a hammer striking a safe or wooden door. In this example, we would expect a circular imprint of the hammer face on the surface. In some cases, irregularities upon such a surface could also be transferred back to the hammer.

Compression marks are another form of impression and can be made by the application of pressure between two surfaces. A screw driver, pry bar, or jimmy that is wedged between a door and frame will leave such marks.



32_4.4 Classifying the Mark

The admissibility of tool mark evidence is based upon uniqueness of signature; each tool will create a distinctive mark, like a fingerprint. When examined microscopically, minute differences will appear in cutting, striking, and the contact edge of similar tools. Tool marks are identified according to their **class** and **individual characteristics**. **Class** indicates the particular kind of mark normally associated with a specific type of tool. For example, marks can be differentiated between jimmies (crowbars and wedges), cutting tools (such as bolt and wire cutters), and wrenches (channel-lock pliers and vice grips).

Individual characteristics are a reverse, or negative image of imperfections impressed upon or transferred to a surface by the positive imperfections on the tool. Microscopic striations (lines and scratches) are formed on the tool by these imperfections.

Identifiable tool marks are actually complimentary to the imperfections on the tool's surface. It is the same as when the lands in a gun barrel become grooves of a fired bullet and the grooves of the gun barrel become the lands of the bullet. The technician compares the striation marks on the tool with known standards.

A study of class characteristics may suggest the type of tool that was utilized in a particular crime. In contrast, identification by individual characteristics can be extremely difficult. Impressions left on certain materials may be distorted or disappear with time. Wood fibers, for example, will bend, expand, and contract. Thus, there may be few if any microscopic marks for striae comparison in such cases.

There are two basic kinds of marks: **impact or impression** (one object striking another), and **striations** or **scratch** marks (an object moving against another surface).

Marks are further influenced by the **angle of progression** or **attack**. This angle is formed between the edge of the tool, key, or object, and the direction of travel of the intersection point. Significant criteria will result from a change or alteration in the angle of progression. Tools can produce a variety of marks based upon the combination of attack angles that result from movement of the contacting surface. The critical issue becomes the ability to identify a tool, and to ascertain what the significance changes in attack angles will have upon marks. That is, at what point will marks change, based upon a change in attack angle?

Most tools have non-sharp edges, and can be seen to have many rows of fine and coarse ridges. Factors that can influence the resulting mark, when considering attack angle include: **thickness of the edge of the tool; general shape in cross section**; and the **relative height and spacing of the irregularities** on its surface. In simple terms, this translates to changes in markings caused by insertion angles of a key within a lock, the rate of insertion, and the force applied)slow or fast). In addition, issues relating to the shape of each cut on the surface of the key must be taken into account, because, as has been noted elsewhere, marks may be caused by such irregularities in the bitting of keys.

32_4.4.1 Striations

A typical striated tool mark consists of parallel scratch marks that are cut into the softer material by a harder surface through sliding or lateral movement. Striae are reproductions of the cutting, prying or striking edge. These are also called shearing, abrasions, friction, or scratch marks. These marks are comprised of minute parallel ridges and valleys that are imprinted upon a surface by corresponding irregularities along the edge or surface, of the acting tool. From an evidentiary standpoint, the marks generally carry a greater significance than impressions, although they will not always provide clues as to the specific type of tool that created them. It can be extremely difficult, for example, to ascertain whether a particular striation mark was produced by a screwdriver, pry bar, cold chisel or wood chisel.

The real value of these marks lies in the investigator's ability to locate a tool whose edges have the same imperfections or traits as found on the imprints at the scene of the crime. Marks containing indentations or similar irregularities resulting from wear or damage to the tool provide the best identification. Striations are created when the edge of a tool has slipped, scraped, or been forced over a softer material. Generally made by a lever (pry bar or crowbar) or a tool with a sharp edge (screwdriver or chisel), the marks can match a suspect tool to the point of entry. Bolt cutters, pliers, snips, wire cutters, and shavings from a drill bit may all contain striation marks unique to the entry tool.

32_4.4.2 Striae and Impressions

Impressions can be most often located on windows, doors, safes, and other barriers. **Striations** are generally found on cash boxes, registers, door locks, safe dials, vending machines, and similar implements. Good impressions are rarely left on wood surfaces, although they should never be overlooked. Marks on painted surfaces are often clear and distinct.

The best striations will be produced on soft metal surfaces, such as brass or bronze door lock assemblies and hinges. Galvanized iron and painted sheet metals also are excellent materials to reproduce marks. Cutting marks that are a form of striation can be reproduced on wood with excellent definition. Photographs of tool markings showing their class characteristics are usually admissible in evidence to show the location of breaking and entering. It is extremely difficult to identify **individual** characteristics through photography because of the inability of the photograph to reveal the height and depth of the striation

marks.

32_4.4.3 Basic Tool Mark Examinations

Tool mark examinations may be conducted with or without the suspect tool. If the tool that is suspected of having made the mark can be used for testing, then the following comparisons can often be made:

- **Examination of the tool for foreign material deposits, such as metal, paint, oils or other debris;**
- **Establishment of the presence or non-presence of consistent class characteristics;**
- **Microscopic comparison of a marked object with several test marks or cuts that have been produced with the tool.**

Analysis **without the tool** can also yield valuable results:

- **Type of tool that was used, by class characteristics;**
- **The size of the tool, by class characteristics;**
- **Unusual features of the tool, determined by class or individual characteristics;**
- **Actions employed by the tool in normal operation, and in the present condition;**
- **Value of the tool mark for identification.**

Other related examinations can be conducted involving marks and similar indicia of contact. These include fracture matches, marks in wood and other soft materials, and pressure contact marks.

Fracture matches

These examinations are conducted to determine if a piece of material left at the crime scene was connected with or formed a part of a suspect item. Fragments from the following items provide examples:

metal bolt
plastic automobile rim
knife
screwdriver
wood gunstock
rubber hose
keys

screwdriver or other prying tool

Marks in wood

Can the marks that remain in a wood specimen, such as a door or window frame, be associated with a specific item or tool, such as drill bits, pruning shears, knife blades, pry bars or other implements.

Pressure contact

These examinations are conducted to determine whether two objects came into contact with each other.

32_4.5 Making an Identification from a Tool Mark

Tool mark identification involves both an analysis of the impressions, as well as other materials which may have come into contact with the tool or affected surface. The forensic analysis of tool marks occurs in several stages. First, the suspect tool and its markings are examined to determine the presence of trace evidence such as paint, putty or other foreign matter. If any material is found, an attempt is made to chemically and spectrographically identify it and link it to evidence from the crime scene.

From tests conducted in the laboratory, four primary factors must be considered in the analysis of a tool in comparison to an impression taken at the crime scene:

- **Direction of tool movement which creates the mark;**
- **Pressure;**
- **Angle of contact or Angle of Progression;**
- **Method of contact by different movements.**

Sample marks must be created by a suspect tool and compared against those taken from the crime scene. Test plates made of similar material to those upon which the impression was initially made are prepared. The edge, blade, or surface that created the mark is used to make a sample impression by pushing and then pulling the one side of the blade over the surface.

The test scratches are repeated with the other side of the blade. The push-and-pull action will help determine the direction of the blade movement when it made the original impression. Pressure and

angle must also be considered in analyzing marks. It is not unusual to produce a number of standards using various movements, angles, and pressure. Using a comparison microscope, the prepared plates are examined against the suspect tool for similarities in striations.

The quality and value of identification information provided by a mark is a function of and directly related to the tool and surface to which contact is made. Depending upon the materials and applied forces, marks may be transient or permanent. Thus, wood fibers in a window frame are generally compressed by the pressure of a jimmy. They will return to their original shape upon removal of the tool. Splinters may also become dislodged, thereby reducing the definition of the mark.

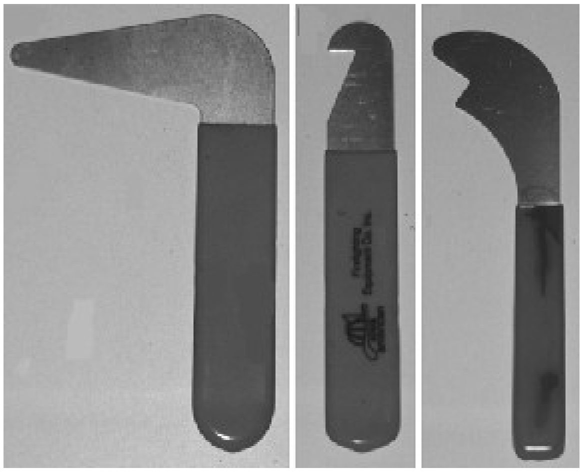
Tool marks found at a crime scene are typically a combination of impressions and striations. A mark, for example, may display both the impressed outline of the end of a pry bar or screwdriver and striations extending from the sides or ends of the impression. These will further identify the tool that produced the marks. Two common occurrences illustrate the point. A hammer blow on the surface of a safe may leave an impression mark. The head may glance upon impact and leave a sliding mark (striation). Likewise, a crowbar that was used to force a door will often leave a perfect impression. Striation marks are created as the bar is forced into position.

An impression can often duplicate the characteristics of a tool quite precisely and may provide information about its general character. The size or shape of the cutting edge, as well as the shape and the color of the tool, may be discoverable. The usefulness of a tool mark, even when it is an exact reproduction of the original, is of significance only if the tool that made it has irregular and individual characteristics. Thus, a jimmy that has never been used would have far less relevance than one whose surface has been pitted or damaged through previous contact with other materials. An impression will have little evidentiary value if it does not show distinct characteristics.

Impression marks may be found anywhere and are dependent upon the method of attack and the tools utilized. Generally, marks are found at the point of entry. A search should be made for tool marks based upon the design of the security device or mechanism and how it was compromised. Door frames, cylinders, sills, safe doors, glass, and any other place where it is likely that entry may have been effected can yield evidence.

32_4.6 Tool Marks at Crime Scenes

Most forcible entries produce some form of tool mark, both on large and small surfaces. Whether they are identifiable or not depends upon many factors. Investigators should expect to find such evidence in all residential and commercial burglaries, as well as other crimes.



Exploded views 1, 2, 3.

Tool marks may appear anywhere and on any surface that may have been exposed to a tool used for forcible entry. Never overlook the possibility that a small piece of a tool may have been broken or shattered. Tool marks are often found in the following areas:

- **Padlocks;**
- **Doors and door frames;**
- **Severed telephone lines;**
- **Safe doors and bodies, dials, dial covers;**
- **Hinge pins;**
- **Nail heads;**
- **Cylinders, both front and sides, when a drill jig is utilized to remove setscrews;**
- **Cylinder guard rings and lips of cylinders, when a plumbers tool (chain wrench) or K-Tool is used to rip the cylinder from its mounting;**
- **Doorknobs;**
- **Cylinder plugs, when a dent-puller is utilized;**
- **Cylinder setscrews, when heads of screws are**

drilled;

- **Internal areas of plugs, when picks are utilized;**
- **Surface of cam at the rear of the plug, when the bypass technique involves the use of a spring steel sharpened wire. Generally, it is forced to the back of the cam lock, then the cam is rotated to open, bypassing the mechanism;**
- **Scratch marks or indents that indicate a knife, ice pick, awl, or loid was used to move the bolt. Generally, marks will appear on the bolt and between the strike plate and frame;**

LSS203: Demonstration of the use of a loid, by MSC

- **Scratch marks on bolt works;**
- **Wood separated from door frame, indicating use of jamb-spreader;**
- **Impressions at the top and bottom of the lock, indicating the use of two screwdrivers to wedge the cylinder loose. This is especially common with Kwikset and other similar locking arrangements;**
- **Jimmy marks that were caused prior to the use of a pry bar;**
- **Use of hacksaw to cut through dead bolt;**
- **Marks from drills used to remove mounting screws from front of cylinder on Schlage locks;**
- **Magnetized areas of safe door, indicating the use of a magnetic drill press. The footprint of the press can often be determined by the use of magnetic spray or powder placed on the surface. The type of press can often be identified;**
- **Fine metal dust particles at the crime scene and on the clothing or in the hair of suspects;**
- **Broken tips of setscrew in door frame indicating shearing and that extreme torque was applied to the cylinder;**
- **Drill marks on the face of a cylinder, internal components, or on the door frame;**
- **Compression marks on door frames, indicating the use of a jamb-spreader. The size and depth of the impressions should be documented, as well as any striae. Tests may be conducted to determine the**

amount of pressure required to spread the jamb. This may provide a clue as to the manufacturer;

- **Marks on the door and frame, indicating the use of a jimmy, crow bar, and pry bar;**
- **Marks on bolt control mechanism in a mortise cylinder assembly, indicating how the cylinder was removed from the door;**
- **Dents, scratches, and metal chips missing from hinges;**
- **Wedge marks within the doorjamb, indicating the use of a wedge that has been forced into the jamb to effect spreading.**

32_4.6.1 Collecting Evidence

Investigators should gather any evidence that contains striae and anything directly associated with it. For example, in a burglary case, a striker plate and the screws holding it in place may be submitted to the laboratory. Although not readily apparent at the scene, there may be a minimal amount of striae on any component that may be sufficient for identification. The investigator must always be vigilant for indicia, including chips or larger pieces of broken metal that separated from a tool during the exertion of pressure.

32_4.6.2 Documenting and Preserving Tool Marks

Tool mark and related evidence should first be photographed, identified on the crime scene sketch, and, if relevant, a cast or mold should be taken. These procedures are required in order to record the extent, location and pattern of each mark. Macro-photographs and casts may be used for comparison purposes in the event the suspected tool is located. Special oblique lighting may be required to illuminate tool marks in order to produce images from which a comparison can be made. The author utilizes a 100 mm macro lens, ring strobe, and a fiber optic light source that produces an extremely narrow beam width which can be easily adjusted for maximum contrast. Photographs must document the location of the tool imprints in relation to the entire object. In a burglary, for example, the entire window, showing the placement of the jimmy marks as well as a macro of the marks, must be photographed.

Materials containing tool marks should be preserved whenever possible to maintain their original state. Moveable objects such

as safes, cash boxes, drawers, and cabinets should be retained. Unfortunately, this is often not possible or feasible due to difficulty and expense. For example, marks found on iron grillwork, a window frame, and sill or doorways present a problem. If it becomes necessary to collect these marks, consideration of several issues are required:

- **Whether the marks represent relevant details of a tool;**
- **Seriousness of the crime;**
- **Value of the object to be removed;**
- **Whether a suspect tool is available for a match;**
- **Likelihood that a tool will ever be found.**

If the object containing a mark cannot reasonably be removed, then the mark may be protected at the scene if it can be shielded from contamination or obliteration. The mark may be covered with a thin film of oil to prevent oxidation if necessary.

32_4.6.3 Modus Operandi

Tool marks can indirectly identify a perpetrator by establishing a **modus operandi.** They can also lead investigators to other more serious crimes. Information regarding the individual who used a tool may also be left at the scene of a crime. Thus, the skill level of the perpetrator may be reflected by the manner in which a tool is utilized. The method of attack may indicate the knowledge and expertise of the criminal about the security device or container and methods of compromise. Depending upon the sophistication of the tool or technique and the **modus operandi (MO)**, an accurate assessment can often be made as to who may have committed the crime.

Investigators should always be alert to markings and any inconsistencies in their creation. The fact that tool markings exist on a door or window does not always provide evidence that a burglary or other crime has occurred. The number, position, and character of the marks must be examined closely for consistency. It is a common ploy of criminals to simulate a burglary or arson, for example, to cover homicide, embezzlement, fraud, espionage, or other offenses.

Those intent upon establishing false leads will often overlook the fact that second marks should be present, or other unique indicia associated with the use of a tool or method of entry.

Consider whether the tool marks are placed in such a position that it would be highly unlikely that they actually contributed to the crime under investigation. The following information can often be derived from the crime scene with regard to MO:

- **Tools;**
- **Techniques;**
- **Sophistication of the method of attack;**
- **Skill level of the perpetrator;**
- **Knowledge and expertise with regard to a particular target;**
- **Position of the perpetrator during the attack with regard to placement and support;**
- **How the tool was held;**
- **Possibility that the forced-entry is a mask for another crime.**

32_5.0 Forced Entry Tools for Motor Vehicles

Although not within the scope of this text, there have been many devices and techniques developed for opening motor vehicles. Many vendors including HPC, MBA, and Tech-Train have a full range of tools for bypassing locks and locking systems in cars and trucks. Some of the more relevant patents have been included here for review. These include Jacobs (**6044672(363)**) for a steering wheel lock removing method in 2000, Markisello (**5701773(364)**) for a dual function apparatus for opening and removing automotive sidebar ignition locks in 1997, and (**5402661(365)**) in 1995 to the same inventor for a tool and method for turning on Ford sidebar lock cylinders, and in 1986 (**4586233(366)**) for a method of disabling various types of lock cylinders in General Motors vehicles, and in 1987 (**4682398(367)**) for a method for removing Ford ignition pin type cylinders.

32_6.0 Hybrid Entry Tools for Locks and Doors

There exists a classification of tools that can be defined for use in both covert and forced entry. These tools typically are utilized to manipulate, bypass, or destroy mechanical locking

mechanisms, such as locks, bolts, catches, and door handles.

32_6.1 Door Opening and Manipulation Tools

Many door opening tools have been invented and marketed during the past two hundred years. Typically, these can be slid under a door or through a mail slot and allow manipulation of locking components. Such a device was patented in 1996 by Helmers (**5540121(368)**).

32_6.2 Powder Technology Forced Entry Tools

Law enforcement, fire, rescue, and SWAT teams frequently must force open locked doors in order to gain access to a premises. Powder actuated tools are well known in the construction field for driving fasteners such as nails, studs, or anchors. This same technology has been applied by Berry in 1993 to a method of neutralizing a lock (**5237613(369)**). The system will disable or destroy a lock at which it is fired.

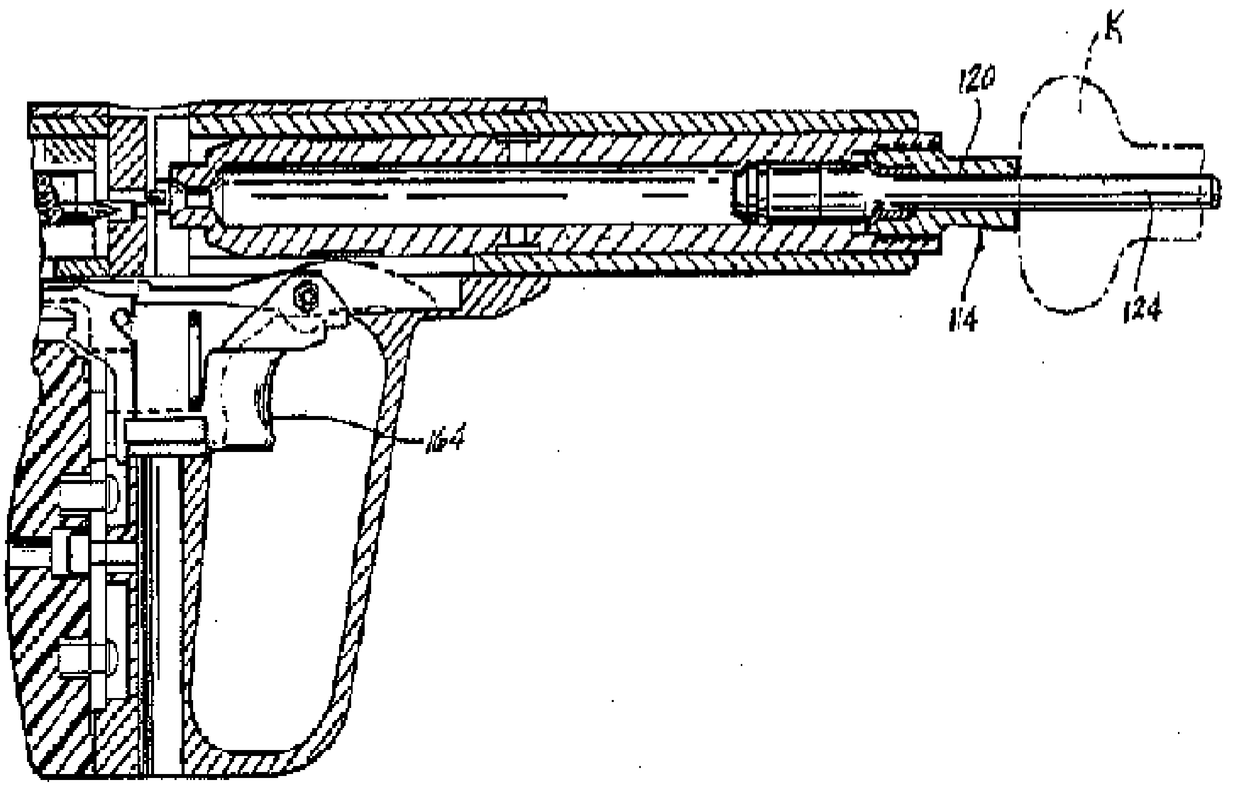


Figure LSS+3206 Power actuated tool

32_7.0 Specific Entry Problems for Doors, Gates, and Windows

Sigma has done an extensive analysis of the different types of barriers, doors, and locking systems with the view of expediting forced entry. The company has developed the appropriate tools to meet the demands of such entries. The following examples detail the most common types of hardware that will be encountered by entry teams. Ian Bauchop (Sigma) provided the narration, and was employed for almost fourteen years by the Metropolitan Police Force in London. His responsibilities included directing forced entries for that department. He is director of training for Sigma.



Figure LSS+3207 External - Right hand (R/H) Inward (I/W) opening timber door with standard Yale type lock; Internal - Left Hand inward opening steel gate in confined area armed with single deadlock.



Figure LSS+3208 External - Left hand outward opening solid timber door with 2 locks; Internal - Left hand inward opening steel grille. Confined space with 1 deadlock and 2 sliding bolts.



Figure LSS+3209 Internal concertina mild steel window grilles (Center locking) behind 6 mm float glass casement window.



Figure LSS+3210 Right hand inward opening solid timber door with Multipoint locking system. Timber door frame



Figure LSS+3211 External - Right hand outward opening steel gate, slightly recessed (more difficult) with single lock and cover plate down lock side on two rising butt hinges; Internal - Right hand inward opening timber door, locks unseen.



Figure LSS+3212 External - Steel cage protecting front door with right hand outward opening single lock with no cover plate. External steel grilles protecting windows; Internal - Inward opening solid timber door.







Figure LSS+3213 Right hand inward opening flush solid timber door with one visible lock (nightlatch type).



Figure LSS+3214 Internal view of LSS+3213 detailing timber braces and additional deadlock and night chain.







Figure LSS+3215 Right hand inward opening solid timber door with four individual locks. Attack made with chain saw on hinge side.



Figure LSS+3216 External - Right hand opening steel gate with single lock, full cover plate and rising butt hinges;
Internal - Right hand outward opening solid timber door, locks unseen.







**Figure LSS+3217 External - Right hand outward opening steel gate, single lock, no cover plate and standard butt hinges;
Internal - Right hand inward opening solid timber door, one lock visible.**



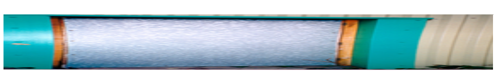
**Figure LSS+3218 External - Right hand outward opening timber and glass door with single lock;
Internal - Right hand opening timber and glass paneled door with two locks.**



Figure LSS+3219 Recessed Left hand inward opening solid timber door with multipoint locking system, set in steel frame + additional top lock.



**Figure LSS+3220 External - Flush with building right hand outward opening steel paneled gate with steel mesh and full cover plate;
Internal - Standard timber door with glass panel.**









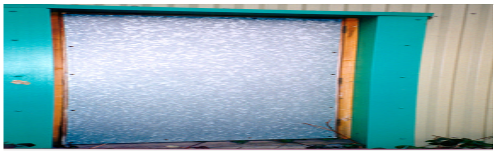


Figure LSS+3221 Left hand outward opening recessed solid timber fire door with steel panel. No locks visible but assumed three point locking using panic bar inside.



Figure LSS+3222 External - Heavy duty right hand outward opening steel gate proud of building line with single lock and no cover plate; Internal - Right hand inward opening timber door, locks unseen.



Figure LSS+3223 External - Recessed right hand outward opening steel gate with three standard butt hinges and no cover strip; Internal - Right hand inward opening timber paneled door with two locks visible.

The KIBB Lock Company, Ltd. in Willenhall, England has developed a unique system for interlocking strike plates that can make forced entry significantly more difficult. Sigma has conducted tests with this system to determine specific techniques to bypass the mechanism, detailed in the video. The company also produces a variety of locks for different security applications. Note the demonstration of different forced entry techniques with traditional and interlocking strike plate designs.

Demonstration of different forced entry techniques on doors utilizing the Kibb interlocking strike plate design. Note the first clip shows a standard strike and bolt arrangement.



Figure LSS+3230 KIBB interlocking strike plate and rim lock design. Courtesy KIBB Lock Company.

Sigma analysis of the Kibb interlocking strike plate, with Ian Bauchop.

BOOK THREE: PROTECTED AREAS

Locks, Safes, Vaults, and Secure Areas

Book III provides detailed information about safes and vaults: their history, construction, individual components, and penetration. The information in the next four chapters is not intended as a comprehensive treatise. It offers a detailed working knowledge of the subject to allow investigators and craftsman to understand the fundamentals of construction and bypass. Methods of penetration, both destructive and covert, are also examined. See **LSS+/^{x} CD/ROM** for a more detailed description of bypass techniques.

CHAPTER THIRTY-THREE: SAFES AND VAULTS

The Origins, Development, and Design of Safes, Vaults, and Strong rooms

Master Exhibit Summary

Figure 33-8 S&G three chronometer mechanical time lock
Figure LSS+3301 A seventeenth century German strongbox
Figure LSS+3302 German chest lock, seventeenth century and a French chest, sixteenth century
Figure LSS+3303 German chest locks, seventeenth century, and fifteenth century.
Figure LSS+3304 Record safe with internal component layout.
Figure LSS+3305 The money safe and internal view.
Figure LSS+3306 Examples of composite safe, cladded safe, and combination safe.
Figure LSS+3307, an example of a floor safe and SMNA labels for fire and burglary rating.
Figure LSS+3308 Examples of fire protected file cabinets.
LSS101: Discussion of safe design by Bill Sherlock.

33_1.1 Introduction

Not until the late eighteenth century did the safe maker begin to incorporate significant technology to frustrate attacks of the safecracker. In **Chapter 5**, detailed information was presented regarding metallurgy and its vital role in the production of secure safes and vaults. This chapter will briefly trace the history of the modern burglary and fire safe, the origins of the safe depository, and will analyze the construction of safes, vaults, and secure areas.

A burglary-rated safe or vault, in its simplest form, is a secure enclosure that offers resistance to penetration by various forcible methods. Once containers for valuables were classified as “safes,” their craftsmen sought to create increasing resistance and obstructions to forced-entry. Manufacturers and burglars have always been at war with each other; often the safecracker having developed more sophisticated technology than the safe maker. The "modern" safe began upon its tortuous road of development about two hundred years ago, probably near Wolverhampton, England. A great deal of the credit for the modern safe technology belongs to Chubb, and thus many of their accomplishments are chronicled here.

The origins of the modern safe and vault can be traced to wooden chests created in medieval times. These enclosures were originally reinforced and secured with hammered iron bands. The

primary concerns, at least initially, were artistic rather than security. Until the introduction of cast iron chests in the seventeenth century, these containers were often covered with very fine ornamental carving.

Commercial production of safes began in Britain towards the end of the eighteenth century. Their frames were covered with sheet iron, strengthened with hoop iron, and crossed at right angles on the outside and riveted through. Safes that were produced in Europe were often made to a very high standard of craftsmanship and ornament. Often, these containers were secured with a great number of bolts: as many as twenty-four in some instances. Unfortunately, once the lock had been picked, all the bolts turned together with great ease. Until the nineteenth century, no attempt was made to make burglary resistant chests fireproof.

The reader will find interesting the description of the security requirements of an **iron safe** by George Price in his book that was published more than one hundred fifty years ago. These same criteria apply today.

33_2.1 Construction of Safes and Vaults

33_2.1.1 Introduction

Safes and vaults are containers or enclosures that have been specially manufactured and engineered to provide certain standardized measures of protection against fire and forced attack. Design is dependent upon their classification and rating. Key and combination locking mechanisms will carry their own ratings independent from the enclosure. The older safes were constructed of heavy cast iron that was riveted to steel plates. Until the beginning of this century, quantity of metal rather than quality of construction was thought to provide the best security against attack.

As our technology and knowledge of metals increased, great strides were made. Today, safes are manufactured of pressed steel or other metal alloy. Unlike their forerunners, all metal pieces are now welded rather than riveted, using tongue-and-groove construction. The metals are also able to conduct heat more efficiently. Fire resistance ratings have been refined to the point where some safes are capable of withstanding atomic blasts.

Safes are rated as to the construction of doors and walls: laminated or solid steel is most generally employed. Laminated

steel is defined as two or more sheets of steel bonded together with no other material between them. The thickness of the doors is usually considered exclusive of the bolt works and locking device. Each door of the safe is usually equipped with at least one combination or approved key lock. Steel, brick, reinforced concrete, and manganese are used in the construction of vaults to surround doors and frames.

This chapter examines the components of safes, vaults, and strong rooms, concentrating on materials, placement, and construction techniques. Ratings and classifications will also be explained. The construction and mechanical operation of combination and key locks is discussed in **Chapter 34**.

33_2.1.2 The First Safes and Vaults

Records indicate that the first significant attempts at constructing treasuries and vaults occurred well over three thousand years ago within many different cultures. For example, Ramses III of Egypt first commissioned a treasure temple to be built. The Greeks stored their State valuables in a vault protected by great bronze doors. The Chinese kept their precious items in ancient chests. The Romans initially produced chests of wood and cast iron to secure cash and smaller valuables belonging to powerful government merchants. Over time, the "technology" of building these containers became more elaborate and complicated. Eventually, the weight of the lid, with its intricate bolt works and lockworks, required a great deal of strength to lift. The early construction practices made them difficult to close.



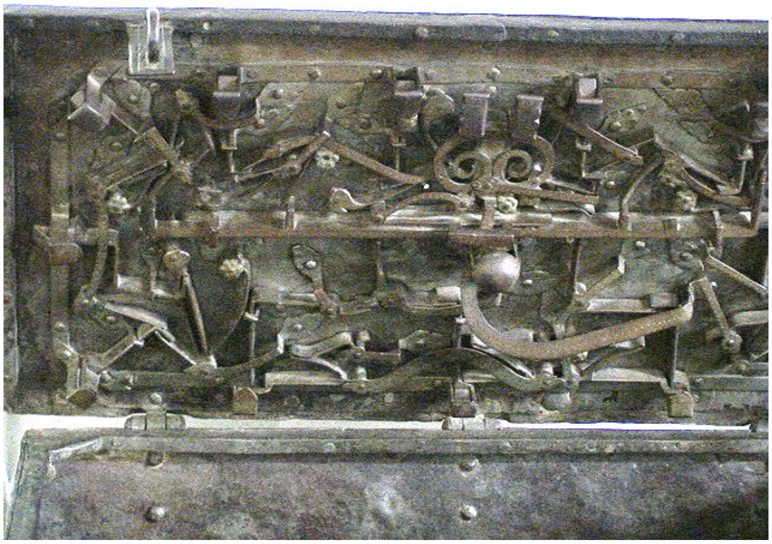


**Figure LSS+3301 A seventeenth century German strongbox, referred to as the Armada
or Nuremberg. See the link for an enhanced view of the detailed mechanism.**

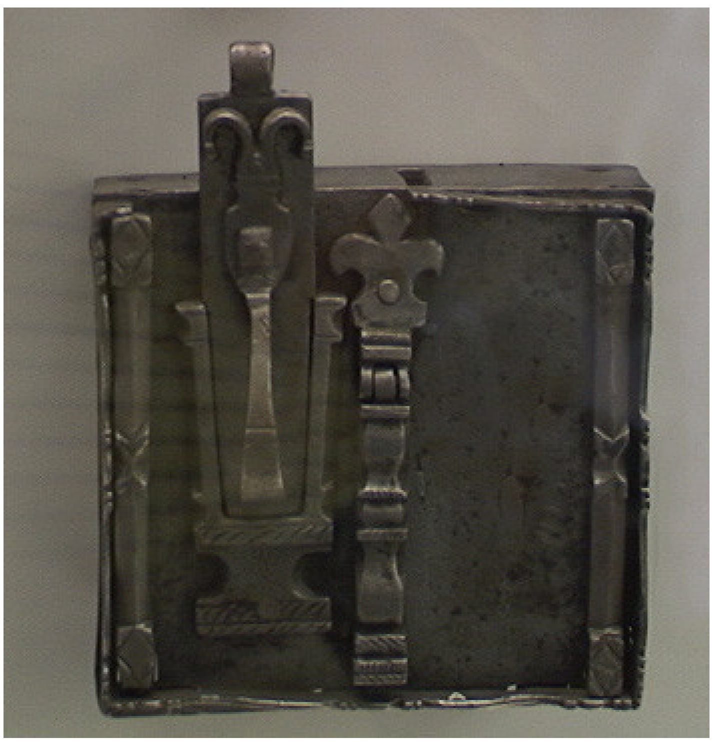




Figure LSS+3302 German chest lock, seventeenth century (left) and a French chest, sixteenth century (right).

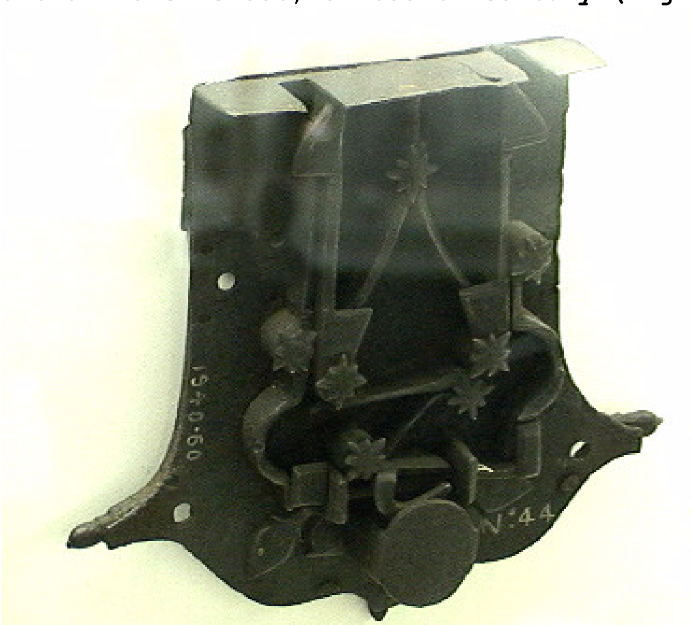




Figure LSS+3303 German chest locks, (left) seventeenth century, and (right) fifteenth century.

Necessity finally dictated that these chests were turned on their side and the lids made into hinged, swinging doors, thus creating

the first safes. These constituted an upright form of the strongbox or chest made of wood. They were lined both inside and out with iron plates held by rivets or screws. Shielded bolt works were the norm, although external hasps could also be found. These “safes” or strongboxes were first produced as a manufactured item at the end of the eighteenth century in London by blacksmiths. They were made on an individual basis using traditional metal-working techniques with quite simple specifications. Beginning in the nineteenth century, the public came to demand added security in their safes and vaults. Consequently, several companies began production of more secure safes to meet the needs of the community.

33_2.1.3 Metallurgy, Materials, and Construction Techniques

Once metals replaced wood in the construction of safes, blacksmiths and manufacturers concentrated on how to make the materials suitable for secure enclosures. As the craft of safe making advanced, metallurgy took on increasing importance and became a vital science to safe makers such as Chubb. The critical difficulty for the metallurgist has always been to produce a material which is hard enough to resist drilling and cutting, yet tough enough to withstand fracture under pressure or percussion. See **Chapter 5** for a detailed discussion.

Initially, iron was the predominant metal used in the production of safes and vaults. Then, carbon and iron were combined to produce steel. As the industry became more sophisticated, steel was mixed with metals that are more exotic, such as manganese. These would add special characteristics of strength, heat transfer, and drill resistance. When first introduced, iron ore was heated with charcoal to produce a spongy material that could be hammered into shape. Next, blast furnaces were developed that were equipped with bellows. These were utilized to blow air across the metal, allowing iron to be poured as a liquid called pig or cast iron. The problem with the new material was that it could not be hammered because it would shatter. It had to be poured or molded.

The availability of charcoal was responsible for Abraham Darby developing a smelting procedure with iron and coke at the beginning of the eighteenth century. A cheaper process, it made mass production possible. Puddling was the next advance. It was the outgrowth of smelting and produced wrought iron using a more sophisticated system and higher temperatures. Wrought iron was a

tougher material, would withstand stresses, and could be forged or hot- rolled into plates and strips. The technique was utilized by safe makers until the middle of the nineteenth century.

In 1856, Henry Bessemer developed a method to produce steel for a small fraction of the prior cost by blowing air through molten pig iron. In 1860, Chatwood the English safe maker took two sheets of iron and sandwiched molten metal between them. The effect of this innovation was that the center was extremely hard and would shatter or flatten drill bits. This was a much better solution than simply multiplying the number of iron sheets, as had been the practice until that time. The technique resulted in rolling high carbon steel to mild steel. This sandwich approach resisted cutting and torching.

Copper plates were located between the steel plates as a conductor of heat. This effectively prevented the steel barrier behind the layer from reaching melting point. Layers of metal were added for security and to perform secondary functions. Many grades of steel have been developed for use in safes. All are based upon the amount of carbon and temperature when added. If one percent carbon is present, the steel is three times stronger than iron. More carbon causes brittleness. The mixture can be finely honed for custom requirements. The addition of more than 2.5 percent carbon will produce cast iron.

As explained in **Chapter 5**, the relationship of temperature and carbon content is critical to the production of steel for use in safes. The needle demonstrates the salient characteristics. If a needle is heated to red-hot then cooled quickly in water, it will break easily but will be very hard. On the other hand, if it is heated then cooled slowly, it will bend like wire. This is known as tempering. It may occur many times by reheating to red-hot, cooling rapidly, reheating to a yellow color and then cooling slowly.

The surface of the material can be treated by a process known as **case-hardening** by increasing the carbon and nitrogen at and below the surface. This technique yields the strength of low carbon-steel with a very hard surface. Special alloy steels, such as stainless, can also be produced for hardness, strength, springiness, and resistance to wear and corrosion. In 1882, it was discovered that steel containing one percent carbon and thirteen percent manganese could be very tough if heated to 1,000C and quenched in water. It was only medium hard, but when

heated would become extremely hard at torch point. This combination prevents sawing, drilling, or filing, and is used today in prison bars and shells of safes.

Safe makers have utilized and developed many sophisticated combinations of metals to increase the security of their products. These materials are employed in the walls, doors, and internal areas of safes and vaults, depending upon burglary and fire resistance ratings. In one Chubb high-security safe door for example, there are ten layers of metal having the following configuration:

1. **Five-ply drill-resisting steel;**
2. **Two of these layers protected by three sandwiches of softer steel;**
3. **Anti-blowpipe material that is a form of concrete and hard mineral chips, with an embedded "I" section steel joist;**
4. **Layer of Siemens steel;**
5. **Layer of copper;**
6. **Five-ply layer of steel;**
7. **Proprietary alloy steel;**
8. **Two layers of Siemens steel;**
9. **Five-ply layer of steel sandwiched between the Siemens layers;**
10. **Anti-concussion spring diaphragm plate.**

Safe engineers must consider many design parameters when producing specialized materials for use in their products. However, their ultimate goal is always the same: prevent penetration, alteration, and compromise of the molecular structure of the materials. Three simple examples can illustrate design characteristics that can be accomplished through metallurgy:

- **Torch resistance must extinguish the flame or spits metal to make cutting very difficult;**
- **Metal in a crystalline form, called speigeleisen, has been used as a layer in a laminate to retain its hardness when heated. If an attempt is made to drill when this material is heated, the drill bit would immediately lose its temper, preventing further penetration;**
- **A drill is a cutting device that works through a process of detempering of the material it is acting**

upon, through reheating and slow cooling. A safe maker will add beryllium and copper layers as heat sinks so that the temperature required for softening cannot be achieved.

33_2.1.4 The Technology of Safes in the Eighteenth Century

From the archives at Chubb, the difficulties of making a secure safe are chronicled beginning in the late 1700s. The safe makers of Chubb and other companies experimented with many different metals, attempting to exploit their characteristics in an effort to stop the safecrackers from achieving their goals. By the middle to late 1800s, safecracking had reached what was considered to be state-of-the-art. Thieves had developed powerful tools, explosives, and various methods for forced-entry. For each advancement that was incorporated by a manufacturer, the safecrackers developed countermeasures.

The second half of the nineteenth century saw the introduction of many innovations by Chubb and other safe makers. They produced containers that afforded more protection from fire and burglars. During this time, the outer doors of fire safes were made of rolled iron or steel, while the inner portion of the door and frame were constructed of cast iron. Burglary safes contained steel plates with different hardness ratings, while joints were covered with forged bands. Drill-resistant metals were developed, such as cast metal and speigeleisen. These were capable of being chilled between outer and inner plates, forming walls. Solid blocks of chilled iron, no less than a foot thick, were grooved, keyed, or bolted together. Each manufacturer developed preferences in safe technology. Thus, Chubb chose to use layers of hard and soft plates, and high-carbon steel welded and rolled between layers of iron or mild steel. The high-carbon steel would provide resistance to cutting tools, while the softer metal would contribute to toughness.

33_2.1.5 Chubb: The First "Modern" Safes

In 1835, Charles Chubb patented his first safe. In that design, he improved upon both the fireproofing and burglarproofing of existing containers. The patent was for "Certain Improvements in the Means of Making Secure Receptacles for Property, such receptacles being either fixed or transported and being such as are usually called Strong Doors, Safes, Chests and Boxes." The early Chubb safe offered significant refinements for that era.

Case-hardened (carburized) or tempered steel plate was added to interior surfaces to increase protection from boring and drilling. In his specification, Charles Chubb used a strong box with side handles and a lid to illustrate his invention. He very quickly distinguished between fireproof wrought iron boxes and plain wrought iron safes in his sales literature. Soon, the safe changed in character from being an iron box mounted on its side, to being a receptacle in its own right.

In 1857, John Chubb received a patent for an improvement to prevent burglars from drilling a hole in the iron plate covering the safe lock. A steel plate was added to the lock cover that would damage the burglar's drill bit and prevent them from gaining access to the levers. Then, in 1865 and 1866, patents were granted to strengthen safe frames and bolt holdings. In addition, Chubb also introduced diagonal bolts that helped to prevent door frames from being bent outwards, which previously had allowed the door to be opened.

In 1874, Chubb's new 'Tee' iron safe was patented. This greatly increased the security of fireproof container construction by making it more difficult to remove the back of a safe and impossible (with the tools then at a burglar's disposal) to remove the inner lining and casing. Until the 1880s, safes were manufactured by constructing an angle iron frame to which metal sheets were riveted. Beginning in 1878, Chubb experimented with metal plate bending. At that time, a great deal of attention was directed to the fastening and securing of doors within the overall frame and housing. Cast iron doors and bodies appeared in the nineteenth century. Containers were later produced of rolled iron, then steel, as the science of metallurgy developed.

Many different boltwork schemes and designs were developed for security, including claws, clutches, hooks, screws, and interlace with the frame. The goal was to form a complete dovetail when door and frame would meet that would hold them together against any form of wedging. Chubb also provided extra security measures to further frustrate burglars. Options included electric burglar alarms, time locks, and keyless permutation combination locks that rendered gunpowder attack futile.

33_2.2 Development of Safes in the Twentieth Century

Directly because of the high number of safe burglaries in America, the U.S. Congress authorized the Secretary of the

Treasury to appoint a special commission to determine the best methods for safe and vault construction. This was the first effort to improve the security of safes used by the treasury, and occurred over a century ago. Experts hired by the Commission conducted exhaustive tests of all major safe brands. Their conclusion was less than assuring. The state of safe making in the United States was poor in terms of resistance to attack. In fact, it was determined that only the Corliss cannonball safe was secure because it was cast in the form of a sphere. One hundred years later, these safes are still found in courthouses throughout the United States.

The high incidence of attacks on safes and vaults both in the United States and in Europe provided the impetus for significant advances in the security of containers during the twentieth century. This need converged with improvements in metallurgy and manufacturing to foster the development of high-security containers. The efforts of safe makers for the past century to make a secure enclosure have primarily focused upon materials and techniques to prevent or delay physical access to locks and bolt works. They have concentrated on means of penetration using drilling, explosives, and the use of high temperatures or temperature differentials.

Early on, metallurgy became a vital science to safe makers. Advances in the science have produced sophisticated and complex barrier materials to meet the constant and difficult challenges presented by the safecracker. There is one essential theory of metallurgy that applies to safe construction: materials that are hard and strong are also brittle and will crack under repeated shock force. That principle has spawned two hundred years of research and innovation by the major safe manufacturers of the world.

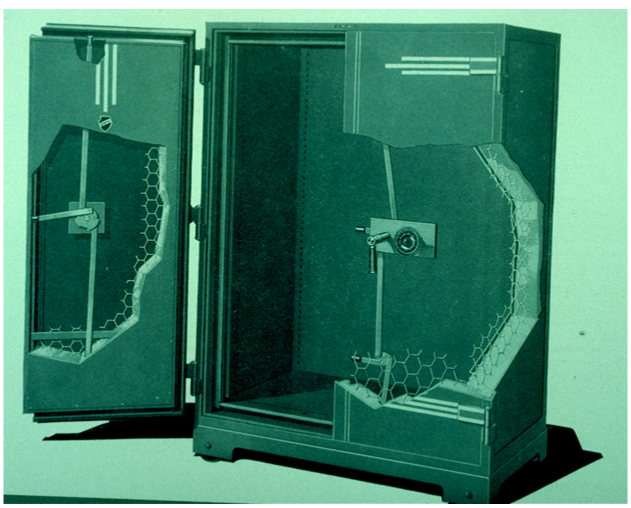
Until late in the nineteenth century, limited materials and processes were available for producing and treating iron and steel; safe makers faced many difficulties in finding materials that would resist heat, concussion, and other forms of physical attack. In 1912, Chubb introduced anti-blowpipe metals into the body and doors of their safes, increasing resistance to attack by drill and oxyacetylene. Then in 1930, solid proofing material was first used in their containers.

It appears that Chubb and other companies introduced relockers during the 1930s. These devices would frustrate a safecracking technique using explosives or blowpipe to blow apart the lock. In

1959, Chubb introduced anti-arc alloy into safe doors as protection against oxy-arc cutting. This was followed in 1962 by the development and introduction of TDR (torch and drill-resisting) alloy. During the 1970s, new protective materials were introduced, based upon specially engineered concrete compounds that combined thermal strength and toughness with drill resistance. Advances in boltwork designs were also developed during this period.

Today, safes provide a high level of security based upon the design of their locks and advances in metallurgy. Although it is still possible to penetrate hard plate and outer barrier materials, the task has been made measurably more difficult through innovations in chemistry, physics and mechanical engineering. Locks can still be opened through manipulation, robot dialing, and drilling, but the requirements of commerce and security now offer a level of protection heretofore unmatched.

Within the category of burglary resistant safe, there are many different designs. These are shown below, and detailed in **Chapter 35**, with regard to their vulnerability and methods of attack.



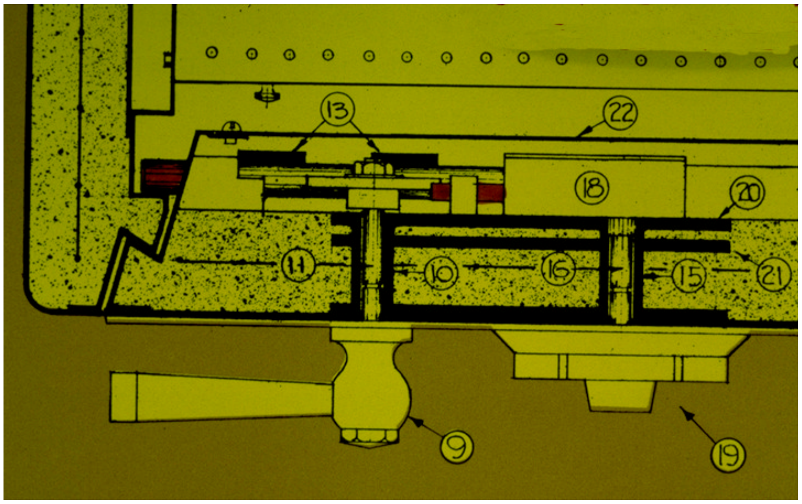
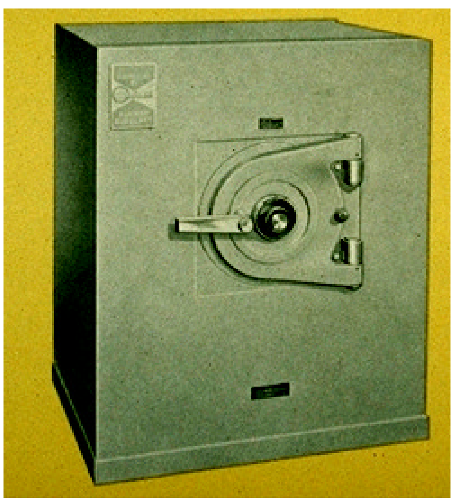
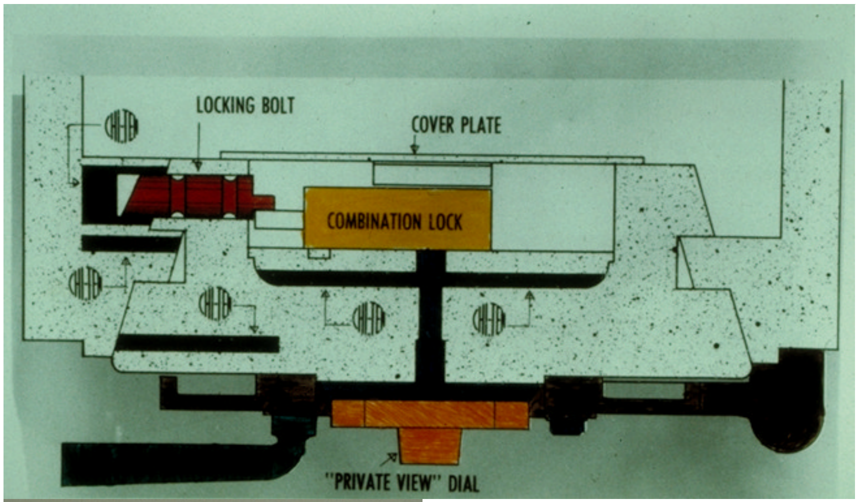


Figure LSS+3304 Record safe (left, ISP-3563-04), with internal component layout (right, ISP 3563-05). Courtesy of Illinois State Police, Bill Sherlock.

LSS101: Discussion of safe design by Bill Sherlock.





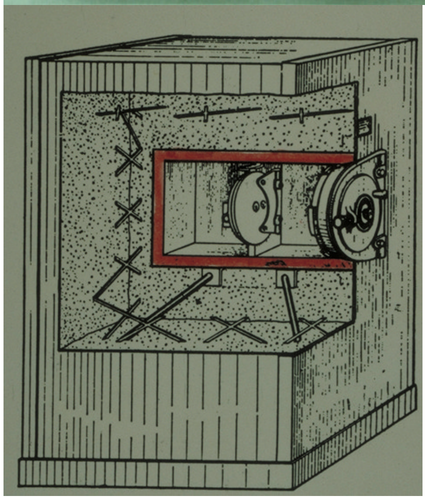
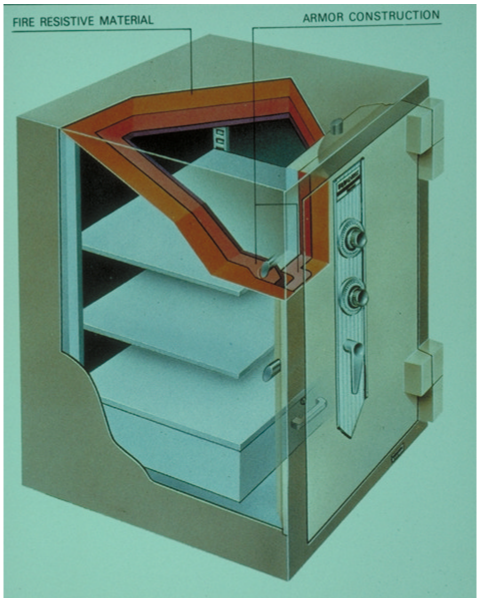
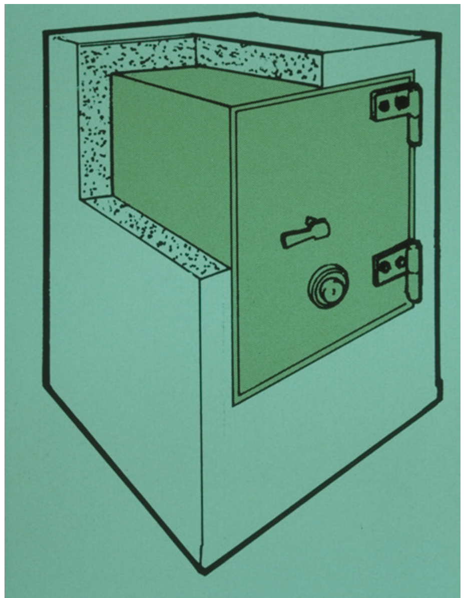


Figure LSS+3305 The money safe (left, ISP 3563-07), and internal view (ISP 3563-08, 09).
Courtesy of Illinois State Police, Bill Sherlock.





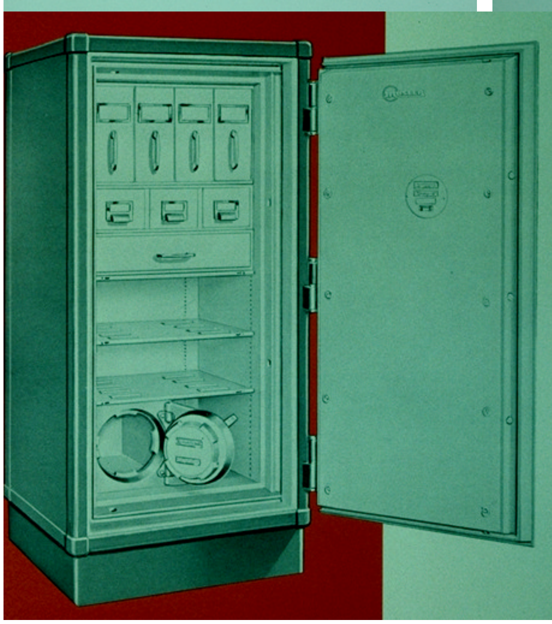


Figure LSS+3306 Examples of (left, ISP 3563-09) composite safe (burglary and fire), Center (ISP 3563-11) Cladded safe or encased safe, door only is UL rated, and (right, ISP 3563-13) combination safe. Courtesy of Illinois State Police, Bill Sherlock.

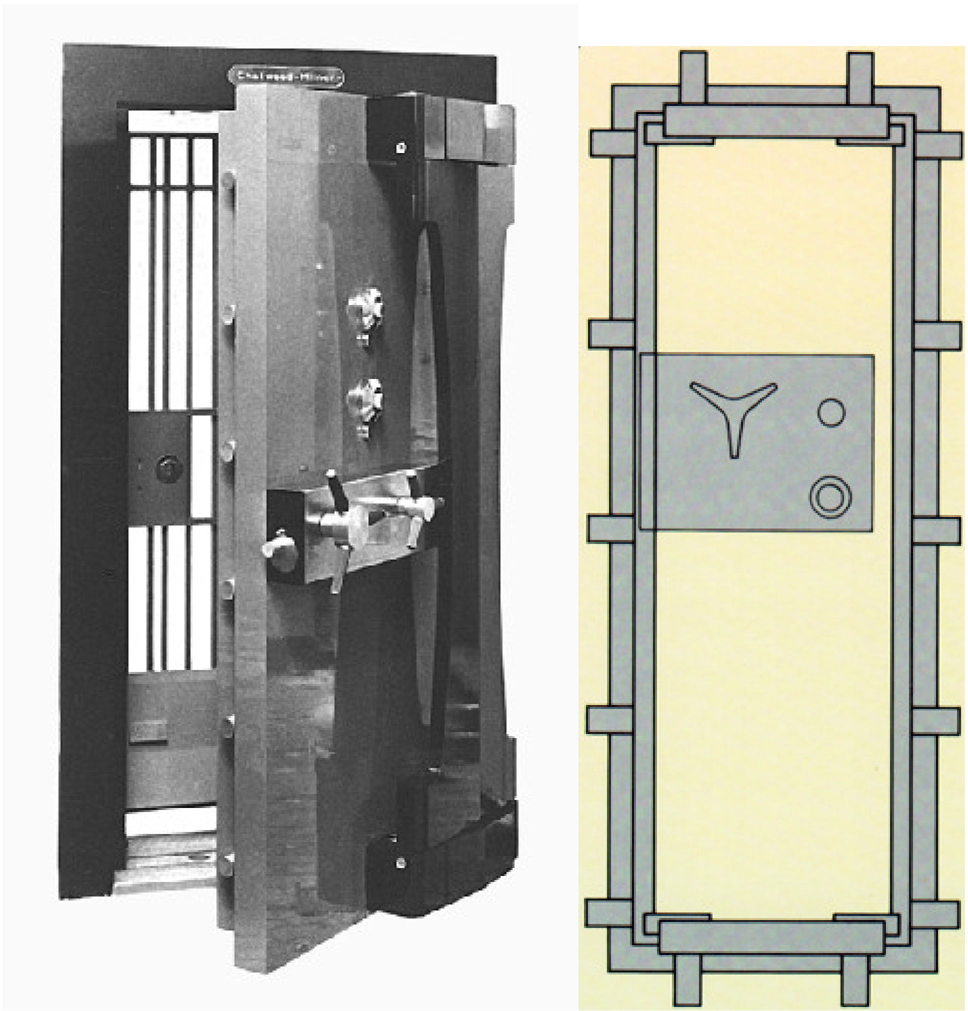


Figure LSS+3307, an example of a floor safe (ISP 12-3563), showing its inherent fire protection because fire burns upward only, and (ISP 21-3563) SMNA labels for fire and burglary rating. Courtesy of Illinois State Police, Bill Sherlock.

33_2.2.1 Vault Doors

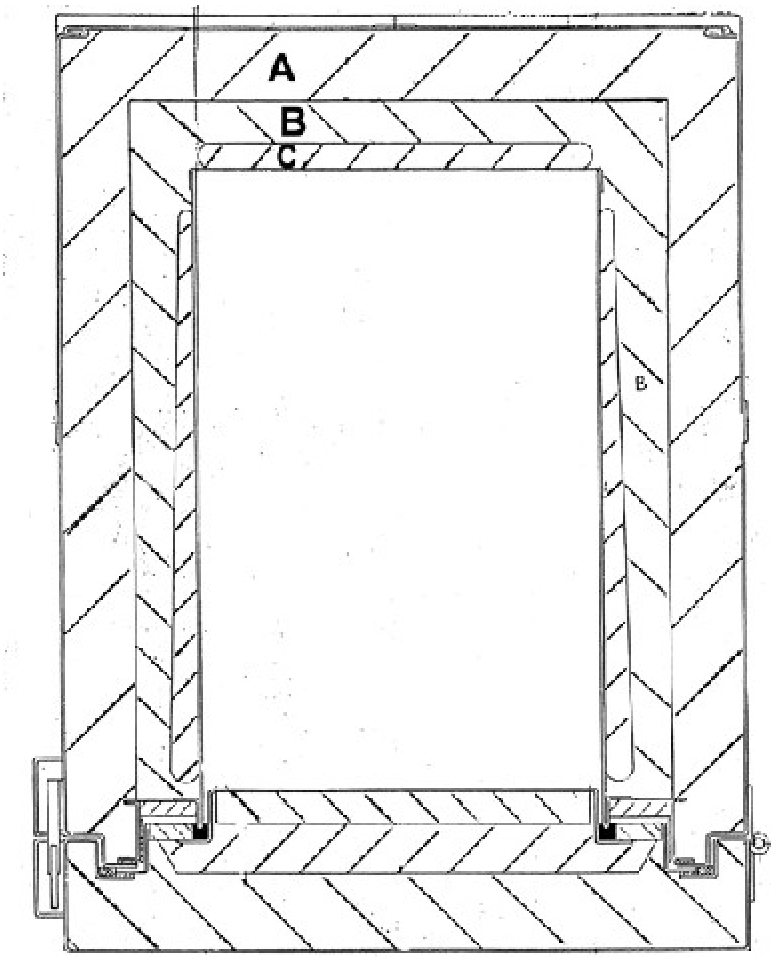
Vault doors are but an outgrowth of a self-contained secure container; they provide the barrier for access into a larger

area. Found in office buildings, warehouses, and other secure areas, they are nothing more than a larger version of fire-resistive or free-standing plate door safes. Vault doors are classified for either fire or burglary. The fire ratings start at one hour and increase to a two- four- and six-hour protection. An additional distinction relates to how doors are set at the entrance to the strong room.

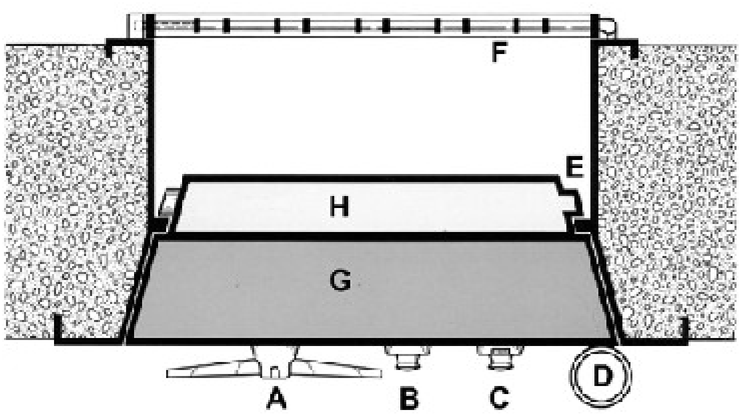


The doors that are set in the vault entrance are of the **grouted** or **non-grouted** type. Grouted door frames are set, then concrete is poured around the frames. Non-grouted doors are not permanent parts of the building and can be removed. If the building settles, the doors can be readjusted. Often, this is preferable because installation costs are reduced. The appearance of these doors can be misleading; bigger does not necessarily mean better or more secure. Penetration or bypass techniques are essentially

the same as with traditional safes because the construction methods are similar.



Generally receiving a “B” security rating, burglar-resistant plate doors will often have a maximum 1/2" thickness. Although "TL" rated doors do exist, they are quite rare. GSA rated doors in government facilities will often have added hard plate, relocking devices, or unusual lock positioning, making penetration extremely difficult for both the burglar and safe technician. Health and safety codes now require all vault doors to be equipped with an internal release to prevent users from being accidentally trapped within the vault. Releases can take many forms, depending upon manufacturer. They include push-in plunger, panic bar, and direct-drive handles. An internal release may also provide another method to open the door in the case of a lockout. For example, a stiff wire placed through a small hole can release the mechanism.

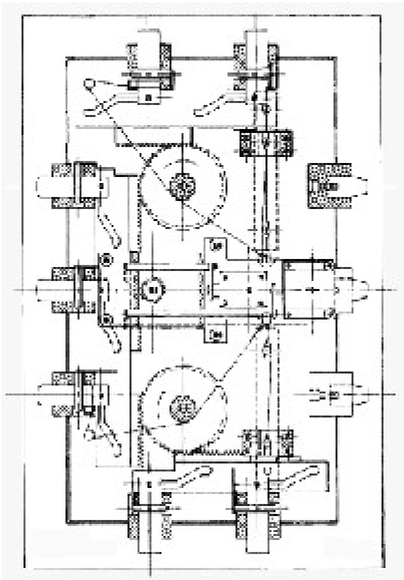


33_2.2.2 Bolt works

Safe and vault doors employ simple to extremely complex boltwork schemes in order to interlock moveable components to the body of the container. Multilevel and four-point systems will provide positive locking completely around the door. The bolts are usually interconnected to a series of deadlocking relockers.

33_2.3 Secondary Protection of Safes and Vaults

Secondary protection of safes and vaults can be incorporated through a variety of devices and techniques including tear gas and other noxious gasses, glass plate, thermal transfer materials, and relockers. Their use is often dictated by the security rating of the enclosure and price. Each technique is described in the following sections, with special emphasis on relockers.



33_2.3.1 Tear Gas, Noxious Fumes and Marker Gasses

Tear gas ejection devices are routinely incorporated in certain high-security safes. Generally placed behind the spindle, they will trigger upon impact. Materials may also be embedded within barrier layers to give off noxious gasses when heated by a torch or lance. Chubb and other companies also include materials that will generate markers in the form of dense colored smoke. This will make working on the safe almost impossible and will leave residue on anyone that comes into close proximity with the enclosure.

33_2.3.2 Glass Plates

Specially engineered glass panes made of Herculite or similar material, together with deflection, plates are placed in front of the combination or key lock to deter drilling attempts. In high-security safes, plates are located on all six sides to block penetration from any angle.

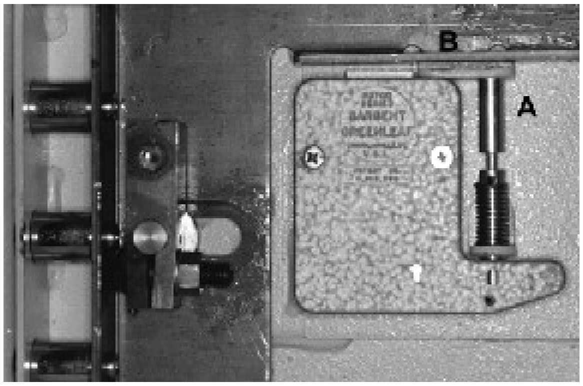
Glass is connected to tensioned **relockers**, discussed below. When shattered, the glass disintegrates, causing relockers to fire. This will make actuation of the bolt impossible without release of the relocking mechanism. Explosions, point-source concussion (such as from a drill point), and excessive vibration will break the glass and trigger the relocker.

33_2.3.3 Thermal Transfer Materials

Sophisticated heat sinks are embedded in the barrier materials of the more secure safes. Layers of copper, beryllium, aluminum, and other metals are utilized to rapidly conduct heat away from a target area. Their function is to reduce the surface temperature below melting point to prevent cutting by a torch.

33_2.3.4 Relockers

When they are triggered, **active** and **passive** internal and external relocking devices are utilized to permanently lock the bolt-release mechanism. They are incorporated within combination and key locks and throughout the boltwork mechanism of all modern safes.



They are designed to protect against the following forms of attack:

- **Punching the wheel pack;**
- **Drilling;**
- **Side-pressure of the bolt;**
- **Thermal attacks;**
- **Vibration and concussion.**

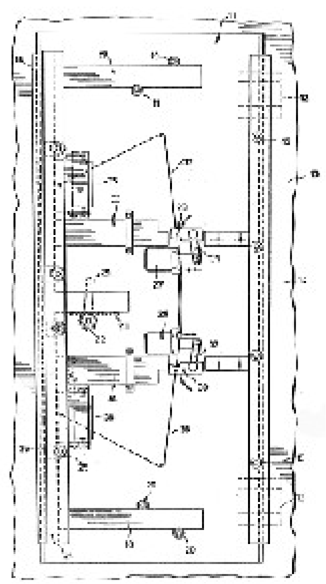
When "fired," a relocker will lock the bolts, throw extra bolts, drop deadlock pins into place, or disconnect the links to bolts from an actuator.

The design of a relock trigger requires that it be reliable for the lifetime of the safe. It must not be too sensitive or insensitive, and cannot be complex or delicate. It must be capable of surviving the normal vibration associated with door openings and closings and it must be rapid reacting. Complex

relockers are constructed with tensioned tourmaline line, connected to secondary bolts and some sort of sensor. As described above, sensors may consist of Herculite glass, weights, spring-loaded levers, pivots, or metal strips that are thermally activated.

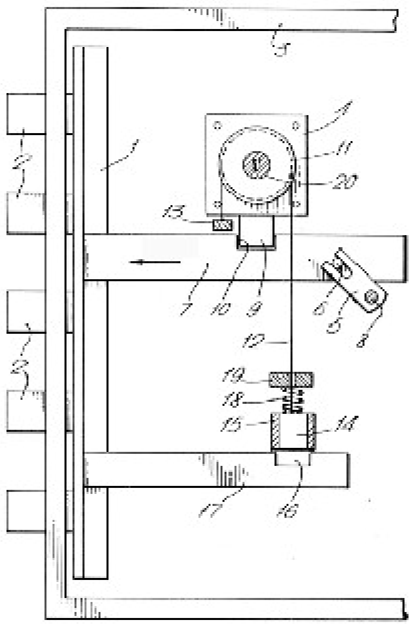
33_2.3.4.1 Relockers on Safe Locks

Internal relockers are mechanisms that deadlock the bolt, thereby isolating it from the wheel pack. The removal, distortion, or destruction of the lock cover or wheel pack usually activates them. Lock case relockers were developed in response to a common burglary technique in small safes that involved an attack upon the lock by punching. This method required that the dial be knocked loose and then the spindle to be driven into the safe and through the lock case. The wheel pack would be removed, thereby eliminating the fence-gate relationship. Using a wire tool, this technique allows the bolt to be retracted through the spindle.



Relockers may be rudimentary or complex in their design and function. Removal, damage, breaking of the lock case cover, or distortion of the wheel pack will prevent the bolt from being withdrawn. The action will cause the trigger to spring outwards, forcing the opposite end to enter a recess in the lock bolt thereby deadlocking it. This design is based upon a simple lever pivot retained by the position of the lock case cover. So long as the cover is loose, the relocker will be engaged. In the more sophisticated design, simply replacing the lock cover will not

reset the device because the relocking pin operates independently of the trigger. A lock within which the relock trigger has fired will allow the combination to be dialed, but will prevent the dial from retracting the bolt.

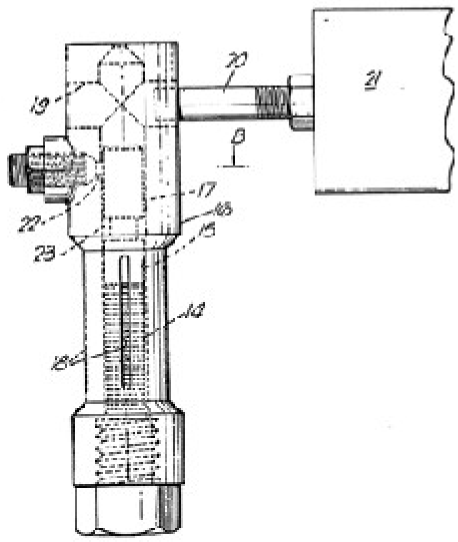


There are many designs for internal relockers within lock bodies. Depending upon the manufacturer and vintage of the mechanism, these can appear as a brass tab (Yale), a formed wire (LaGard), a pivoting lever (S&G), and a spring-loaded pin (Mosler). Whichever design is adopted, the primary function is to prevent the bolt from being retracted. Manufacturers will generally place **lock case** relockers in one of two positions:

- **Within the lock case. They are activated by the breaking or removal of the wheel pack, complete lock, or handle shear device;**
- **Within the door. They are triggered by breaking or removal of the lock case cover.**

If the lock cover becomes loose or detached from the case, a lockout problem will exist that can be extremely difficult to solve. This condition can occur from normal opening and closing of heavy vault doors. A more detailed discussion of combination

lock relockers is presented in **Chapter 34** and disclosed in several U.S. and British patents. See U.S. Patents (**4266488(370)**, **4470275(371)**) and British patents (**2172931A(372)**, 2179094A, **2241983A(373)**, **2119011A(374)**, **2069589A(375)**, 2114649A).



33_2.3.4.2 Thermal Relockers

Thermal relockers make inoperable the bolt-release mechanism upon the application of heat to the walls of a safe or its lock. Materials that are sensitive to rises in temperature are employed to release tensioned mechanisms, thereby triggering various relockers. The **thermal link** or **fusible link** is activated by a rise in the internal temperature of the enclosure or of the barrier material. A "fusible link" consists of two overlapping metal pieces that have been bonded with low-temperature solder. A ring is formed on each end of the link. One end is attached to the target area of the combination lock or barrier material; the other to a rod, wire or chain that is in turn connected to a remote relocker. The link will retain a spring-loaded bolt that, if activated, will block action of the primary boltwork. Heat above a predetermined threshold level (release temperature) at the target point will cause the solder to melt, firing the link. Fusible links can be installed anywhere within the door.

33_2.3.4.3 External Relockers

External relocking devices outside the lock case will deadlock the bolts or bolt- retracting assemblies, or directly act as secondary bolts to secure the door. Most relocking mechanisms,

by whatever name, are spring- or gravity-activated bolts or bolt blockers placed in critical locations within the container. They may be connected to the lock case, handle, walls, or glass panels.

The glass plate relocker is activated by shock, vibration, or point source pressure caused by drilling. The specially formulated glass in some ways resembles the type used in automobiles. Panes are placed in front of the lock case and are anchored in flexible rubber grommets. These are utilized to minimize the potential for fracture in normal use. Tensioned wire or string is attached to the glass plate. So long as these wires are spring-biased, the relockers will be held in position, thereby inhibiting their plungers from being released. If the glass is chipped, scratched, subject to excessive vibration or pressure, or is contacted by a moving drill point, it will shatter into minute fragments.

33_2.3.4.4 Handle Shear Pins

Handle shear pins are another form of protection used in conjunction with relockers. They are designed to break loose and disengage the linkage if excessive force is applied. The handle shaft is also purposefully weakened during manufacture, so that it will break if too much torque is applied.

33_2.3.4.5 Bypassing Fired Relockers

Relockers are designed to offer anyone attempting to penetrate barrier material a great deal of difficulty. They are intended to cause substantial delays to both the safe technician and burglar. In the higher quality safes, there may be several different types of relockers randomly placed. The author’s rule: if not sure of the type or location of a relocker, don’t drill or take any action that may trigger a device.

Relockers can be bypassed by drilling at a precise location that will allow their retraction. Generally, a template is required for accuracy in result. Based upon their design, the drill point locator for the trigger should allow for the disengagement of the mechanism by either pushing or pulling.

33_2.4 Safe Classifications and Ratings

Safes can be categorized as either fire or burglary resistant. Fire safes will protect the contents against destruction from

heat; burglary, against unauthorized access. Some safes also have both fire and burglary ratings, but generally there is a compromise in characteristics. A safe utilizing plastics has been developed by Chubb to provide both forms of protection. Although Chubb was awarded the first patent for such materials, there will doubtless be others in the future. See **Chapter 37** for a more detailed discussion of ratings and classifications.

33_2.4.1 Fire Ratings

Fire ratings are based upon temperature and time: the likely maximum temperature to be encountered and the time until the fire will be extinguished form the primary guidelines. The internal temperature of the safe, based upon these two parameters, will determine which materials can be stored within. Underwriters Laboratories provides ratings based upon three primary tests: **endurance**, **impact**, and **explosion hazard**.

33_2.4.2 Burglary Ratings

Underwriters Laboratories and other world testing organizations have developed comprehensive standards for testing locks and safes against both forced and surreptitious entry. Safes are rated for their resistance to torch, tool, and explosive attack in terms of time and sophistication of required equipment. Locks are classified as to their resistance to forced-entry, manipulation, and other forms of bypass.

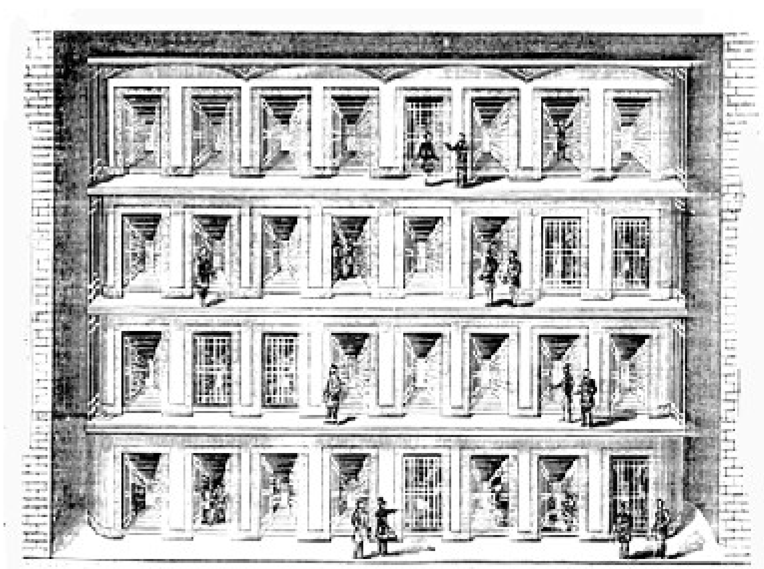
33_3.0 Safe Depositories, Strong rooms, and Vaults

33_3.1 Introduction

In the medieval period and the Middle Ages, owners of property would conceal their valuables behind thick stone walls made inaccessible with a wide and deep moat or in cellars protected by hardwood doors. In the United States, valuables were placed below ground. The development of safes and strong rooms is also traced by George Price in **Chapter 8**. The idea of the safe depository was conceived and first introduced by Francis Jenks in New York. By 1861, he obtained a charter for the "Safe-Deposit Company of New York" that was to eventually become the National Safe-Deposit Company of America.

The initial design for vaults required that they be placed underground and have thick brickwork and sheets of iron as a lining. The next progression involved the same methods of assembly but with improved components. The American Hough and Harper Vault, in the 1880s, for example, used chilled iron from blocks weighing 1,700-10,000 pounds each. These were dovetailed together on each edge and set in a granite base bound by steel rods. Within a quarter century, this construction technique was made obsolete by the advent of the oxyacetylene torch.

By 1870, the safe-deposit concept appeared in Britain; the first company was the National Safe-Deposit Company on Queen Victoria Street in London. Requiring seven months to construct, there were thirty-two separate vaults located on four floors. The bottom level was forty feet under the street and had thirteen feet thick outer walls and layers of sheet steel. The hydraulically-operated doors were a foot thick and weighed five tons.



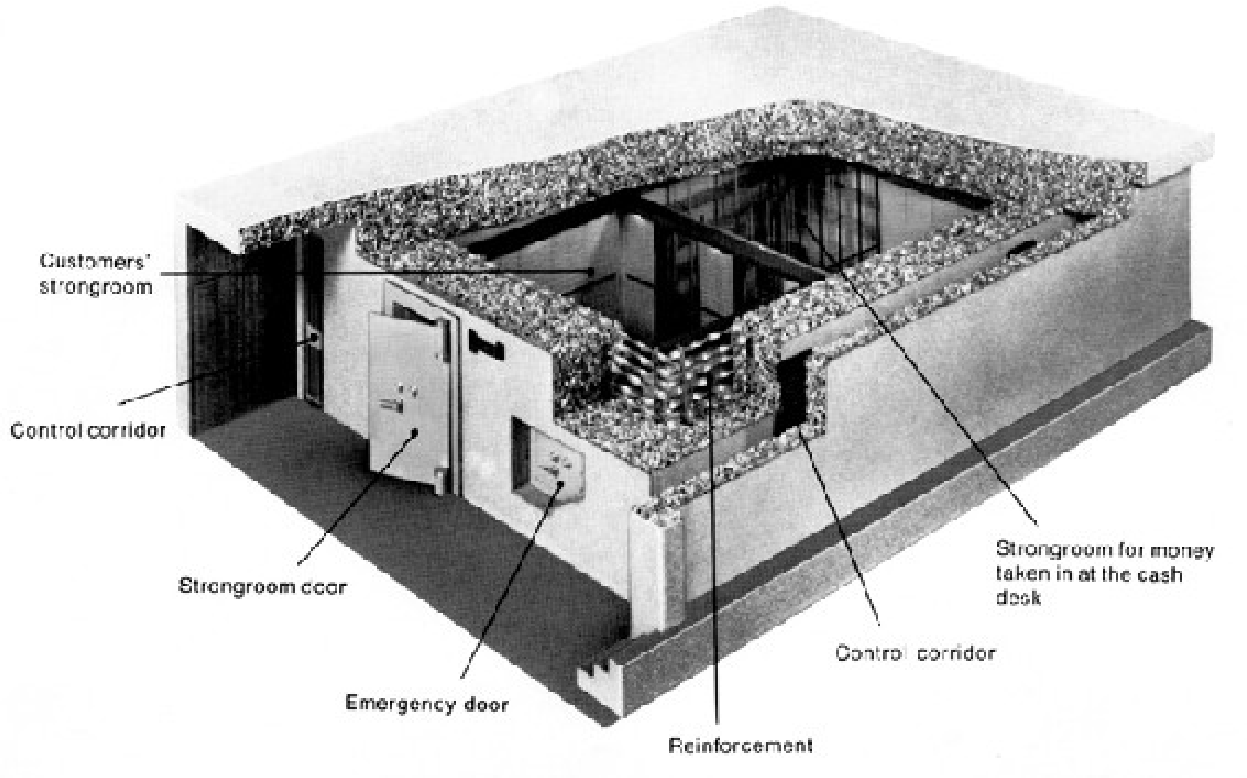
In the 1880s, safe depositories were quite popular. In Chancery Lane for example, there were 40,000 separate lockers. Generally, safe-deposit companies would associate themselves with safe makers. By the 1890s, Chubb was the major manufacturer in Britain of safe-deposit vaults and strong rooms. Today, the rental of safe-deposit boxes is one of the primary services offered by banks. The rise in popularity of safe-deposit vaults can be traced to the economic growth and changes in society that allowed the individual to accumulate wealth. It was not until the 1890s that banks actually got involved in providing this function to

their customers. Today, virtually every financial institution contains a safe-deposit vault.

33_3.2 The Modern Strong room

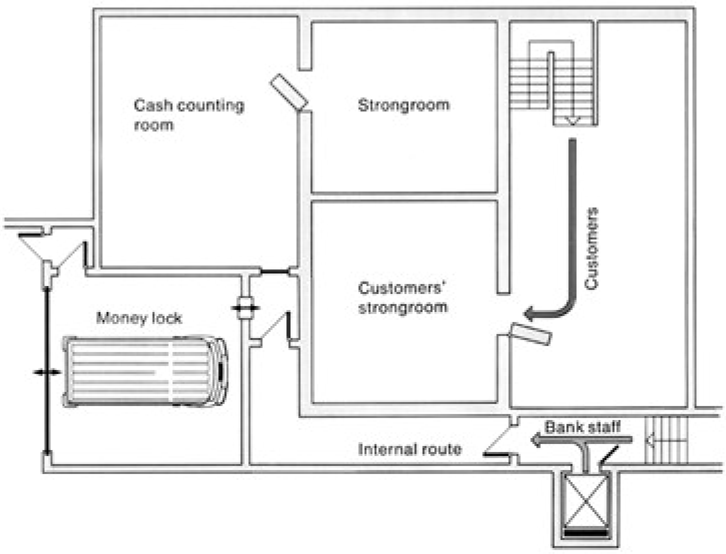


A strong room is nothing more than a large safe with every individual element magnified in its design. They are primarily required to protect high-value items such as gems, trade secret information, magnetic and optical media, precious metals, company data, and cash.



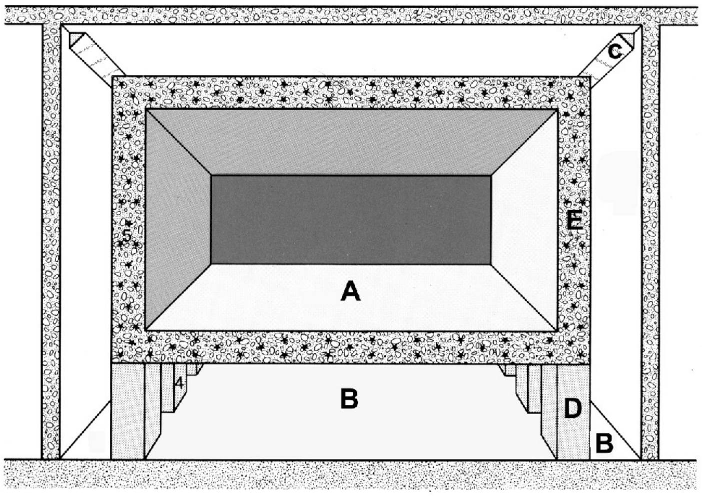
The walls, doors, locks, and defensive systems must be engineered to withstand a prolonged professional attack, as well as war or natural disaster. Interestingly, only one vault has been tested and survived against atomic blast. The strong room at the Teikoku Bank in Hiroshima was close to the center of the explosion and yet remained intact.

The level of security of a strong room is based upon the value of the contents. Even the most secure strong rooms can offer limited resistance against sophisticated burglary tools, such as diamond-bitted drills or oxygen lances. The entrance to a strong room must be massive, and have an extremely precise and tight mating between doors and frame. Doors may weigh up to thirty tons and are often two or more feet thick. Often circular in shape, their tolerance will allow zero gaps to achieve a tighter fit. They may also be rebated, having an interlocked tapered zigzag pattern. Most modern doors use the “plug” technique rather than stepped.



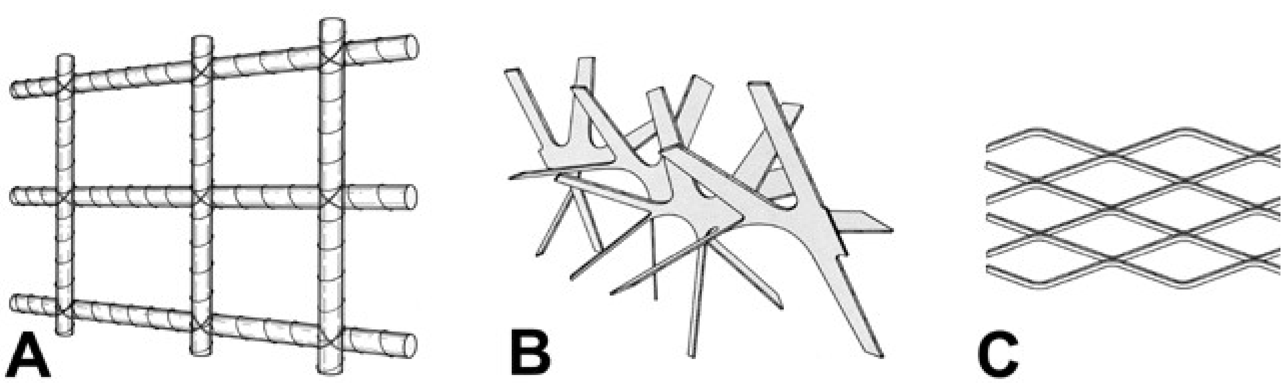
Generally, the newer vaults will utilize two locks and a time lock. Many will also have two doors. See **Chapter 34** for a detailed discussion of combination locks. Walls are designed and constructed based upon perceived risk: fire or burglary being the prime consideration. Construction techniques generally call for multi-ply walls consisting of brick or concrete, reinforced with steel bars. A second ply will generally consist of open-hearth steel, which is itself protected by yet more layers of chrome steel and flame-cutter resistant materials.

The specially formulated concrete used in vaults is usually a minimum of 18” thick and can take up to one year to cure. Simple concrete is not secure and can be penetrated by pickax or drill. Chips of hard stone or metal are often embedded in the mixture in order to deflect and break drill bits.



Concrete must be reinforced with steel for strength and rigidity. Regular steel rods are generally too thin and widely spaced to be effective barriers; their size makes them easy to cut. Initially, "I" beam girders such as railway steel from tracks was utilized in a close pattern, resembling a fence. Twisted bar with two kinds of metal were subsequently employed. This consisted of mild steel rapped around an anti-blowpipe metal core. The improved configuration offered more protection against penetration.

The concrete and reinforcing material must be intimately mixed to form a unified body. Ideally, the steel must present a number of surfaces that form a perpetual recurring obstruction to penetration. A basket weave pattern created between steel and concrete is usually the most effective.



Strong rooms will also contain an elaborate framework of steel

girders. These are often placed in H sections, interlocked, and embedded in concrete and are designed to provide the maximum barrier to penetration. Sophisticated alarm and constant monitoring capability is also required.

During construction, the vault is often finished first, then the protecting structure built around it. Vaults should be considered a separate entity, completely self-contained and independent. They should not be relied upon for structure or support.

33_3.2.1 Designing New Strong rooms

Critical considerations for the design of any strong room include:

- **Location of the building;**
- **Position of the strong room within the building;**
- **Size and type of the strong room;**
- **Supervision and security.**

33_3.2.2 Location of the Building

Proposed sites must be evaluated with respect to their proximity to underground galleries or shafts, because subways or sewage systems can provide a relatively safe access point for attack. Construction sites or businesses located near the vault where oxygen cylinders or heavy tools could be utilized for penetration may constitute extra risk. Particular attention to surroundings is required where vaults are to be built in remote areas. If an underground garage is located next to a strong room, care should be taken that no cars are parked there at night. If that is not possible, then parking should be forbidden in the area around the strong room. If it is impossible to avoid positioning a strong room beside, above, or below rooms that are used by other persons or entities, then access to these areas must be guaranteed by security staff, and electronic monitoring should be in place. No power or water supply should be available in the immediate vicinity of the strong room that would make it possible to use heavy penetration tools.

33_3.2.2.1 Placement of the Strong room within the Building

Generally, strong rooms are constructed on the lowest floors. The

precise location is based upon many factors including expediency, security, building material specifications, and cost.

33_3.2.2.2 Expediency and Convenience

The shortest transport routes for cash and other valuables will often dictate the position of the strong room. Movement of materials should never leave the protected area of the vault. Thus, access to counter areas and other internal cash transport routes, customer safe-deposit boxes, and other secure areas will determine where the strong room is to be located. Proper design requires that all areas wherein cash is transported, counted, accessed, dispensed, or stored should be next to the strong room.

33_3.2.3 Construction Requirements

The floors and walls in most facilities simply cannot meet the physical requirements of a strong room. In the properly engineered installation, strong rooms are usually placed on supporting columns to insure structural integrity. The alternative requires that they be sunk into the groundwater or built on solid rock. The security offered by ground water should not be overestimated, as the conditions can change based upon many man-made or natural causes. The outside walls of a building or of adjacent buildings should never be utilized as the primary barrier for the vault.

33_3.2.4 Security Considerations

All sides of a strong room should be capable of supervision and monitoring. Rooms adjacent to the strong room that are not permanently occupied pose a security risk, because they are good places for initiating break-in attempts. These include filing offices, closets, or maintenance rooms for air-conditioning and heating equipment.

One unique approach to this problem involved the placement of a strong room onto the facade of a high-rise building. The wall that formed the entrance to the strong room was part of the façade; the rest of the enclosure was constructed to hang in the air. Only one wall could be tackled from within the building; all other surfaces were situated in the air and could be seen from every side.

33_3.2.4.1 Security Analysis of Existing

Strong rooms

It may be prudent to analyze existing strong rooms to assess their security. This should only be attempted with a full set of blue- prints and building plans. Special attention must be paid to older buildings, because early construction techniques often called for the use of brick or quarry stone. These materials and the procedures for making joints are totally inadequate to protect against modern burglary tools.

Security may be enhanced by inserting new walls, floors, and ceilings of prefabricated concrete blocks that can be linked together to form secure barriers. Generally, an old strong room that has been upgraded will require a new door. Determine if there are other unsecured doors leading into the vault. Attention must also be paid to openings that have been covered with concrete or lined with building material.

Access routes must be carefully evaluated, especially those that are adjacent to strong rooms. Likewise, the storage of tools near vaults should be discouraged. Finally, alarm systems that were installed years ago should be analyzed in terms of modern bypass techniques.

33_3.2.5 Size and Design of the Strong room

The strong room should be designed of sufficient capacity when first constructed so that later expansion is not necessary.

33_3.2.5.1 Openings in Walls

The number of openings in the walls must be as few as possible. These generally include:

- **Doors (the number is dependent on the demands of organization);**
- **Emergency doors;**
- **Ventilation openings;**
- **Deposit tubes of night safes.**

33_3.2.5.2 Strong room Secure Areas

Several secure areas are usually incorporated within strong rooms:

- **Areas for money received at the cash counter; Secure areas for money taken in at cash counters usually only need one door. Where strong rooms are also used by customers, they should be separate from other areas, both physically and in terms of access routes. The use of alternative transfer methods such as money lifts is not recommended because they offer additional openings and the potential for compromise.**
- **Customer safe-deposit vault;**
- **Special rooms, such as a silver chamber;**
- **Receiving-safe of the night depository;**

Special precautions must be taken to ensure that the deposit shoot that is connected to the outside opening of a receiving safe or night depository cannot be attacked or bypassed.

- **The receiving safe should be located in the strong room to store money taken in at the cash desk. A safe with an adequate security rating should be utilized.**

33_3.2.5.3 Control Rooms and Corridors

Constant monitoring of floors and ceilings and observation from all angles of all outside surfaces of the strong room must be possible at all times. If after an alarm has been activated there are no traces of a break-in within the interior of the strong room, control corridors make it possible to check the outside surfaces.

In order to expedite observation, the strong room is usually built on supports with floors forming the ceilings for the room below. Monitoring should also be possible in spaces between floor and ceiling, especially if the room above is not utilized by security cleared personnel. Control corridors are placed between strong room walls and outer barriers. In such cases, the outside walls should not have the strength of the interior, so that they will yield to hydraulic pressure in case of an attempted penetration. The width of control corridors should not exceed 600 mm; narrow spaces make the use of power tools difficult.

33_3.2.5.4 Walls, Floors, and Ceilings

Burglars will generally direct their efforts to walls, ceilings, and floors rather than vault doors due to their inherent strengths. Thus, each must be sufficiently secure in their individual design and construction. The thickness of strong room floors and ceilings must at least be equal to the walls. The doors should be at least fifty percent as thick as walls. Modern installations generally require concrete whose absolute minimum compression strength is at least 450 N/cm^2 after twenty-eight days. In some jurisdictions, government agencies recommend 600 N/cm^2.

Additives may increase the strength and physical resistance of concrete. Steel splinters, plastic threads, and other materials can provide greater flexibility. They will prevent the immediate destruction of the structure when explosives are employed. They can also protect the material from being destroyed by power tools such as hammers, chisels, hydraulic spreaders, and paving breakers. If properly engineered and implemented, such precautions can offer significant resistance to most cold tools with the possible exception of a diamond-bitted core drill. However, such measures will afford no protection against thermic lances and in fact can enhance their ability to vaporize the material. Reinforcement is frequently embedded in the innermost section of the strong room wall to minimize this threat.

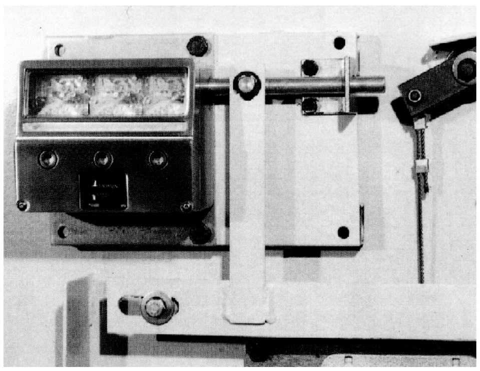
33_3.2.5.5 Strong room Doors

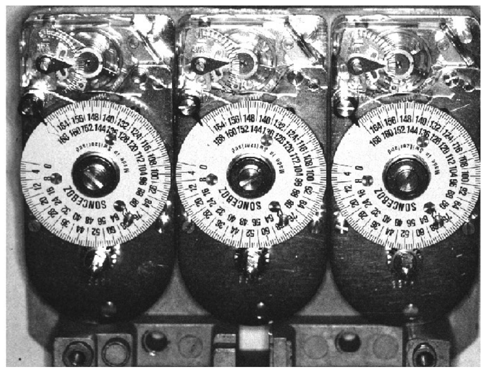
Doors to vaults and strong rooms must have at least the same strength and penetration resistance as that of the outer walls. Doors are generally laminated with many layers of different materials, each to present a barrier against a specific form of attack. Cold tools, torches, lances, drills, and concussion are all considered as threats.

Doors should be equipped with at least two separate and independent acting locks and further protected by a time lock. This design will generally prevent a lockout. Time locks, as detailed in **Chapter 34**, will usually contain three separate movements. Any one of them will release the boltwork. Generally, if a lockout does occur, penetration is accomplished through a wall rather than the door, using core-drilling equipment. Once a breach is made, the door will be opened by a safe technician from the inside.

33_3.2.5.5.1 Time Locks

Time locks disable or block the boltwork within specific timing parameters. When activated, the locking mechanisms cannot be opened, even if the correct combination or key is utilized. There should be no bypass available within the time lock in order to prevent hostage-taking and other means to circumvent the safeguard. During normal business hours, day doors and day locking mechanisms are utilized to provide a lower level of security.





33_3.2.5.6 Ventilation

Secure ventilation shafts should be present in the walls, providing openings of no more than 50 mm diameter tubes. They are usually encased in concrete and separated. Within the strong room, vent access should be sealed with a flap or a bolt to prevent objects from entering. Externally, tubes should be connected with steel plate that is anchored rigidly to the concrete.

33_3.2.5.7 Supervision and Monitoring

To insure maximum security, electronic alarm systems must be capable of monitoring walls, adjacent rooms, and all interior areas. Typically, video surveillance, motion detection, and seismic sensors are utilized.

33_3.2.5.7.1 Motion Detection Systems

Motion sensors will generally incorporate long-range microwave and proximity detectors. Reliability will require that a coincidence of at least two individual sensors be present before an alarm signal is validated. Microwave and infrared are often utilized in one device. Capacity systems can also be employed to

monitor specific targets such as safe-deposit vaults and individual safes. These devices will alarm whenever anyone approaches the target. Surface trips on doors are also standard. See **Chapter 40** for a detailed description of alarm devices.

33_3.2.5.7.2 Alarm Circuits

Wiring between sensors and the central station monitoring facility must be supervised, preferably electronically and visually. Video surveillance may also be essential. Fiber optics, RF transmission, and use of dedicated data circuits or the Internet make real-time video observation both feasible and economical.

33_4.0 Fire Safes

33_4.1 The Early Development of Fire Safes: Enclosures and Materials

Fire safes are specifically designed to protect contents from the effects of high temperatures; burglary resistance is of secondary concern. Today, there are many configurations available for record, document, and data storage. Traditional enclosures, as well as record and data vaults will successfully maintain the integrity of paper, magnetic, and optical media, even in the most intense fires and explosions. Materials used in fire safes must have special properties in order to create a heat sink and buffer for high temperatures. Materials used for fireproofing must be incombustible and non-conductive of heat.

Generally, diatomaceous earth, Portland cement, vermiculite mica, gypsum, and wood chips may be used as insulators. Many proprietary compounds have been developed by fire safe manufacturers that are often but a unique mixture of these materials. Initially, wood satisfied the requirements for a fire-proof layer to absorb heat. The material, thickness, consistent and even distribution, and lack of any gaps through which heat could be transmitted allowed the material to perform satisfactorily.

It appears that the first patent for a fire-resistant chest was granted to Robert Scott in 1801 in England. Scott introduced the essential elements for the construction of such enclosures. See also the **Milner patent** for one of the first fire safes, and **Chapter 3** in Price for a detailed history of the development of

fire safes. His “fire-resisting safety chest” was produced of iron plates crudely welded at the corners. The significance of his patent was the utilization of an internal lining of metal that formed a cavity on all sides into which charcoal or wood, steeped in a salt solution, was packed. Chubb and others made improvements to the original Scott patent. Chubb was the leading manufacturer in the development of fire safes; they still maintain their superiority today and have perhaps the largest fire testing facility in Europe.

Successive linings of sheet metal enhanced protection from fire. A unique improvement, these metal sheets were fitted together to create interspaces. These were filled with air or slow heat-conducting materials such as burnt brick, pottery, wood ashes, charcoal, and coarse sand.

In order to ensure that the proofing material was packed tightly in the interspacing, Chubb introduced the use of flat cases or bags made of sheets of cartridge paper, folded in round forms. Hollow molds were filled with the proofing and inserted into the cavities. The proofing material in early Chubb safes consisted of sawdust packed in tins. Later, loose sawdust mixed with **alum(376)** (a double sulfate of aluminum and potassium) was utilized.

It appears that the first fire test of a Chubb safe occurred in 1836. Papers were enclosed in a fire-proof box and exposed to the furnace of a 22 hp steam engine. In the test, the box became red-hot in three minutes and remained in that state for a considerable time. Reportedly, the papers were “perfectly uninjured” when removed. These new iron chest safes gradually came into use as depositories for documents, bank notes, books of account and other valuable papers and property. Originally, they were either mounted cupboard-fashion on piers of brick or built into walls. They were also regarded as secure against burglars. Three years later, Chubb patented “Improvements in Apparatus and Machinery for Preserving Books and other papers, documents and articles from fire”. This apparatus was commonly known as “the well safe.” It was attached to machinery that lowered it into a chamber to increase its protection from fire.

A new and superior fireproofing material was introduced in 1873 that was designed to take the place of sawdust. It was called “**infusoria**,” and consisted of diatomaceous earth. In a much improved and purified state, it is used today for the same purpose. Infusoria is actually the residue of algae silicate

skeletons found in fossil deposits mined from land that was once below the sea. It was mixed with alum to create the most effective balance of properties. Initially, a 6:1 mixture of infusoria to alum was recommended. Later, that formula was modified (in 1876) to a 4:1 mixture. Originally, the alum was packed wet until 1879; then it was placed into containers in a dry state.

Today, fire record safes must protect floppy discs and other fragile magnetic and optical media. These special containers have required the development of new materials that will absorb heat during a fire as well as stabilizing the temperature rise below a critical point. One exception to the traditional design of containers for fire or burglary protection is the Chubb Planet. This safe carries both fire and burglary ratings and is one-third the weight of traditional enclosures. It is constructed of plastic that is rated to withstand 1,000C for one hour. The material is extremely hard and is unique to Chubb. It can be poured to form strong rooms, safes, hasps, and other special items.

33_4.2 Design Theory of Fire Safes: Heat-Absorbing Materials

The underlying theory for the design of virtually all fire safes is quite simple: keep the heat that is in the outer layers from reaching the internal components. Channels of air and specially developed materials will accomplish this result.

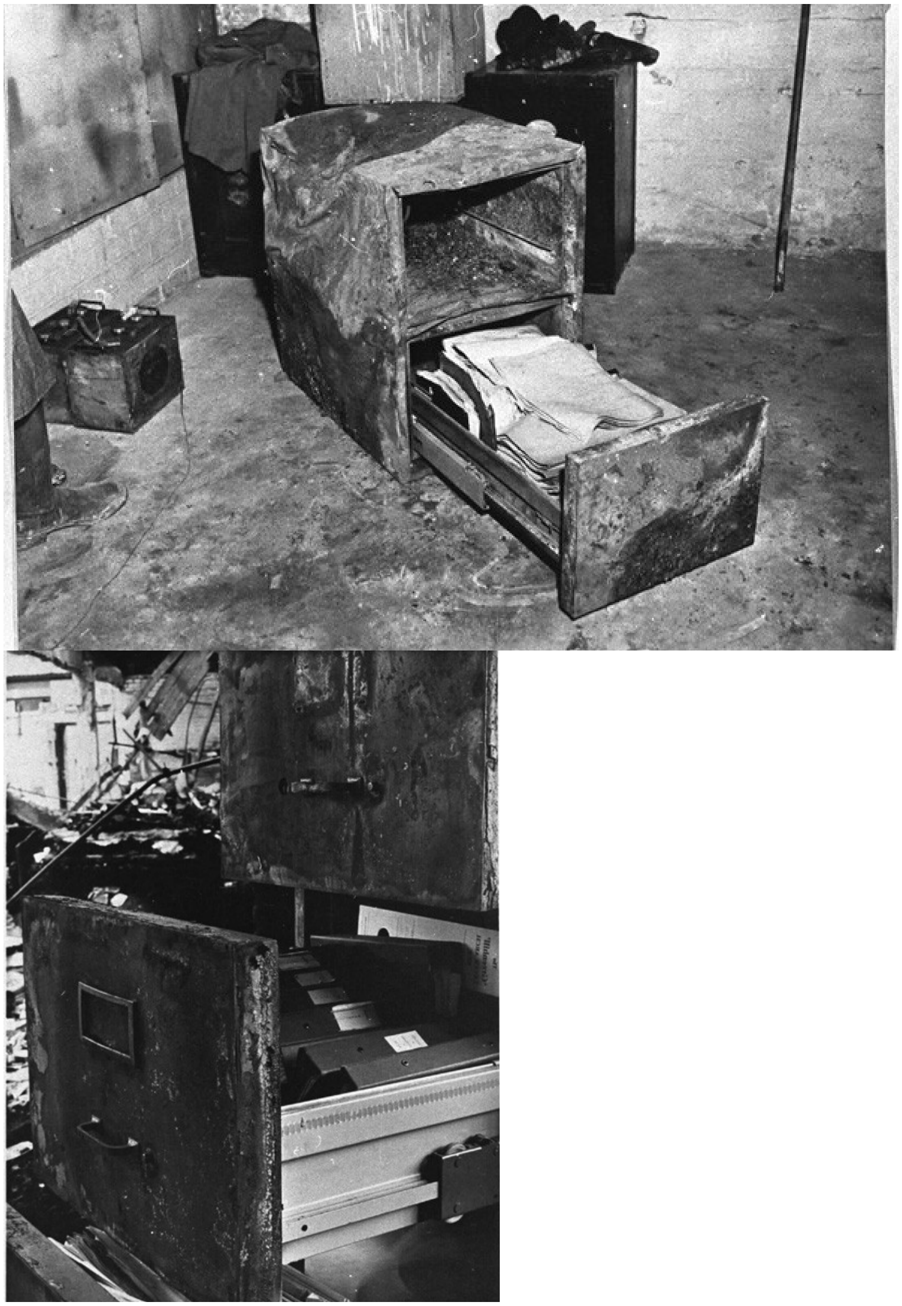


Figure LSS+3308 Examples of fire protected file cabinets.

Safes that are exposed to fire will cook inside; the materials within become quite brittle. If the safe is opened prior to cooling, then the contents will come to a flash-point and burst into flame. Air is a poor conductor of heat. Thus, much like a thermos, layers of contained air can retain high temperatures. If other materials are utilized, even a more efficient storage

medium could be provided. In initial safe designs, certain "poor" conductors would combust with the heat, minimizing their efficiency. This was true for example, when charcoal and sawdust were mixed. The answer was to compress the material, allowing no air gaps.

Later, chemical treatment was applied to fire-resistant materials. Usually salt, the crystals would contain water that would release at a high temperature. Asbestos, fire clay, slag wool, silicate cotton (resembles fiberglass), cement, plaster of Paris (dry or mixed with water), cinders, ashes, or slag have all been used as insulators. The result of pouring acid on marble chips would produce carbon dioxide and a fine white powder that also made a good inert insulator. Sheets of sawdust and alum bonded by Koalin or gum, as well as gypsum chips are quite popular. By the twentieth century, fire-resistant materials were inexpensive. Most manufacturers utilized sand, cedar wood sawdust, alum, and soda. These materials were compressed to eliminate as much air as possible.

33_4.2.1 Diatomaceous Earth

Quite popular for use in fire safes, this material is made from silicates composed of fossilized algae from land that had originally been under the sea. It retards the transmission of heat because each particle constitutes a minute air pocket. Diatomaceous earth would be dried and mixed with pure crushed alum, to form heat buffers in many fire safes.

Chubb and many other manufacturers utilize Portland cement diatomaceous earth (PCDE) sand and an aggregate with wire reinforcement. The mixture will retain up to seventy percent of its moisture and never actually dry. When heated, the material will absorb high temperatures and generate steam. Cement is always the outer barrier. Caution must be exercised that the concrete is not fractured during manufacture, transport, or placement, as any cracks will create a heat path.

33_4.2.2 Materials for Data Protection Cabinets

Enclosures designed for the storage of records must meet more stringent standards for temperature control. Data protection cabinets will often utilize phase-change materials that will modify their molecular structure between liquid, solid, and gaseous states at different temperatures. Typically, the materials will suspend states between liquid and solid at about

49 C. There are generally three protective layers in data cabinets: a phase-change layer, polyurethane foam, and a PCDE layer.

33_5.0 Terminology: Safes and Vaults

Many terms are used to describe the components or measurements of locks, safes, and vaults. The more common of these that specifically pertain to safe and vault construction are defined below. Terminology directly related to combination locks is presented in **Chapter 34**. A comprehensive list of terms may be found throughout this Infobase and in the **www.security.org** Infobase. They are utilized as the nomenclature to specifically define drill points in safe lock diagrams found in that Infobase.

Alloy Hard Plate: Hard plate is a combination of materials that create an extremely drill-resistant barrier (see **Chapter 5)**.

Arbor: Same as spindle.

Cam: The cam and drive wheels are the same component and control retraction of the bolt.

Cannonball Safe: The name that was used to describe a group of round door safes produced from the late 1800s until around 1920. They were so named because most were cast in the shape of a sphere and resembled a large cannonball sitting on a pedestal.

Carbide Chips: Carbide chips, an extremely hard material, are contained in alloy hard plate.

Carriage Bar: A flat bar that provides the linkage within the safe door to retract all of the locking bolts in unison.

Compression Bar: This consists of a metal bar mechanism that is mounted across a safe door to control its position with respect to the body. When the bar is rotated, it will force the door inward to a full locking position. The opposite action withdraws the door from its entrance.

Door Thickness to Bolt: This measurement will define the distance from the surface of the door to the center of the locking bolt.

Door Thickness to Lock: This will define how far to drill before entering the lock case. The measurement will include hard plate,

air gaps, and copper or other materials between the door and the lock.

Drill Point: This is the precise position, located through measurement and reference to the safe lock, where a hole is to be made for safe and vault penetration. A drill point locator overlay, or a direct measurement may be utilized. The standard convention utilized in the industry and in the drill point Infobase on **www.security.org** requires that measurement be made from the center of the dial through the indicated number on the dial ring. A line is extended outward at the angle created by drawing a straight line through those two points for the required distance. The coordinates are written as **D times L**, where **D** is the dial number through which a line should be drawn from the center and **L** is the length of the line. Thus, a drill point of **98 times 2** would require that a line be drawn through the dial number 98, extending two inches.

Drive Wheel: See cam.

Drop-in Point: This is the exact place where the fence enters the wheel gates.

Handle Rotation: This is the direction to turn the handle to lock or unlock.

Lock Bolt: The portion of the lock that blocks the main boltwork from retraction or opening. It is directly linked to the wheel pack and drive cam. The bolt may extend and retract, may roll back and forth, or may be absent altogether. In the latter case, the boltwork of the safe may be directly controlled by the final turn of the drive cam.

Lock Mounting Type: This will define the mounting position of the safe lock. There are four possible orientations: vertical down (**VD**), vertical up (**VU**), right hand (**RH**) and left hand (**LH**). This information is critical when penetration is by drilling.

Lug Door: A door style that requires rotation to lock or unlock.

Relockers: These devices, either internal or external, are utilized as secondary protection to prevent penetration of safes and vaults. **Internal Relockers** are located within a lock case to prevent the bolt from being retracted. An **External Relocker** will block the movement of a cam or bolt bar. They are separate bolts

that prevent the door from opening.

Relocker Drill Point: This location would indicate the precise position to drill in order to release a fired relocker.

Spindle: The long threaded rod that connects the combination dial to the drive cam and wheel pack.

Wheel Pack: The wheel pack consists of the three or four individual gated wheels within a combination lock and is connected to the spindle. Materials utilized for wheels are brass, steel, aluminum, plastic or nylon. Synthetic materials are used in high-security **1R** locks to protect against radiographic attack. Depending upon the manufacturer, these may be called delrin, acetal, celcon, or polymeric.

Zamak: A composite of aluminum and zinc having good qualities of casting and tensile strength. It is used for making lock cases and other components (see **Chapter 5)**.

33_6.0 Identification of Locks and Safes

A proper determination of the manufacturer of the safe and lock is critical for a successful penetration. When a safe has been repaired or upgraded with a newer lock, identification can be more complicated. There are many characteristics to identify a safe, safe door, or lock. Identification may be made by:

- **Recognition of the manufacturer by general appearance;**
- **Manufacturer logo or identification label;**
- **Artwork, designs, logos, or imprints;**
- **Dial and dial ring design;**
- **Does dial ring have a change index;**
- **Dial index design: line, star, arrow;**
- **Left-hand or right-hand door;**
- **Handle-center to dial-center measurement;**
- **Location of the dial;**
- **Numbering on dial;**
- **Markings on dial;**
- **Dial type and finish;**
- **Number, location, and type of locks;**

- **Logo on lock dial;**
- **Shape and design of keyways;**
- **Number of levers within a lock and bitting pattern;**
- **Door size, shape, design, and color;**
- **Body color (original);**
- **Corner shaping and design;**
- **Hinge style: vertical, horizontal, bolted, welded, specially shaped;**
- **Enclosure generic description;**
- **Container is on wheels;**
- **Distributor label;**
- **Overall enclosure size, shape, weight, and color;**
- **Mounting of enclosure;**
- **Opening handle design, shape, action, location, and position with reference to the dial;**
- **Distance between opening handle and dial;**
- **Location of contact points;**
- **Direction of bolt rotation;**
- **Hinge design;**
- **Wheel or caster design;**
- **Body construction: plate steel or composite;**
- **Handle style: "L", "T", round, plastic, brass, chrome, black, flat, round or tapered;**
- **Wheel count in wheel pack;**
- **Determine left and right contact points;**
- **Force handle toward opening: does it affect the dial.**

CHAPTER THIRTY-FOUR: PERMUTATION LOCKS

Combination Locks

Master Exhibit Summary

34_1.0 History and Development of Locks for Safes and Vaults

The modern combination lock is a refinement of letter or number padlocks that have appeared during various periods in history.

Originally known as permutation locks (262271), these devices were initially developed for convenience and not for security. In fact, until relatively recent times they were never taken seriously and primarily thought of as a novelty.







Figure LSS+3409 Examples of early combination padlocks. Shown is an Italian nineteenth century puzzle lock (left), another example of a permutation lock, origin unknown (middle), and an eighteenth century four wheel lock.

The original locks utilized numbers, letters, or symbols as an index to move critical locking components into alignment. Regardless of the design, they required that one or more discs or plates be rotated or otherwise moved so that some form of protrusion (fence) would retract into a recessed area (gate).

The design of the mechanical combination lock, as it is known today, began prior to the Civil War; it is an American invention. Although combination locks are utilized in other areas of the world, in most locations keys have been preferred over numbers. That is because physical keys have traditionally been more difficult to compromise. At least in Europe, it was the feeling that requiring that something "material" be utilized to open the lock would enhance security.





Figure LSS+3410 A copper tobacco box with lock, eighteenth century.

Commerce can be said to have created the demand for the lock. Although technology would progress at a rapid pace, the basic premise that relied upon the wheel did not. Today, as always, the combination lock is favored in the U.S., while key locks (lever) for safes and vaults are predominant in Europe. Some manufacturers utilize both for a higher level of security.

Mark Bates (MBA) and Lockmasters are the two leading companies in the United States that provide tools and training to the safe and vault industry worldwide. They also have the finest collections of antique safe locks, keys, and time locks. The following photographs and descriptions were provided courtesy of Mark Bates, and offer an insight into the designs that were prevalent for the past two hundred years, and which led to the state-of-the-art in modern safe and vault locking mechanisms.

Chatwood Invincible Key Lock

Dalton Permutation

Damon's Patent Lock

Day and Newell Parautoptic Safe Key

Dodds MacNeale & Urban's "Excelsior"

W.B. Dodds

Hall's Double Dial Premier (mid-size) with Consolidated Time Lock

Hall's Premier (mid-size)

Hall's Crescent

Hall's Crescent

Hall's Safe Lock

Hall's Single Dial Premier (mid-size) with Consolidated Time Lock

Herring, Farrel, and Sherman Double Dial

Herring Grasshopper Key Lock

H.C. Jones Patent Combination Lock

"Hobnail" (Early American) Safe Key

Lillie (attributed) Click Lock with Key

Lillie (attributed) Dial Lock w/Knob

Lillie (Lewis) "Click Lock" Safe Key

Miller Combination Lock Patent Model

Rosengrens Safe Lock

Safe-Deposit Lock-1

Sargent's Magnetic Lock #2 (early)

Sargent & Greenleaf #3 Fire Proof Lock

Sargent & Greenleaf #1 Vault Door Lock

T. J. Sullivan

Yale Double Dial Bank Lock Earliest pat. Date-July 14, 1857
Yale Double Dial Split-Bolt Vault Lock

Yale Pin Dial Time Lock (56 hour, 2 movement)

Yale 101-1/2 Double Dial

Yale Quadruplex Safe Key

In the United States, there are four primary manufacturers of combination locks: Sargent & Greenleaf, LaGard, Federal (Lori Company), and Yale. S&G is the oldest and most well known company. S&G was founded in 1857 by James Sargent and Hobart Greenleaf. Sargent had a background in lock design; Greenleaf supplied capital for the growth of the company and was originally in the military. The company was originally located in Rochester, New York. In the 1950s, it was purchased by Harry Miller, one of the pioneers in the development of modern combination lock technology. The Miller family owned the company until about 1982. Harry Miller, who originally was employed by Diebold as an apprentice, worked for the government throughout the Depression and war years developing high-security locks. Miller was granted many patents for designs and modifications to combination locks. See for example (**2575674(377)**).

During World War II, his background became vital to the United States, because he was an expert in new lock design and manipulation. He would later conceive of the first electronic lock and would develop manipulation-proof devices. In 1949, the State Department summoned representatives of the industry in an attempt to gather information regarding the covert entry of safes and loss of valuable information. Harry Miller gathered a sample of every lock installed by the government in order to determine how they could be manipulated and compromised. Consequently, several patents were issued to S&G. In the process, the company acquired the most comprehensive collection of combination locks in the world.

34_1.1 Predominant Manufacturers

As noted, there have been four predominant safe lock manufacturers in the United States since the industry decided upon standardization. S&G is the favorite, providing its 6700 series lock to most safe makers. Except for the relock trigger, the R6730 has not changed in size and mechanical configuration since the 1920s.

LaGard is the second largest lock manufacturer in the United States. Their products can be found on many fire and burglar-rated safes, including GSA containers. This company and its founder, Nick Gartner, have been responsible for many significant innovations in mechanical design and electronic systems.

Many other companies outside the United States produce combination locks. Some of them adhere to the U.S standards. The locks produced by many other manufacturers cannot be interchanged with the accepted footprint.



Figure LSS+3411 Examples of early designs of modern Yale three-wheel combination locks. (left) is shown a three-wheel lock produced about 1920; (right) is an S&G manufactured about 1948.

34_1.1.1 Other Combination Locks

Information is presented here on locks that can be found on safes, chests, and other containers that are utilized throughout the Department of Defense. These include the Diebold 180, Yale)C5, and S&G 6600 series. All locks meet the criteria of AR 380-5, paragraph 5-102. Some of the following material has been excerpted from the **Intelligence Materiel Division Technical Data Handbook No. 2.**

Some background data may be helpful in tracing the history of these locks. About 1980, Sargent & Greenleaf manufactured a 6600 series key-change combination lock that was originally certified by Underwriter's Laboratories (UL) as Group 1. This 6600 series differed from the earlier 6600 hand-change series of the 1950's and 1960's, which were true Group 1 and 1R locks utilizing the classic S&G anti-manipulation feature. That consisted of a split drive cam controlled by the center arrow knob (butterfly), which allowed the nose of the drop lever to engage only when the arrow knob was actuated.

The 1980's version (using the 6600 series designation), is a key-change type utilizing a drop lever that has a roller bearing installed in the nose. This roller bearing was eccentric in shape to give erratic readings when manipulation was attempted. In April 1982, the S&G Model 6600 Series Combination Locks were tested against Military Specification (MILSPEC) MIL-L-1556E for manipulation resistance. Both the S&G Model 6600 Series Key Change Group 1 and Group lR failed the 20 man-hour resistance to manipulation.

The Defense Industrial Supply Center, Philadelphia, Pennsylvania, was notified and arrangements were made between S&G and the U.S. Government to replace those 6600 series combination locks that failed the MILSPEC with either the S&G 8400 or 8500 series combination locks.

Because of the various styles of dials and dial rings on S&G products, the only positive way of determining the S&G Model 6600 Series Combination Lock of the 1980's is to remove the back cover plate and inspect the drop lever. Changing combinations on the 6600 Series lock is the same as that of any other S&G key change lock.

Another combination lock manufactured by LaGard Corporation of Torrance, California, was introduced into the system. Model 1800 RL was originally certified by UL as Group 1R. In December 1982, this lock was also tested against the MILSPEC for manipulation resistance. This lock failed the required manipulation resistance of 20 man-hours.

Although both the S&G Model 6600 Series Combination Locks and the referenced LaGard Group 1R Combination Lock have been certified as either Group 1 or Group 1R by UL, these locks have proven susceptibility to manipulation. NEITHER THE S&G 6600 SERIES COMBINATION LOCKS OF THE 1980'S NOR THE LAGARD COMBINATION LOCKS

ARE TO BE USED AS REPLACEMENT LOCKS ON GSA APPROVED SECURITY CONTAINERS.

Diebold Model 180 Series

These key-change combination Locks may still be found on old containers and safes, but are no longer manufactured. They do not meet Group 1 or Group 1R requirements.

To Unlock:

(1) Rotate the dial a minimum of four times to the LEFT. Stop EXACTLY at the opening index mark the fourth time the first number of the combination has reached the opening index mark;

(2) Rotate the dial to the RIGHT. Stop EXACTLY at the index mark the third time the second number of the combination has reached the opening index mark;

(3) Rotate the dial to the LEFT. Stop EXACTLY at the opening index mark the second time the third number of the combination has reached the index mark;

(4) Rotate the dial to the RIGHT, pausing a moment at zero, and then continue turning to the RIGHT until the dial stops. The locking bolt is now retracted. This enables the handle of the drawer or door to be "thrown", allowing it to be opened.

NOTE: Always turn the dial slowly and evenly. Spinning the dial is unnecessary and may cause loosening of component parts that could cause a lockout.

Changing Instructions:

This lock is considered a "0" (zero) change lock; therefore, no changing index is provided.

(1) Operate the lock on the old combination, stopping when the last number comes to the opening index at the top of the dial ring;

(2) Insert the change key through the hole in the back of the lock case. The key must be inserted until the end comes to a stop on the bottom of the case. Turn key to LEFT (counterclockwise), as you face the inside of the door, through approximately half a

revolution to stop;

(3) Select three numbers on which to set the lock;



Figure LSS+3408 Diebold Model 180 Series

(a) Keep numbers above 10,

(b) Below 90, and,

(c) A minimum of 10 digits apart.

(d) Use high, low, high or low, high, low; i.e., 32-19-71 or 19-71-32.

(4) Rotate the dial LEFT (counterclockwise), stopping when the first number aligns with the opening index the fourth time around;

(5) Rotate the dial RIGHT (clockwise), stopping when the second number aligns with the opening index the third time around;

(6) Rotate the dial LEFT (counterclockwise), stopping when the

third number aligns with the opening index the second time around;

(7) Rotate the change key to the RIGHT (clockwise), as you face the inside of the door, approximately half a revolution to stop, and withdraw the change key;

IMPORTANT: The lock is now set on the new combination. Operate the new combination several times before you close the door to be sure that it works correctly and that you know the combination. If the lock fails to operate, a mistake has been made.

Procedures If Combination Fails:

(1) Remove the cover of the lock;

(2) Arrange the three combination wheels so the key hole in the wheels is in line with the keyhole in the cover. This is easily done by inserting the key through the wheels and into a hole in bottom of the case. Be sure not to turn the key while the cover is removed;

(3) Withdraw the key, and replace the cover;

(4) Insert the key and follow changing instructions from the beginning;

Yale Model OC5 Series

These hand-change combination locks may still be found on old cabinets, but are no longer manufactured. They do not meet Group 1 or 1R requirements.

To Unlock:

(1) Turn the dial a minimum of four times to the right stopping exactly at the opening index mark the fourth time the first number of the combination has reached the opening index mark;

(2) Turn the dial to the left, stop exactly at the opening index mark the third time the second number of the combination has reached the opening index mark;

(3) Turn the dial to the right, stop exactly at the opening index mark the second time the third number of the combination has

reached the opening index mark;

(4) Rotate the dial to the left, pausing a moment at zero, and then continue turning to the left until the dial stops. The locking bolt is now retracted. This enables the locking linkage to be retracted by the handle, thus allowing opening of the door or drawer.

NOTE: Always turn the dial slowly and evenly. Spinning the dial is unnecessary, and may cause loosening of component parts, which could cause a lockout.

To Change Combination:

(1) Open drawer or door and release bolts to locked position. This will prevent inadvertent lockouts due to drawer being closed without attached wheel pack and released relock. (If unit is equipped with a locking bolt interlock, it will be necessary to depress the interlock plunger before the bolts can be thrown.);

(2) Remove cover from lock by removing two screws attaching cover to case (on some safes, it may be necessary to remove a panel or small circular cover from the inside of the door or drawer to expose lock);

(3) Remove retaining clip from wheel post;

(4) Remove wheels and spacers and align in proper order for reinstallation. (These wheels are generally not numbered as to sequence.) The last wheel removed from the post is number-one wheel and the first number of the new combination, etc.;

(5) Hold number-one wheel assembly with numbers up and push the center disc upward until it is removed from the outer ring. Rotate the center disc until the setting mark is opposite the desired number on the ring. Carefully press the center disc back into position until it is flush with the outer ring. Change the combination number on the remaining wheels in the same manner.

NOTE: When selecting numbers for the new combination, use recommended methods as listed below:

(a) Keep numbers above 10;

(b) Below 90, and

(c) Ten digits apart;

(d) Use high-low-high or low-high-low;

(e) Whenever possible do not use numbers ending in 5 or 0.

(6) Replace parts on posts in proper sequence. Numbered side of wheels are to face up. When the retaining clip is replaced, make sure that it is properly seated in the groove on the post;

(7) Turn the dial off zero, and then replace the cover and screws. Tighten screws firmly to preclude vibration causing loosening and allowing the relock to trigger;

(8) Try the lock at least twice on new combination with door or drawer open to be sure the lock is set properly and operates smoothly;

Bode-Panzer Combination Dial Lock

The Bode-Panzer Combination Lock, which is manufactured in Hanover, West Germany, is also included in this text because of the quantities found in use throughout Europe.

To Unlock:

(1) Rotate the dial to the RIGHT, and stop when the first number of the combination reaches the opening index for the fourth time;

(2) Rotate the dial to the LEFT, and stop when the second number of the combination reaches the opening index for the third time;

(3) Rotate the dial to the RIGHT, and stop when the third number of the combination reaches the opening index for the second time;

(4) Rotate the dial slowly to the LEFT to stop;

NOTE: This is just the opposite of locks manufactured in the United States.

IMPORTANT: When dialing, you may stop and resume turning the dial as often as you like without changing the direction of the turn. If you overshoot your mark by rotating the dial beyond the number

required, the unlocking procedure must be started over again; otherwise the mechanism will not work. Such dialing mistakes do not affect the lock in any way.

Each lock delivered by the factory is set to a combination of three numbers which are divulged to the buyer in a special registered letter. The lock must be reset immediately after its receipt to a new three-number combination to preclude compromise. Before you start changing the combination, write down the three numbers which you intend to use for the new combination on your lock. In the interest of security, it is recommended that you select three numbers as far apart from one another as possible (with intervals of at least 10 digits), distributing them as evenly as possible over the dial. Do not use numbers ending with a 0 or a 5, exclusively.

To Lock:

Rotate the dial to the RIGHT at least five times;

Changing the Combination:

Change the combination as follows. The Bode-Panzer Combination Lock is considered a "0" (zero) change lock; therefore, a separate changing index is not provided. The single index mark suffices for both opening and combination changing procedures.

(1) Proceed exactly as described in the Unlocking instructions without making the last turn to the LEFT;

(2) Insert the combination change key as deeply as possible into the change key hole provided in the back of the lock;

(3) Turn the change key 90 degrees to the RIGHT, and leave it in that position;

(4) Rotate the dial at least five times to the RIGHT, and stop when the first number of the new combination reaches the index mark;

(5) Rotate the dial to the LEFT, until the first number has passed the index twice, and stop when the second number reaches the index;

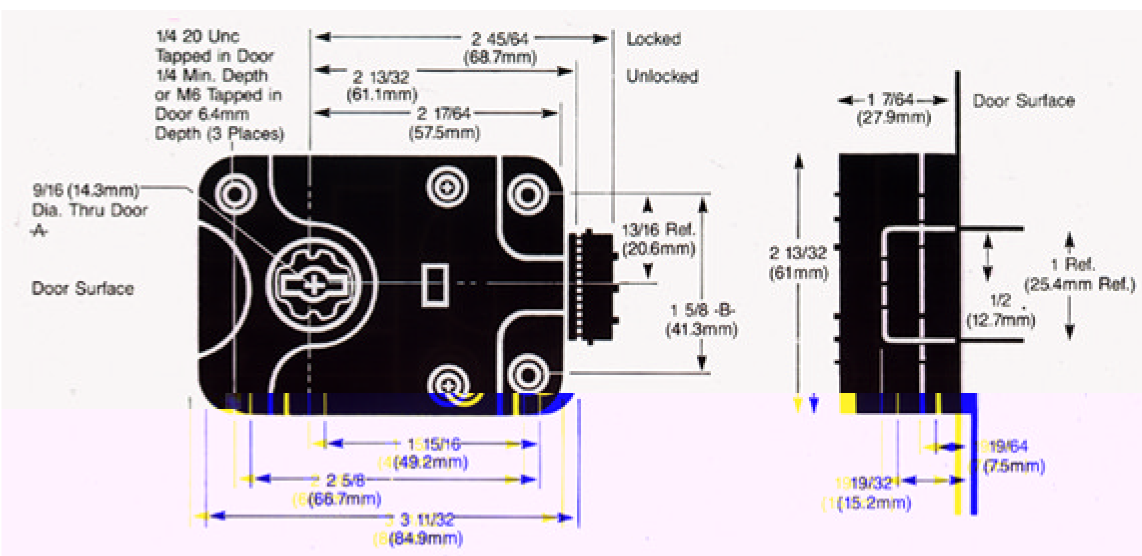
(6) Rotate the dial to the RIGHT, until the second number has passed the index once, and stop when the third number reaches the index;

(7) Rotate the change key 90 degrees to the LEFT, until it can be extracted. Extract the change key;

(8) Rotate the dial to the LEFT, until it comes to a stop. The lock is again open.

34_1.2 Industry Standardization

Until the 1930s, there was no industry standardization of locks utilized in safes and vaults with respect to their size and the design of protective cases or enclosures. Prior to standardization, locks came in many different configurations and were custom mounted for a particular safe. Some locks did not even have cases to protect the wheel pack. Manufacturers began the process of adopting common footprints for lock cases to allow interchangeability for any container. The only company that did not follow suit was Mosler. Their lock case did not conform to the rest of the industry until the 1970s when they introduced the Model 302.



Today, only two safe manufacturers actually produce their own locks: Mosler and Diebold. Other than for GSA Class 6 security containers, these companies will always utilize their own locks on their enclosures. Until 1989, only the S&G 8400 and 8500

series were acceptable to the United States government on GSA security containers, and thus Mosler and Diebold were required to utilize them.

Individual locks may differ in the way they function, but the overall operating principle is the same. For example, it may be required to return a dial to zero and be depressed in order to engage the lever. Relock triggers may be slightly different in design and placement. Locks may have a zero change function and different dial and ring designs. Other than the Yale OC5, most locks are extremely close in their dimensions, and thus they may be easily interchanged. With few exceptions, the mechanical components are identical and thus:

- **The wheel diameters are essentially the same size;**
- **The wheels are equipped with moving flys;**
- **Each lock uses a pivoting lever with a fence;**
- **All locks utilize the same method of bolt retraction;**
- **All locks are equipped with a relock trigger;**
- **The physical drop of the fence is in the same location.**

There are some differences between S&G, Mosler, Federal, LaGard, and Yale. These include:

- **Yale retracts the bolt with the dial turned counterclockwise;**
- **Mosler, Federal, and Yale mount wheels on the lock case cover rather than a wheel post;**
- **The drill points will vary because the drop in points are different: Yale OC5 is 80, Mosler is 91, LaGard, Federal, Diebold, and S&G is at 97.**

34_2.0 Combination Locks: Operation and Theory

34_2.1 Introduction

As described elsewhere in this text, there are several primary means to provide security within any lock. In the key lock, single and double-acting detainers, keyways, guards, wards, and

other devices have been utilized to enhance resistance to bypass. The introduction of gated wheels in the combination lock provided yet another technique for making locking mechanisms more secure by eliminating any physical opening. As will be discussed subsequently, the mechanical combination lock suffers from certain fundamental limitations in its design. Electronic locks can overcome such problems and offer far superior reliability and security. Perhaps the most advanced of this new technology is the revolutionary Mas-Hamilton X-07. A detailed analysis of this lock is presented later in the chapter because of the impact that it has had on the entire security industry.

34_2.2 Combination Locks v. Key Locks

The modern combination lock offers significant advantages over any other type of mechanism:

- **The lock generally offers from one million to one trillion distinct permutations, making random openings and cross-keying impossible;**
- **No key can be lost, duplicated, or compromised;**
- **Greater resistance to bypass, including picking, manipulation, and radiographic attack;**
- **Mechanical reliability.**

34_2.2.1 Mechanical Reliability

The modern mechanical combination lock is extremely reliable if produced to accepted industry standards. Established manufacturers such as S&G maintain extremely high tolerances to ensure consistent performance. Strict quality control procedures are implemented as well as extensive product testing. Sargent & Greenleaf, for example, will cycle their locks routinely for 30,000 - 40,000 openings without ever encountering a problem. The UL requirement contemplates a minimum of 10,000 openings.

If locks are routinely serviced, cleaned, and lubricated they will function without difficulty. The removal of debris and resetting of wheel-torque is critical to trouble-free operation. When a lock does malfunction, many indicators can provide the necessary information to determine the precise nature of the problem. Certain techniques are utilized by the safe technician to determine the cause of a lockout. These are discussed in **Chapter 36**.

34_3.0 Components and Principles of Operation

34_3.1 Introduction

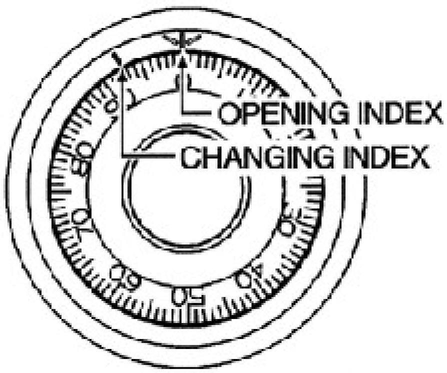
Our discussion will examine the theory of operation underlying the modern mechanical combination lock. We will focus on the three interrelated component groups that comprise the primary system:

- **Driver**
  Dial
  Spindle
  Drive cam
  Spline key

- **Wheel Pack**
  Wheels
  Wheel post
  Gate
  Tension washer
  Isolation washers
  Retaining ring
  Lock case (when wheel post is part of case)

- **Bolt works**
  Lever
  Fence
  Bolt
  Relocker
  Case

The operating theory for almost every mechanical wheel lock is identical and in many respects parallels that of the lever lock. They all contain a dial that performs the same function as a key. It is marked and subdivided into segments, using numbers or letters in the same way that a key has bitting corresponding to different depths. When turned, the dial allows the movement of critical locking components (wheels) much like the levers in a conventional lock.

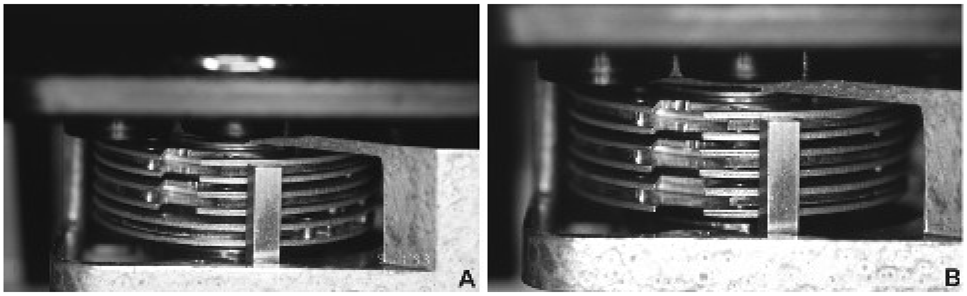


Wheels are equivalent to levers; the only difference is that they are rotated rather than lifted. Each wheel, like their counterpart, has a slot or gate that must be aligned with a fence or protrusion. The proper combination must first be entered. When this occurs, all of the gates are positioned just like all levers or pins are brought to shear line by the proper key. Upon proper alignment, the nose of the lever can enter the gates via the drive cam. The dial, as with the key in the lever lock, is used to mechanically retract the bolt.

34_3.1.1 Overview: Entering the Correct Combination

The mechanical theory and operation of the combination lock is actually quite simple in comparison to pin tumbler devices. Although Underwriters Laboratories requires a minimum of 1,000,000 unique combinations in Standard **UL 768**, this fact does not affect the relative simplicity of design. To open the lock, all discs must be arranged so that their gates are in precise alignment, thereby creating a recess into which the fence can drop. Movement of the wheels is accomplished through dial action in sequentially alternate turns; the drive cam links rotational energy using flys and carries each wheel to the correct position.

A wheel can be rotated without disturbing the other wheels, with drive pins and flys. These are precisely moveable protrusions on both faces of each wheel that are designed to contact and stop each other during one complete revolution, based upon the order that the wheels are turned. Thus, movement of wheel number-one will engage wheel number-two, which will then catch wheel number-three.



When the dial is first turned, all discs are moved together in the same direction, along with the drive cam (which is connected to the dial and spindle). This occurs because the drive pins and flys interact with each other. After three revolutions, the wheels are in effect linked together and moving as if they are one. Now the dial is stopped at the first number in the combination sequence, aligning the first wheel gate with the fence. The lock still cannot be opened because the remaining wheels have not created a complete recess for the fence. All gates are not perfectly aligned, so the fence still has nowhere to go.

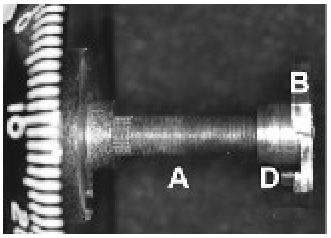
The second wheel must be placed in a position where its gate is in the same position as that of the first wheel. To do this, the dial is turned in the opposite direction, carrying tumblers number-two and three (and four, if a four-wheel lock) in the reverse direction. Because of the design of the drive pins and flys, wheel number one will not be disturbed, but wheel number two will be brought to alignment.

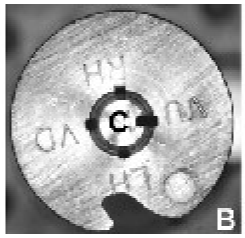
The dial is turned in the opposite direction in order to bring the third tumbler into alignment. All gates are now in the same position and create a vertical slot or recess for the fence. Once the nose of the lever is able to drop into all of the gates, the entire lever can pivot and allow the bolt to be retracted. The lock is now open. Extending the bolt to the locked position simply requires turning the dial in order to force the lever-fence out of the drive cam and gates.

34_3.2 Driver Group

The Driver group consists of the **dial**, **spindle**, **drive cam**, and **spline key**. These components control how each individual wheel is aligned and thus are perhaps the most critical. Usually, the **dial** is affixed to the **spindle** that is threaded into the **drive cam**. A groove (**spline**) in the threaded rod allows the drive cam

to be indexed to the spindle with a **spline key.** Together, the driver group is responsible for transferring information to the individual wheels regarding their positions with respect to the fence.





34_3.2.1 Spline Key

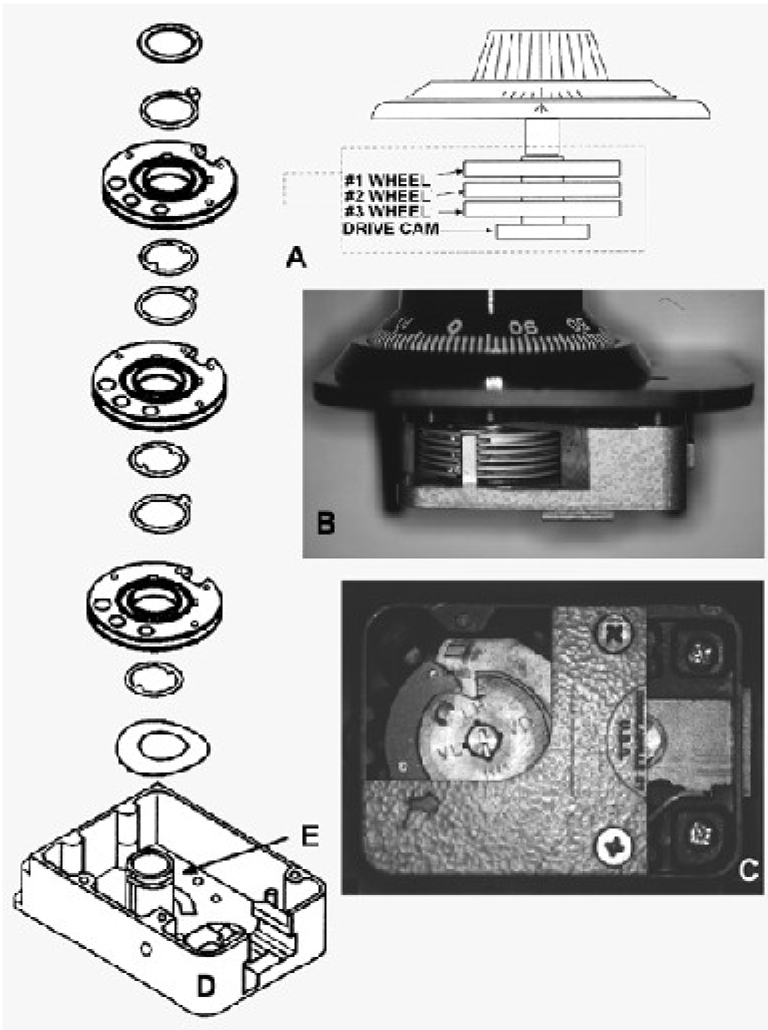
The function of the spline key is critical: it provides the mechanical link between the drive cam and spindle. Equally important, it sets the relationship between the position of the gate on the drive cam and the individual numbers on the dial. Any play between these two components will directly affect the combination. If the spline key should become dislodged, there is no way for the spindle (and dial) to cause wheel rotation.

34_3.2.2 Drive Cam

The drive cam makes contact with the first wheel through a fly and drive pin. It is moved by the action of the dial and linked by the spindle. As the wheels are turned, their gates will be brought into alignment with the fence. When all wheels are set to the proper position, the fence is able to drop into all of the gates simultaneously. At the same instant, the nose of the lever enters the recessed area of the drive cam.

34_3.3 Wheel Pack

The wheel pack determines the combination for a given lock. It is comprised of the individual wheels stacked in parallel, together with the wheel post, tension washer, isolation washers and retaining ring. Depending upon manufacturer, the wheel post may be part of the lock case or lock cover. The wheel pack is controlled by the action of the drive cam. Each wheel rotates freely within the pack; however, they do not change their **positional relationship** with each other once set. The drive pins and flys allow the drive cam to position each wheel.

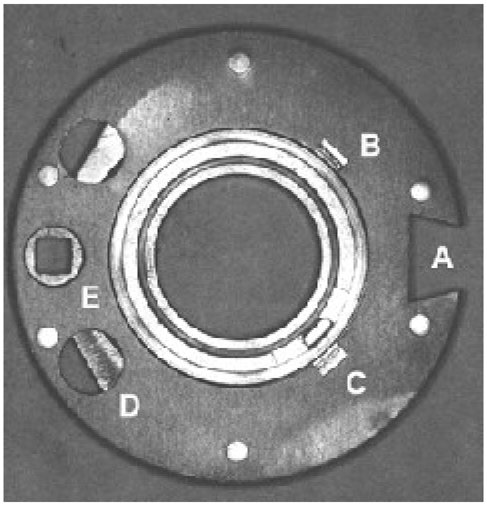


34_3.3.1 Individual Wheels

Wheels or discs are circular in design and made of metal or polymers. Each is perfectly round and has a precisely dimensioned recess in the form of a slot, called a **gate.** Each wheel is free to turn independently, is mounted on the wheel post and is separated by **"isolation washers".** Lugs within each isolation washer engage grooves in the wheel post to maintain their fixed position and stop them from rotating.

These washers prevent adjacent wheels from being "carried around" as the combination is entered. Convex thin metal **tension** washers provide spring bias to the components of the wheel pack to inhibit vibration or movement of other wheels while the

combination is dialed. The **retaining ring** keeps the wheels and isolation washers on the wheel post and works against the tension washer.



34_3.3.2 Development of the Wheel in Combination Locks

Many wheel configurations have evolved since Linus Yale produced the first combination lock. Major changes have occurred in the design of both the gate and method of changing the relationship between gate to the spindle position. Materials used in the production of wheels have undergone many improvements and have become more sophisticated. The following discussion analyzes the development of gates, wheels, materials, drive pins and flys, and the methods utilized to change the gate-wheel relationship.

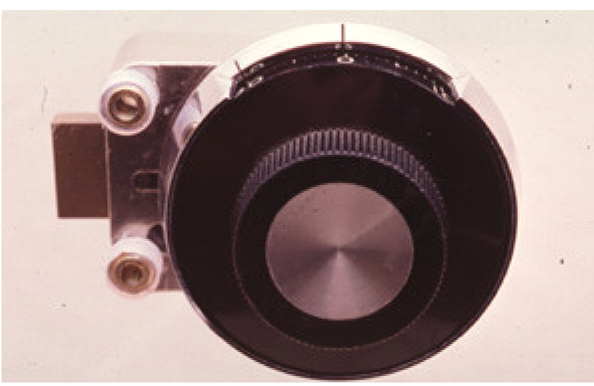
34_3.3.2.1 Gate Design

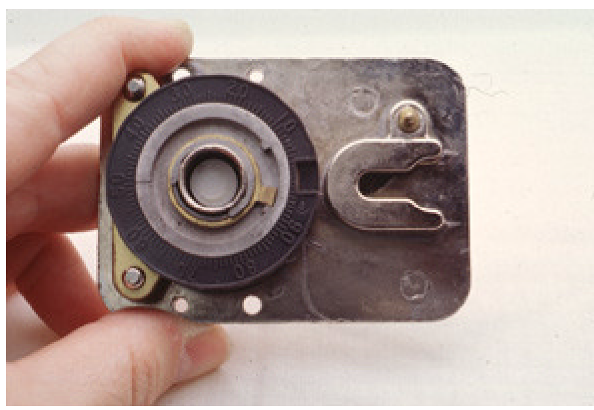
The gate is a precise slot that is cut into the edge of each wheel. Its function is to provide a place for the fence when the wheel is in the proper position for the lock to open, based upon the number dialed. Many advances in the design of wheels, wheel packs, and gates have occurred since the first combination lock made its debut. Perhaps the most critical change was made by S&G engineers after burglars discovered that they could open a lock by vibrating the wheels so they would turn on their own accord and stop under the fence. Interestingly, a patent was granted to Jacobs in 1961 (**2974517(378)**) for a device to cause vibration to a safe lock to cause the wheels to rotate to a position where the gates were aligned with the fence.

From 1925-1954, the S&G wheel was solid with a square gate. In these early locks, the lever generally had a very limited pivot arc, or it entered the gate at the 12 O'clock position. Because the wheel was solid, it was heavier opposite the gate. Like the tire on a car, it was out of balance. If vibration was applied, the wheel would move to where its heaviest segment would naturally be positioned: at the bottom. This action would align the gate to the fence.

Consequently, both the lever and gate were redesigned. In the new configuration, the lever and fence entered the wheel off-center. The gate-slot angled to the right to match the pivot angle of the lever. In addition, small gear-teeth were added to the edge of the disc, with corresponding grooves on the fence. The theory was that the lever fence would hold the wheels in position. Unfortunately, the opposite occurred. The meshing of the teeth actually caused a ratchet effect, making it even easier to vibrate the lock to the open position. The design was discontinued in 1957. Balancing-holes were one remedy to inhibit vibration from rotating wheels. As lead weights are used for tire alignment, holes were placed in each wheel so that the weight might be perfectly distributed.

34_3.3.2.2 Changing the Wheel-Gate Relationship











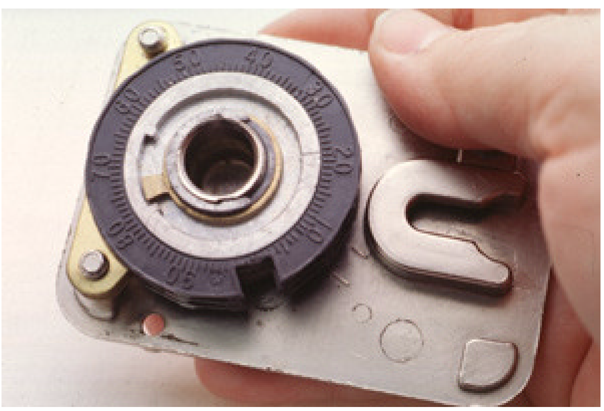


Figure LSS+3412 Changing procedure for hand-changeable locks. Shown is the Mosler CD302, which requires disassembly in order to change the relationship between the outer and inner wheels. Note that each disc has numbers that correlate to the dial markings. Courtesy of Mark Bates, The National Locksmith Guide to Modern Safe Locks.

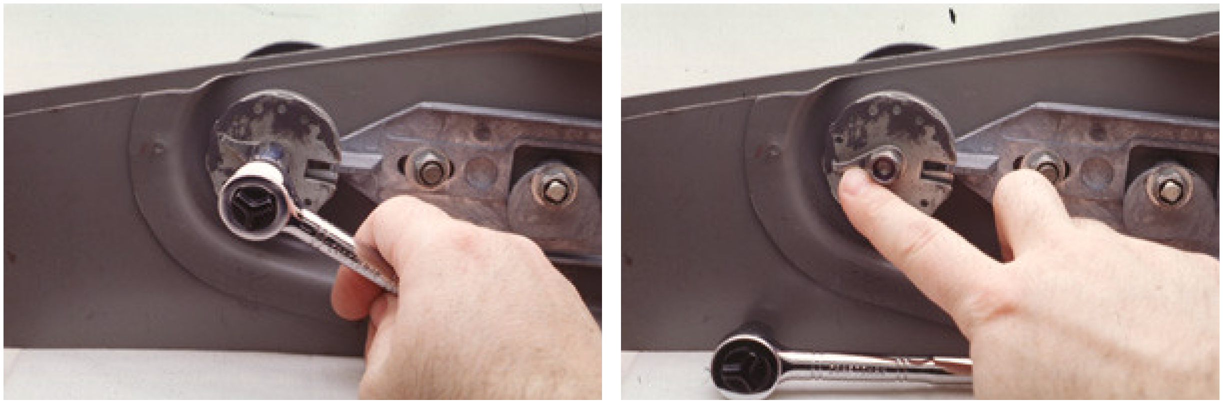


Figure LSS+3413 Changing procedure for hole-changeable locks. This lock is more primitive than the hand change model shown above. Shown is the Sentry safe lock, found on fire resistant containers. There is no lever or bolt. The rear wheel which constitutes the drive cam has an arm that connects into one of a series of holes on the wheel. To alter the combination, the wheels are loosened on the wheel post. The arm is then moved to a different hole, and the wheel tightened. Courtesy of Mark Bates, The National Locksmith Guide to Modern Safe Locks.

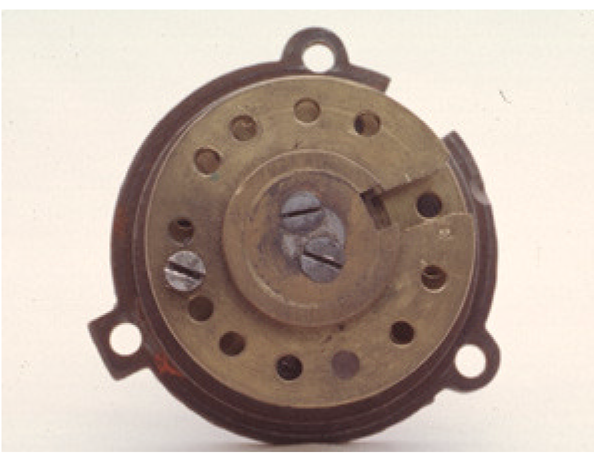
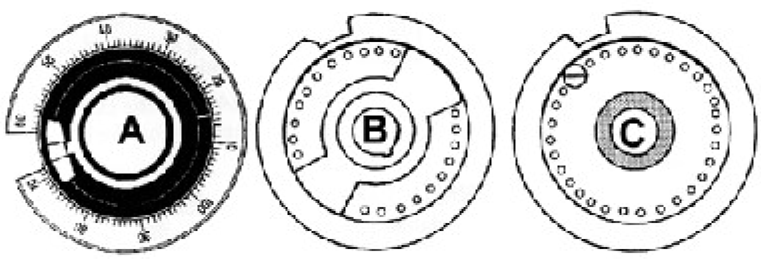


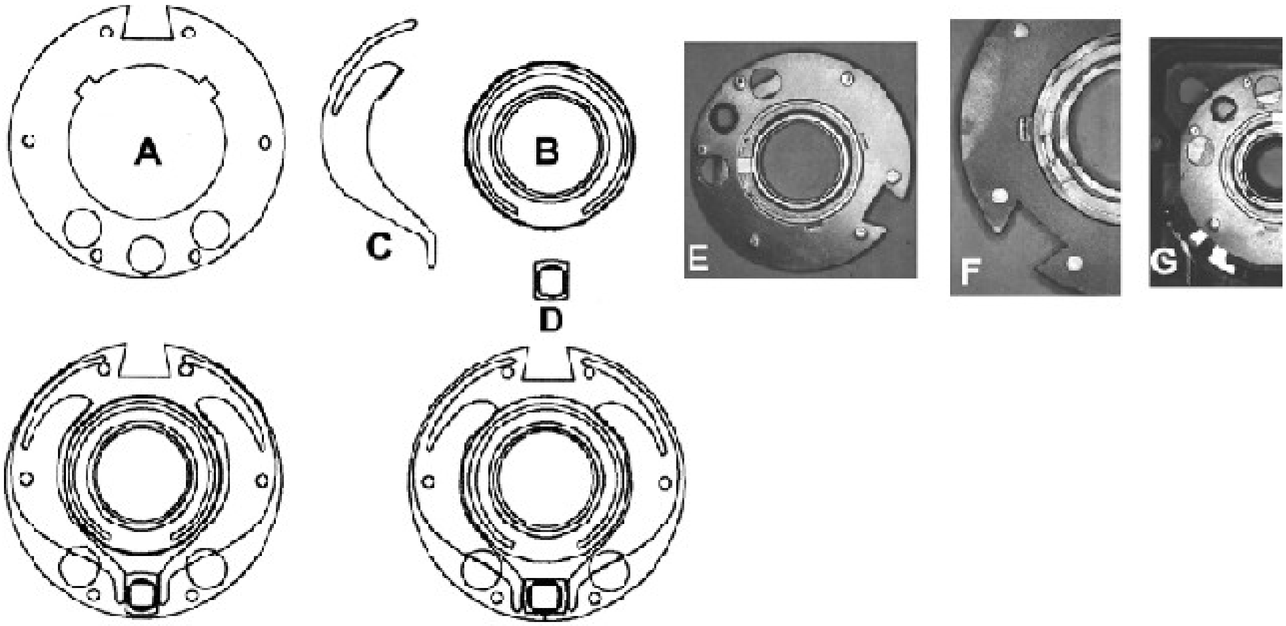
Figure LSS+3414 A screw-changeable lock is similar in function to a hole change lock. A screw is driven into a hole on the wheel. Each wheel will have its own set of holes. Courtesy of Mark Bates, The National Locksmith Guide to Modern Safe Locks.

From the beginning, it was recognized that some form of mechanism was required to permit changing the combination for a given lock. Although many different methods have been developed, they all must accomplish the same function: to alter the positional relationship between the gate and the index marker on the dial ring (or the spline key). In the early locks, this had to be done manually by disassembly of each wheel. Later, a key could be inserted and the wheel-gate relationship changed automatically.



At first, the technique was quite simple: a **hole-change** wheel was able to create a new combination by moving a pin or screw to a different position. A predetermined range of numbers would be available, depending upon where the pin or screw was placed. Then, the **mesh-change** wheel was introduced, together with a fly. This allowed all 100 numbers to be used for the combination. Still, the lock had to be opened and disassembled in order that each wheel be taken apart to effect the change.





In 1857, the **key-change** wheel was invented by James Sargent, one of the cofounders of S&G. This mechanism allowed the combination to be changed by the insertion of a key at the rear of the lock case. The key would pass through each of the wheels simultaneously and could alter the position of all of the gates, thereby changing the combination. Today, almost every lock utilizes the technique of dual mesh locking of the inner and outer sections of the wheel. In addition, the gate design allowed the wheel to be utilized in left and right-hand locks. Different designs have been described in U.S. patents (**1899739(379)**, **4375159(380)**) conventional locks (**3533253(381)**, **3983724(382)**, **2830447(383)**, **5109684(384)**) and padlocks.

34_3.3.4 Wheel Materials

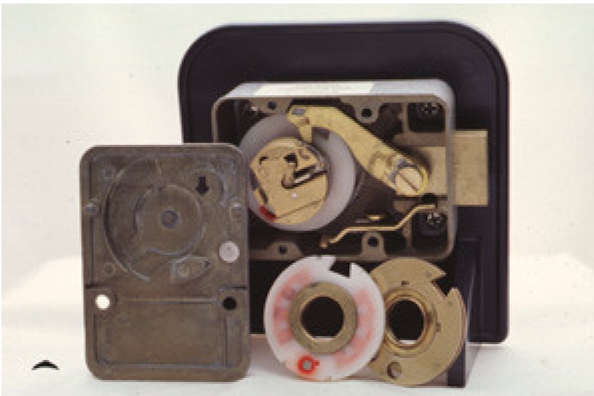


Figure LSS+3415 Metal and plastic wheels. Courtesy of Mark Bates, The National Locksmith Guide to Modern Safe Locks.

The materials selected for wheels are as important as their shape. Lock manufacturers must be concerned with non-electrolytic corrosion, radiographic attack, manipulation, vibration, microbiological growth (green film in wet climates), resistance to chemicals (such as oils, solvents and grease), self-lubrication, and conduction of electricity. Originally, wheels were made of brass, then steel or aluminum. In the 1950s, S&G made nylon wheels for the Group 1R lock, allowing the relock trigger to rest on a nylon button. Center Manufacturing then made an all-plastic wheel pack in their Model 100 that even had plastic moveable flies.

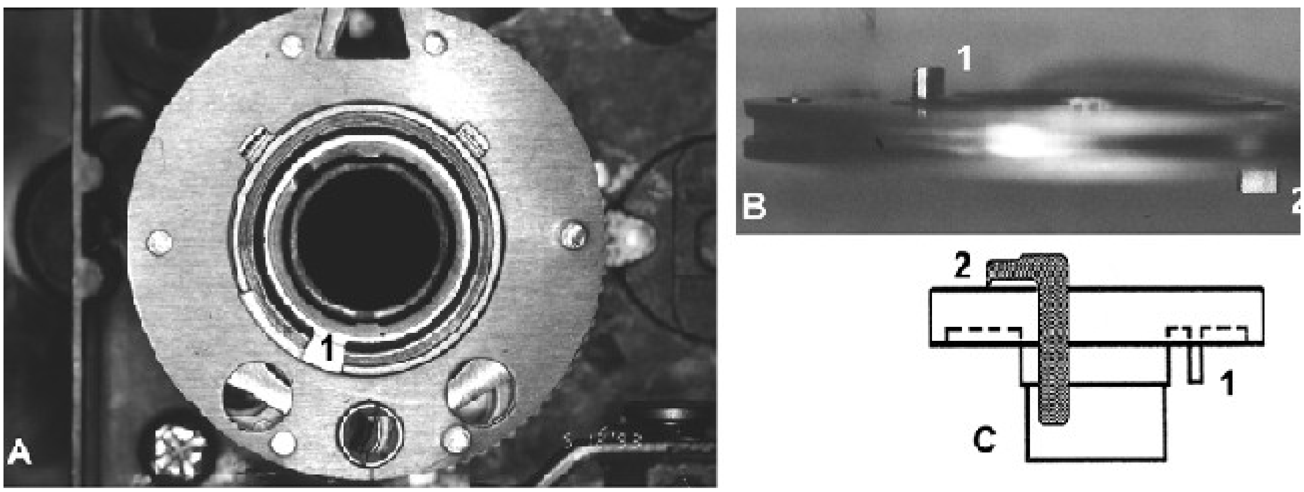
Plastics such as delrin, acetal, nylon, celcon, and polymeric materials are widely in use by manufacturers. Co-polymer fabricated wheels are light, self-lubricating, and do not require balancing. In addition, the materials can defeat radiographic attack and manipulation as well as the other problems associated with metal discs. They have excellent resistance to chemicals, corrosion, microbiological growth, and build-up of scale. Oils, grease, or solvents do not affect them.

Plastic wheels such as the S&G celcon can be manufactured to a high tolerance. An added advantage is that they will retain their gate position even if they should become unlocked during normal use. Although some safe technicians to not like the feel of these wheels, they have a decided maintenance advantage in preventing lockouts.

34_3.3.5 Drive Pins and Flys

Drive pins and flys are the mechanism that transmits the

rotational information to each of the wheels as the combination is entered. They link each of the discs together in succession, so that once the position of each wheel is set it will not be disturbed as the others are moved. Each wheel contains a fly on one surface and drive pin on the opposite side. As each disc is rotated, the flys and pins catch at a specific point in the arc and will move the next wheel in succession. The system is designed so that direction of rotation will not affect the relationship between dial number and position of the gate.



34_3.4 Bolt Group

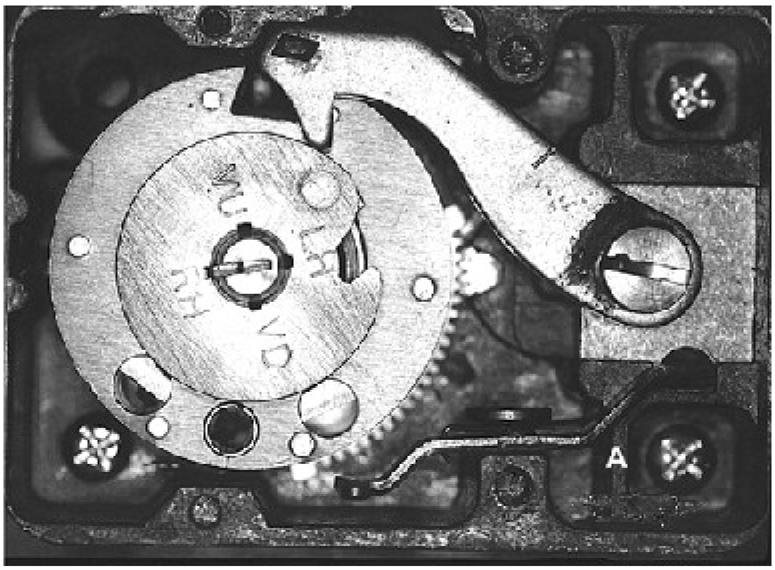
The bolt group includes the **lever**, **fence**, **bolt**, **relockers**, and **case**. The **fence** is the protrusion that must enter the gate of each wheel in order to be positioned properly. The **lever** carries the fence and engages the drive cam to actuate the bolt. **Relockers** are utilized to protect the lock case and wheel pack from forced penetration.

34_3.4.1 Lock Case Design

The case usually contains all parts of the locking mechanism, although in older safes this was not always true. It will usually consist of the body and back cover. The cover will hold the relocker, as well as the guide for the change key. The wheel post is usually an integral part of the case and performs the function of a bearing surface and guide for the drive cam. The wheels are generally affixed to the post with a clip and rotate around it.

34_3.4.2 Case Cover and Relocker

The cover is generally fabricated of the same material as the case and is utilized to seal the mechanism as well as provide a triggering mechanism for relockers. The design of a relocker depends upon the manufacturer; however, they are always released if the cover is altered or removed. They can take the form of breakaway parts, protrusions to hold down the relock trigger, weakened areas around mounting screws, or pin-depression schemes.



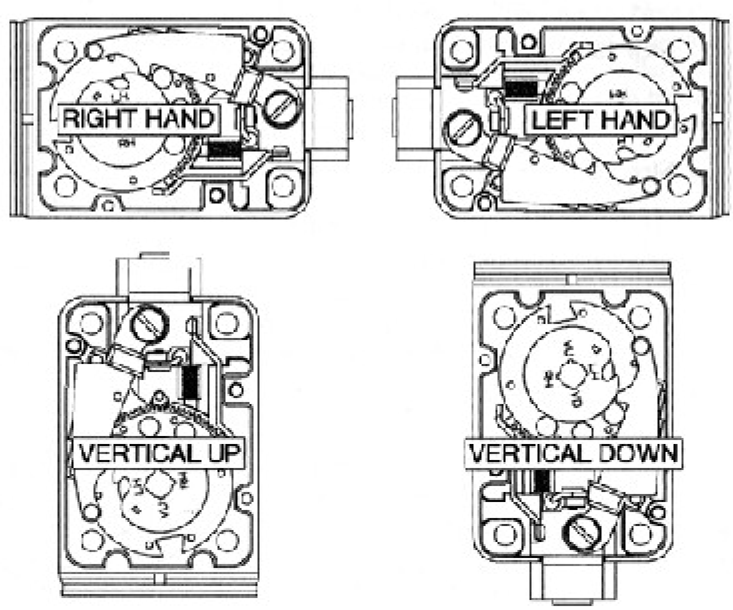
34_3.4.2.1 Materials

Cases that meet UL specifications must be fabricated with a corrosion-resistant material. Zamak, composed of aluminum and zinc, is the favorite, although older locks are made of brass, bronze, steel, or cast iron. Zamak exhibits good casting qualities allowing drilling, tapping, sanding, and filing. The material also has good tensile strength.

34_3.4.2.2 Mounting

Locks are mounted in one of four orientations, depending upon the design of the safe. This is known as "handing" and is referenced from the rear of the safe door, looking forward. Handing is significant when the safe is to be penetrated through drilling or manipulation. All mounting screws are now standardized at ¼-20 Allen head design. In some cases, the screws will be surrounded in a well to prevent one that is loose from falling into the

mechanism.

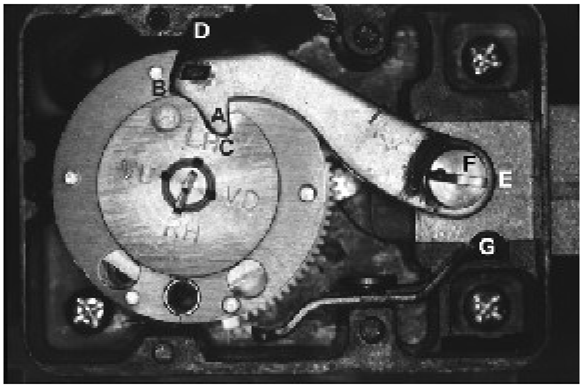


34_3.4.2.3 Case Size

The case size and hole patterns for mounting screws of almost all manufacturers are virtually identical.

34_3.4.3 Lock Bolt

The bolt is generally made of brass or cast in zamak and coated with Teflon or other material. The lever is directly attached to the bolt. Its purpose, once extended, is to block movement of the boltwork or actuating mechanism (such as the handle-cam or carriage-bar) until the correct combination (or key) has been entered. Modern safes generally do not use the lock bolt as the actual securing mechanism for the door but rather link to a more sophisticated boltwork. This reduces the potential for lockout and minimizes stress on internal components.



34_3.4.3.1 Detent Ball

There is usually one detent ball and spring, known as a **timing ball**, located under the bolt within the case. LaGard utilizes two such balls, one for each bolt position (locked, unlocked). This mechanism performs several functions:

- **Holds the bolt in a fully extended or retracted position;**
- **Prevents bypass through vibration;**
- **Keeps the lever from binding against the lock case;**
- **Insures that the lever is in the correct position with the gates during opening.**

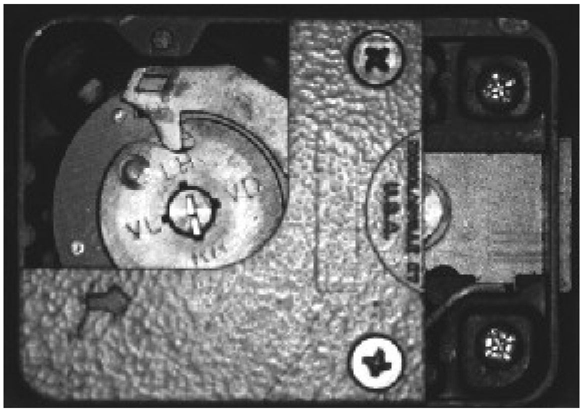
34_3.4.4 The Lever

The lever performs three critical functions:

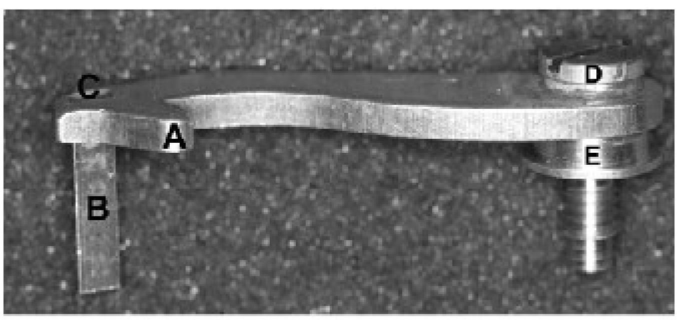
- **Positions the fence above and isolates it from the wheel pack;**
- **Engages the drive cam in order to extend and retract the bolt;**
- **It is blocked from movement once it reaches the lever stop. This prevents bolt retraction until the correct combination has been entered.**

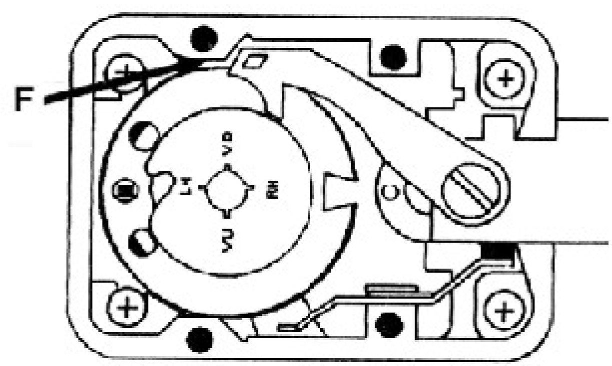
The lever is usually constructed of brass or zamak, although other materials have been utilized with limited success. Mosler, for a short while, used a cast black polycarbonate for the lever, fence, nose, and other components in the Group 1R lock for GSA containers. However, the design proved too brittle, resulting in

the nose breaking off and causing serious lockouts. It was soon discontinued.



A spring maintains downward pressure on the lever, forcing it to make contact with the drive cam. In manipulation-proof (MP) locks, the **accelerator spring** forces the lever to drop into the gate. Certain levers in MP locks are designed so that the dial or thumb-turn knob must be depressed. These control the spindle and opening of the drive cam gate.





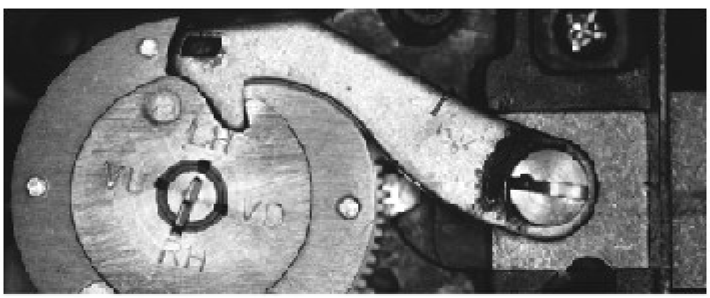
The lever has three primary components: the **fence**, **nose**, and **bushing**. The **lever stop**, **screw**, and **spring** are also part of the assembly. The **bushing** holds the lever screw, allowing the assembly to pivot as the bolt moves. The **nose**, at the opposite end from the bushing, rides on the ridge of the drive cam and drops into the gates when aligned. The **lever stop**, which is cast as part of the case, will prevent the lever from being forced to the unlocked position. The **lever screw** provides the pivot point and anchor for the lever assembly to the bolt; it is generally made of brass.

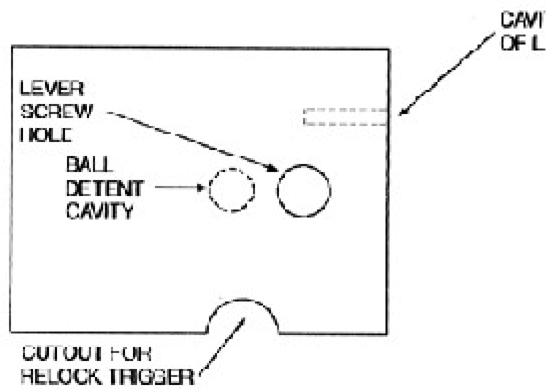
34_3.4.4.1 Nose of the Lever

The nose skirts the drive cam during rotation and keeps the fence from making direct contact with the wheels until they are properly aligned. It is designed to enter the drive cam gate and be "hooked." Once in this position, a turn of the dial will cause the lever to rotate **with** the drive cam, carrying the bolt to the unlocked (or locked) position.

34_3.4.4.2 The Lever Screw

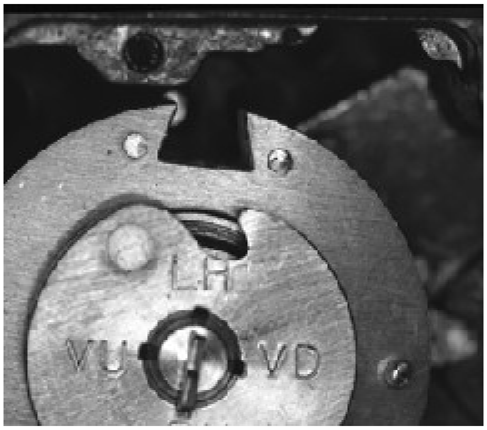
Most locks contain a shouldered lever screw, usually made of brass. The screw holds the lever in place, and allows it to pivot. The shoulder guarantees freedom of movement, and prevents overtightening.





34_3.4.5 Fence

The fence is a metal protrusion that is soldered to the lever and is one of the critical components within any combination lock. It is constructed as a short horizontal stump or bar on the lever nose that extends in a perpendicular fashion laterally across the wheels. The fence is designed to precisely fit within corresponding slots (gates) in each individual wheel or lever when the lock has been set to open. The locking mechanism prevents actuation of the bolt until the fence is completely retracted into the aligned gates.



The fence will only make contact with each of the wheels when the proper combination has been dialed and the drive cam is in position to hook the nose of the lever and retract the bolt. When all of the wheels have been properly set, the lever assembly drops into the wheel pack and the bolt is withdrawn.

34_3.4.5.1 Fence Designs

There are four basic fence designs: **direct entry, gravity, friction, and spring loaded.** In each configuration, the fence is controlled or biased differently as it enters the gates. In a lock with a **direct-entry fence**, the bolt is part of the fence; it retracts into the gates upon opening. The wheel pack forms the obstacle, preventing entry except when aligned. If pressure is exerted upon the bolt by turning the handle, the location of each gate can be ascertained. Often, these locks will contain false gates to prevent this practice. In this type of mechanism, there are no contact points.

A **gravity fence** functions as the name implies. The weight of the bolt will cause the fence to drop into the aligned gates. A **friction fence** was utilized by Yale, and to a lesser extent, Mosler. It utilizes a gear drive to force the fence against the wheel pack when the gates are aligned. There will only be one contact point in these types of locks. The **spring-loaded fence** is the most common mechanical configuration. A spring will bias the fence to force it against the drive cam and wheel pack. This design is clearly distinguishable by the presence of contact points.

34_4.1 Relockers

As described in **Chapter 33**, **active** and **passive** internal and external relocking devices are designed to permanently block the bolt when activated. They are incorporated within combination and key locks and throughout the boltwork mechanism of all modern safes. They are designed to protect against several forms of attack:

- **Punching the wheel pack;**
- **Drilling;**
- **Side pressure of the bolt;**
- **Thermal attacks;**
- **Vibration and concussion.**

When "fired," a relocker will lock the bolts, throw extra bolts, drop deadlock pins into place, or disconnect the links to bolts from an actuator.

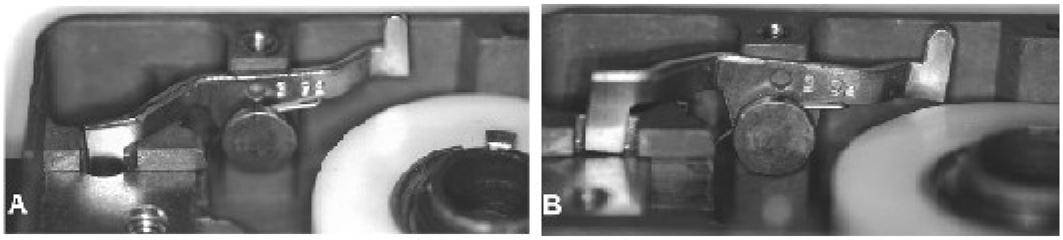
34_4.2 Relockers on Safe Locks

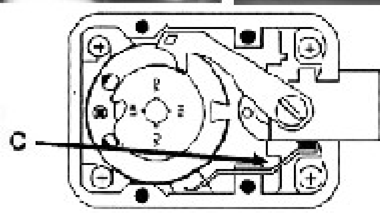
Internal relockers are mechanisms that deadlock the bolt, thereby isolating it from the wheel pack. The removal, distortion, or destruction of the lock cover or wheel pack usually activates them. Manufacturers will generally place lock case relockers in one of two positions:

- **Within the lock case. They are activated by the breaking or removal of the wheel pack or complete lock, or handle shear device;**
- **Within the door, triggered by breaking or removal of the lock case cover.**

34_4.2.1 Relock Trigger Designs

Depending upon manufacturer, the relock trigger can take many forms. Although all are activated when the back of the case is compromised, the way in which the bolt, handle, or cam is blocked will vary. Although the term "relocker" is used for both safe locks and safes, the proper description is "relock trigger" when referring specifically to locks utilized in safes and vaults. The relock trigger is designed to function whenever the lock is attacked, when the cover becomes loose, or the spindle has been punched.





In early S&G designs, a spring-loaded pin or a one-piece arm protected the wheel pack from punching and deadlocked the bolt. This mechanism presented service problems and required that the trigger be removed in order to access the wheel pack. It was utilized until 1951, at which time it was modified to incorporate two components. S&G employed this system until 1962, and it was then returned to a single piece design. Currently, S&G utilize a single pivot arm to block the bolt. LaGard uses a spring wire; Mosler, a spring-loaded pin; Yale and Diebold, a spring brass tab.

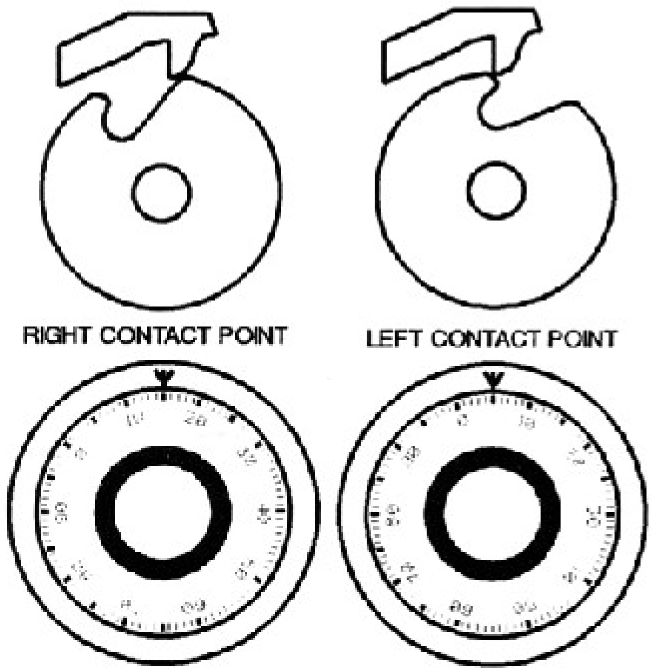
Relock triggers will prevent a burglar from punching the wheel pack through the back of the lock case in an effort to gain clear and unobstructed access to the nose of the lever. Typically in this form of attack, the dial is broken off and the spindle driven into the lock case. The impact of the drive cam will generally result in part or all of the cover fracturing and breaking loose from the case. In the absence of a relock trigger, a burglar can move the wheel pack out of the way of the lever. It is then a simple matter to hook the nose and pivot the arm in order to retract the bolt. Techniques are described in U.S. patents (**4266488(385), 4470275(386)**) and in British patents (GB **2172931A(387),** GB **2069589A(388),** GB **2119011A(389),** GB 2114649A, GB 2179094A).

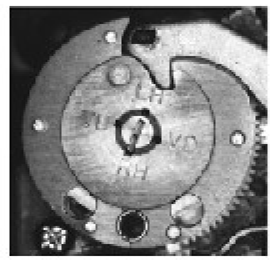
34_5.1 Physical Drop v. Dial Indication

The place at which the lever actually drops into the individual wheel gate is referred to as the **physical drop.** In contrast, the **dial indication** provides left and right contact points where the lever makes contact with the **drive cam gate.** This location will change depending upon the **handing** of the lock. The distinction

becomes important in drilling and manipulation.

The relationship between the spindle and drive cam will determine the physical drop location. The spline key is usually set at 50, although LaGard also places it at 44.



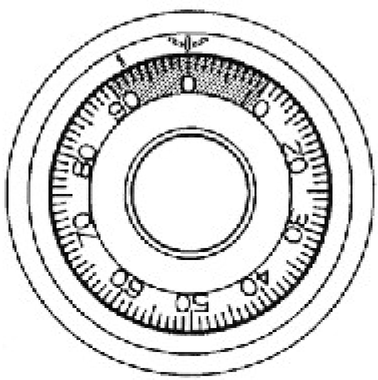


The physical drop location provides the absolute reference (with a dial index of zero) as to where the gates must be aligned in order for the lock to open. This location is calculated based upon the handing. For example, the S&G 6730 mounted RH has a physical drop of 97. If the lock is rotated to VU, 25 (1/4 revolution of the dial) would be added to 97, for a physical drop of 22. LH would be 47, and VD, 72. A dial revolution of a quarter turn of a 100 number index requires that 25 be added as the lock is rotated clockwise for each orientation.

The physical drop will be the same for all S&G 6700 and later series, as well as Federal, Diebold (800+ series), LaGard, and some imported models. Mosler locks have a shortened lever, and thus the drop is in a different position (RH 91, VU 16, LH 41, and VD 66). The Yale locks that use a roller-fence have different physical drops of (RH 80, VU 5, VD 55, and LH 30).

34_6.1 The "Forbidden Zone"

The forbidden zone refers to a mechanical problem inherent in all combination locks: the last number of the combination cannot be within the range of this area. It relates to the movement of the drive cam and the third or last wheel and their flys and drive pins. The problem is limited to mechanisms utilizing a pivoting lever and fence and cannot occur in a Yale roller fence (such as OC5) or a lock with a push-in dial.



The potential result of violating the "forbidden zone rule" is that the bolt cannot be retracted because the dial cannot be turned. Serious maintenance problems and lockouts will occur if the rule is violated. One result of the forbidden zone limitation is that the number of useable combinations is reduced. A block of numbers, generally ± 5 from the drop-in point, will be unavailable for use as the third or final number of the combination.

34_6.1.1 Violating the Forbidden Zone Rule

The forbidden zone rule only applies to the third or last wheel and its location with respect to the nose of the lever. If this wheel is positioned within the zone, it may still be possible to "run" the combination and open the lock. However, there will be no tolerance between the drive pin of the drive cam and the fly of the last wheel. When the dial is turned to retract the bolt, the last wheel is moved in order to rotate its gate to alignment with the fence.

The fence is trapped in the gate before the nose can be carried by the contour of the drive cam gate, thereby blocking the extension of the bolt. This will prevent locking of the safe. Excessive wear occurs from this condition and will eventually lead to a lockout. The problem can be exacerbated when the customer tries to force the bolt to the locked position, causing

serious damage and a potentially difficult opening procedure.

If a combination is programmed that violates the forbidden zone rule, the problem can be corrected so long as the wheel pack is still accessible. The wheels are simply set to one number, the lock placed so that a change key can be inserted, and a new combination entered.

34_6.1.2 Relationship Between Physical Drop and Forbidden Zone

As with the physical drop, the zone will move in the same ratio, based upon handing. Thus, combination locks having a physical drop of 97, for example, will have a forbidden zone of zero through twenty. One exception is the S&G 8500 series with a push-in dial at zero. In this lock, the zone is 90-10. The newer LaGard locks with a spline located at 44 will have a forbidden zone of 94 through 14. The Mosler zone is 89 through 11.

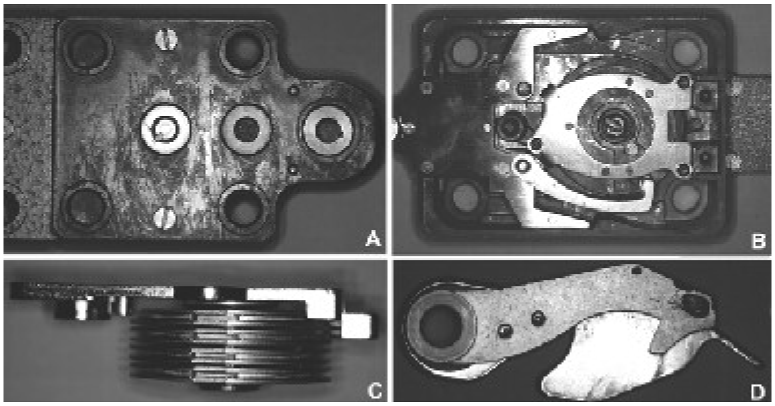
34_7.0 Combination Lock Security

34_7.1 Introduction

Security, as it applies to combination locks, relates to two issues: surreptitious and forced-entry. All locks are designed to minimize their exposure to each of these threats. Mechanical considerations, materials, maintenance, and user convenience are all factors that determine the overall security of any lock. Underwriters Laboratories and many other world standards organizations have developed criteria for analyzing and rating the security of a combination lock. See **Chapter 37**.

34_7.2 Primary Security Ratings

There are two primary security classifications or groups for combination locks: **Group 1**, **1R** (a subgroup), and **2**. Group 1 listed locks are devices utilized by government agencies and entities that require the highest security, such as nuclear and missile facilities and federal law enforcement. Although the cost of Group 1 and Group 2 locks is about the same, their design is not. The public has no need for Group 1 devices.



Locks within the Group 1 category contain features specifically designed to prevent manipulation and radiographic imaging (1R). Group 2 locks such as the S&G 6730 provide a high level of security but not to the same extent as Group 1. The U.S. government, through the General Services Administration, promulgates the requirements for the use of locks on high-security containers.

34_7.2.1 Manipulation Resistance

A combination lock may be opened surreptitiously by externally sensing the position and dimensions of each of the wheel gates, thereby extrapolating the combination. The generic description of this process is known as **manipulation**. A more thorough examination of this technique is presented in **Chapter 36.**





Figure LSS+3416 S&G 6700 MP three wheel key changeable combination safe lock. Courtesy of Mark Bates.

Manipulation is possible because of imperfections in manufacturing processes and tolerances. Slight variations are encountered in the machining of parts and in mass production that allow certain locks to be opened by sensing the position of the gates.

Shortly after World War II, Harry Miller and others began developing anti-manipulation technology that was incorporated in the S&G and other locks (including padlocks) for use by the government. S&G actually copyrighted the term "manipulation-proof" in the 1950s. These locks are described in several U.S. patents (**2852928(390)**, **2814940(391)**, **2775112(392)**, **2625032(393)**, **2673457(394)**, 3045467, 3073145).

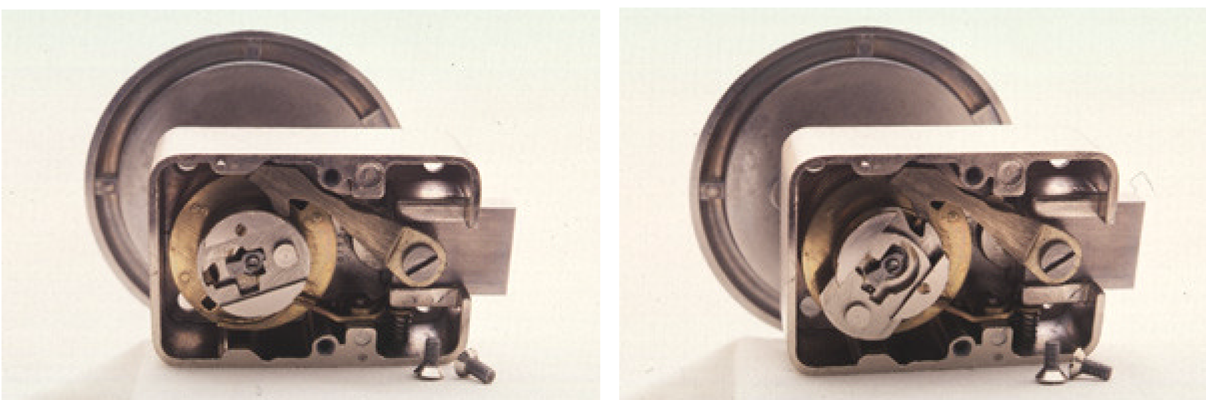


Figure LSS+3417 S&G M-6730 MP with drive cam closed and open. Courtesy of Mark Bates.

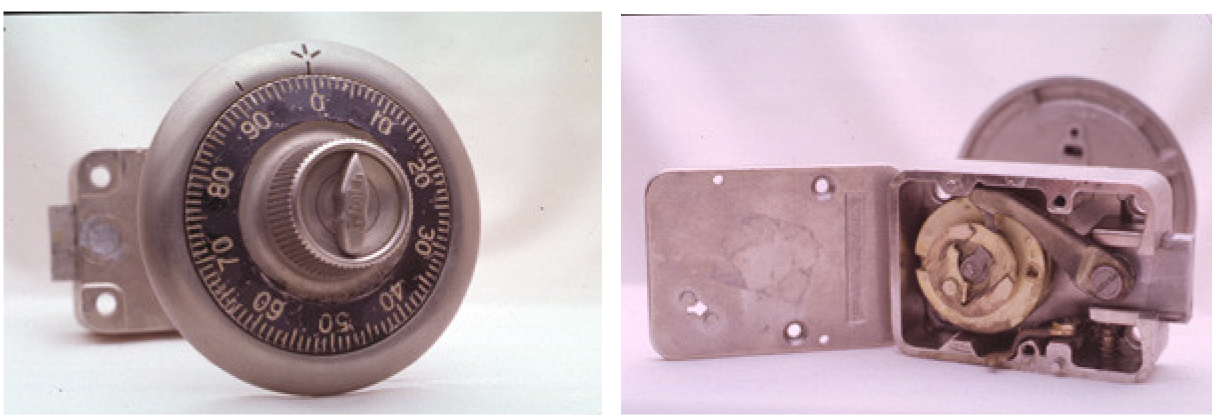


Figure LSS+3418 S&G 6700 MP lock. Courtesy of Mark Bates.

Manipulation can be accomplished manually by the operative

repeatedly turning the dial to derive the required information for the correct combination. A lock may also be opened automatically with robot dialers. These devices can be programmed to try every combination, can sense when the lock opens, and in some cases actually can hear or feel contact points. A dialer can open a three-wheel combination lock in as little time as forty-five minutes, depending upon a number of factors.

Auto dialers, such as produced by ITL, can dial up to one combination per second, depending upon the coefficient of friction in the wheels. Robot dialers will only function with Group 2 locks, although Mas-Hamilton has developed a unit for Group 1R mechanisms. These devices are programmed to take advantage of the inherent gate-fence tolerances so that a minimum number of attempts must be made in order for a successful opening. If one of the numbers of the combination is determined by manipulation before the dialer is activated, the time required to derive the remaining combination is greatly reduced.

Modern Group 2 locks are by no means manipulation proof, although some can be extremely difficult to open. Virtually all Group 2 locks can provide information (by using the dial) that will provide an indication of gate position. This is possible, even though almost every manufacturer isolates the fence from the wheels until the drive cam is in a position to allow an opening. Group 1 and 1R locks, by their very definition, cannot be manipulated now. Sensory access is denied with an **eccentric lever** that eliminates contact points by keeping the lever off the cam. It is anticipated that there will be a change in the rating criteria of Group 2 locks, or elimination of the classification altogether in order to increase resistance to manipulation. Mas-Hamilton and others have developed sophisticated technology that will defeat Group 1 locks. Electronic locks such as the X-07 cannot be opened with this technique.

Older lock designs prior to the 1950s and locks of inferior quality can be manipulated. This results from mechanical designs that allow the fence to ride on the ridge of the wheels. Sound, feel, and friction can provide the needed information to open the lock. The introduction of nylon wheels, sound baffles, secondary fences, and automatic random wheel rotation drastically reduced the potential for covert entry. Higher manufacturing tolerances, improved lubricants, and changes in mechanical design also contribute to increased security.

34.7.2.1.1 SARGENT AND GREENLEAF (S&G) 6600 SERIES COMBINATION LOCKS.

Note: The material in sections 34_7.2.1.1-7.2.1.7 has been excerpted from the **Intelligence Materiel Division Technical Data Handbook No. 2** **"Combination Locks,"** September, 1997.

There are at least three versions of Sargent and Greenleaf (S&G) combination locks in use bearing the 6600 series model number. The first version was a hand-changed lock introduced by S&G in the early 1950's. Although the lock has a spyproof dial and dial ring, the majority of them are equipped with a front-reading dial and dial ring.

The second version of the S&G Model 6600 series, also a hand-changed lock, was manufactured by S&G in the late 1960's for use on the Hillside Metal Products, now known as Art Metal, Class 6 Security Containers. This lock, as well as the earlier version, is no longer manufactured, nor are spare parts available from S&G.

The third version using the S&G 6600 series designation was a key-change lock manufactured in the 1980 to 1981 time frame, and bears no resemblance to the previous versions. This model was originally certified by Underwriter's Laboratories (UL) as a Group 1 or Group 1R, depending upon the material of the wheels. Subsequent tests of this lock by the Government revealed that the design should not be considered a Group 1 combination lock. All data in this Section is only relevant to S&G 6600 Series 1950 and 1960 version locks.

To Unlock:

Before operating the lock or changing the combination, read these instructions thoroughly. At the top of the dial ring, an opening index mark is provided for normal dialing and opening. This is a precision mechanism; therefore, extreme care must be used to align the combination numbers with the index mark.

Rotate the dial slowly and steadily. If, after turning the correct number of revolutions, any number is moved beyond the index mark, the entire series of combination numbers must be redialed. DO NOT ROTATE BACK TO REGAIN A PROPER ALIGNMENT WITH THE NUMBERS. Each time a selected number is aligned with the index mark, a revolution is counted.

CAUTION: Do not turn the Arrow Knob when the dial is set at any position other than "0", because the internal spring will be bent; this will require the mechanism to be replaced. All locks in this series are set on 50-25-50 after final inspection at the factory. Rotate dial to "0" and make sure the arrow knob is pointing to "0", then:



Figure LSS+3401 S&G Model 6600 Series (1950Version)

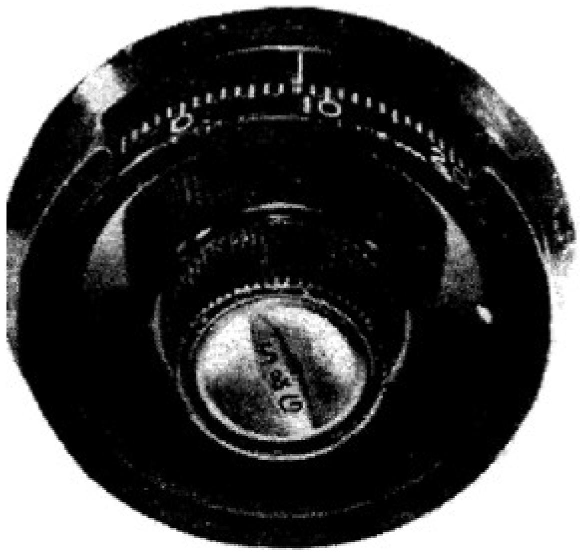


Figure LSS+3402 S&G Model 6600 Series (1960Version)

(1) Rotate dial to the LEFT, stopping when "50" is aligned with the index mark, the fourth time around;

(2) Rotate dial to the RIGHT, stopping when "25" is aligned with the index mark, the third time around;

(3) Rotate dial to the LEFT, stopping when "50" is aligned with the index mark, the second time around;

(4) Rotate dial to the RIGHT, stopping when "0" is aligned with the index mark, the first time around;

(5) On the 1950's version, hold the dial with "0" aligned with the index mark, and turn the small arrow knob to the RIGHT as far as it will go. NOTE: On the 1960's version turn the arrow knob to the LEFT as far as it will go;

(6) Rotate the dial to the RIGHT until it stops. The bolt is now

fully retracted and the safe or cabinet may be opened. The above procedure is used with any three number combination substituting the selected numbers for the example numbers 50-25-50.

To Lock:

To lock, rotate the dial to the LEFT, stopping when "0" is aligned with the index mark. Hold the dial in alignment and turn the arrow knob as far as it will go opposite to the opening direction, then continue to rotate the dial to the LEFT for at least four complete revolutions.

Changing to a New Combination:

Make up a new combination, selecting three numbers that meet the criteria for a secure series. Do not use numbers between 0 and 20 for the last number (e.g., 46-82-13). For maximum security, do not use numbers ending in 0 or 5, and do not use numbers in a rising or falling sequence (e.g., 35-50-75 is not as good a combination as 54-38-72).

(1) Make sure lock is in locked position with dial set on 50 before removing lock cover;

(2) Remove two cover screws and lift cover from lock;

(3) Remove spirolox washer or retainer clip from wheel post and remove three wheels and two washers and lay out in order of removal. CAUTION: Wheels must be replaced in the same order after changing;

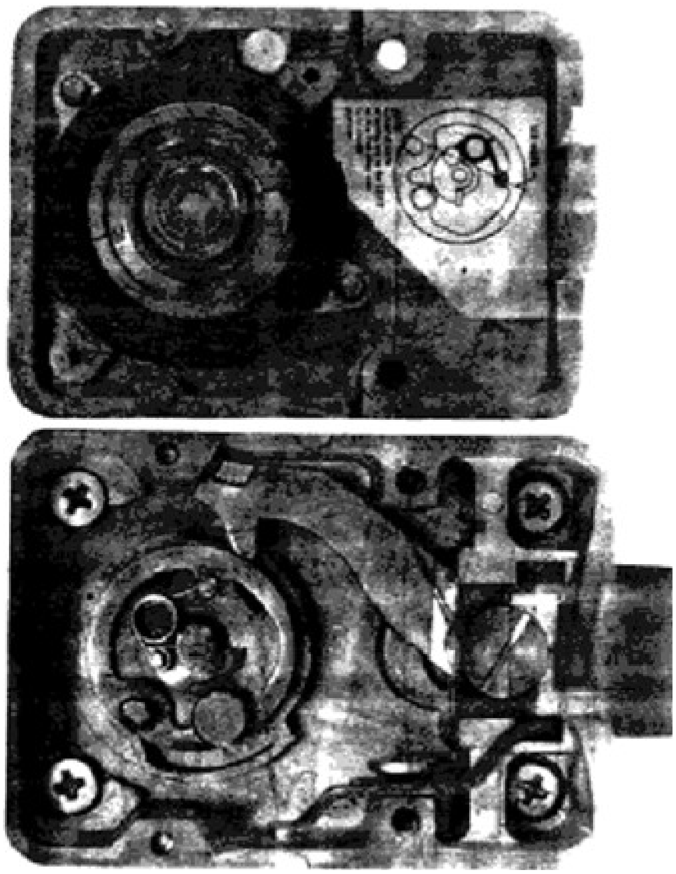


Figure LSS+3403 S&G 6600 SERIES (1960 VERSION) DISASSEMBLED

(4) Take the last wheel removed with numbers facing you, and press up the inner disc separating it from the outer ring;

(5) Reset the inner disc in the outer ring with the index mark on the metal insert opposite the number selected for the first number of the new combination. Replace the wheel on the post with numbered-side UP. Replace washer. CAUTION: Observe that the numbers increase counterclockwise on the wheels;

(6) Repeat the above process with the middle and top wheels. To help identify the wheels, observe the middle wheel gate (cutout) is approximately 180 degrees opposite the number, 92;

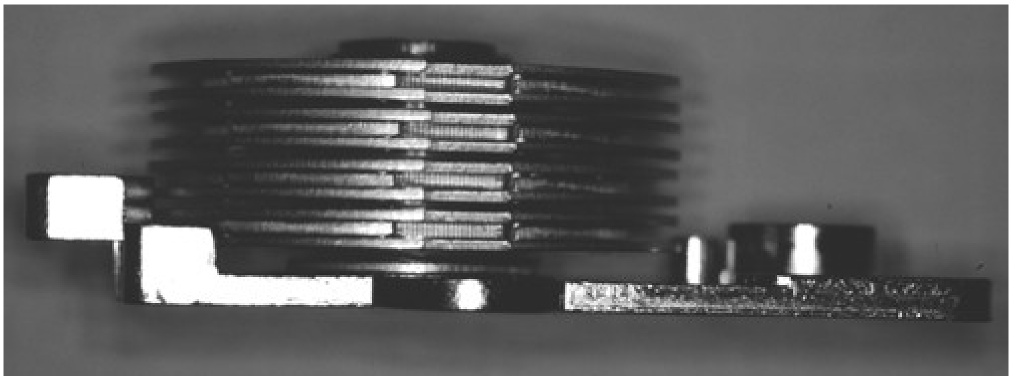
(7) Replace the spirolox washer or retaining clip. Cover is now ready to replace on lock;

(8) Before closing the door, operate the new combination several times to test it.

34_7.2.1.2 S&G 8400 SERIES

The **8400 Series** S&G Combination Locks are key-changeable Group 1 and 1R "Manipulation Proof" (MP) identified with the typical S&G arrow knob (butterfly) in the center of the dial knob. The drive is **gear** indirect type to increase **manipulation resistance.**

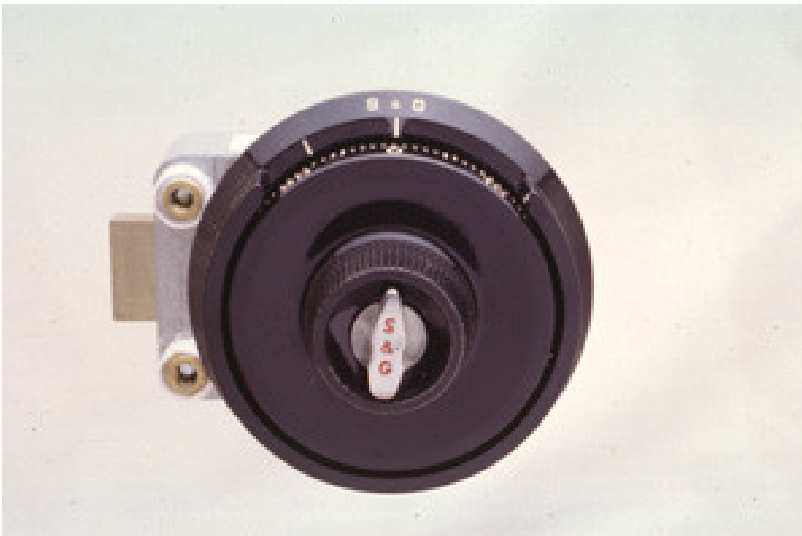
Opening the 6730 MP and 8400 Mp, by Harry Sher

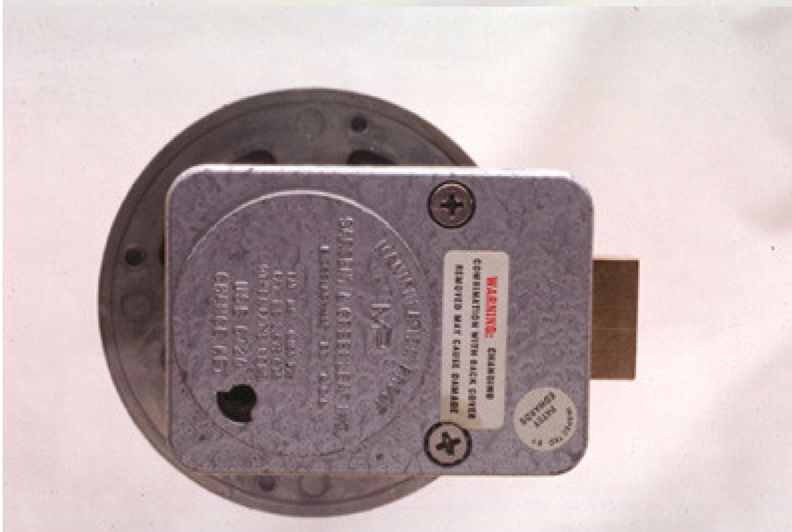


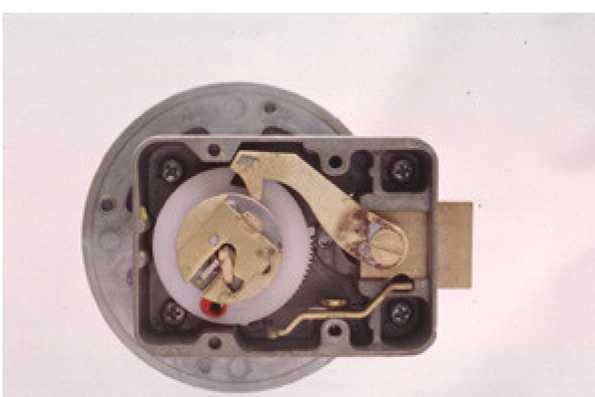


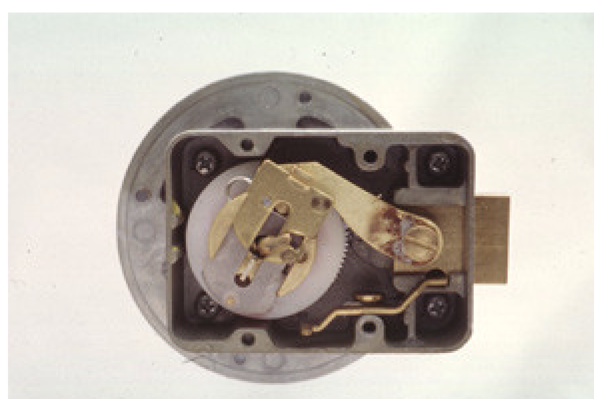
Unlocking Procedure:

At the top of the dial ring, an opening index mark is provided for normal dialing and opening. This is a precision lock, therefore, extreme care must be used to align the combination numbers with the index mark. Rotate the dial slowly and steadily. After rotating the correct number of revolutions, should any number be rotated beyond the index mark, the entire series of combination numbers must be redialed. DO NOT ROTATE BACK TO REGAIN A PROPER ALIGNMENT WITH THE NUMBERS. Each time a selected number is aligned with the index mark a revolution is counted.




WARNING: CHANGING
COMBINATION WITH BACK COVER
REMOVED MAY CAUSE DAMAGE





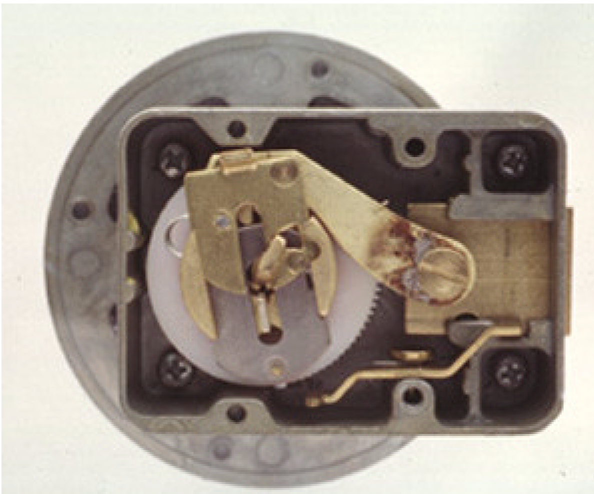


Figure LSS+3419 The S&G 8400 series lock. Notice the distinctive back cover for this MP lock. The photographs show the drive cam closed (left), open (center), and retracted (right). Courtesy of Mark Bates. Courtesy of Mark Bates.

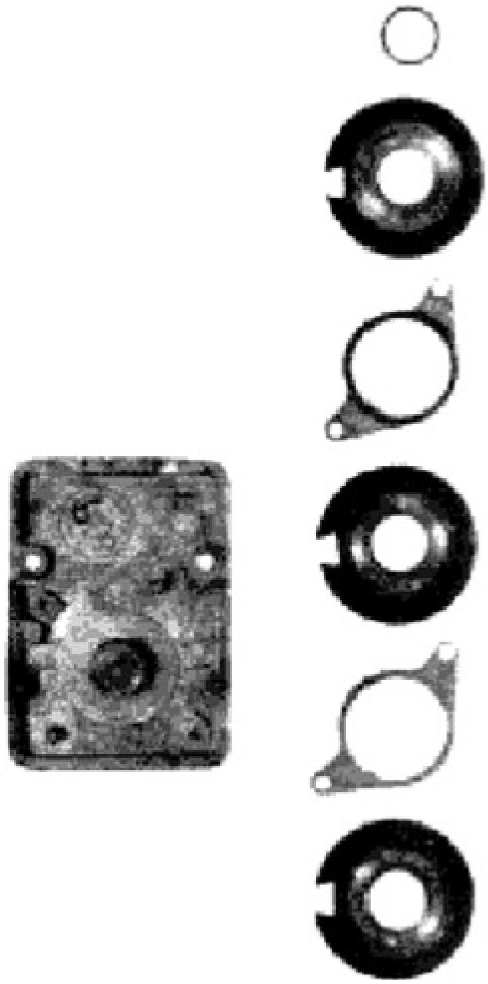


Figure LSS+3404 Disassembled hand change wheel pack; Spirolox Washer, No. 3 Wheel, Cover Plate Spacer, No. 2 Wheel, Spacer, No. 1 Wheel

CAUTION: Do not turn the arrow knob when dial is set at any position other than "0", because the internal spring will be bent, requiring the lock to be replaced. All mechanisms in this series are set on 50-25-50 after final inspection at the factory. Rotate dial to "0" and make sure the arrow knob is pointing to "0" then:

(1) Rotate dial to the LEFT, stopping when "50" is aligned with the opening index mark, the fourth time around;

(2) Rotate dial to the RIGHT, stopping when "25" is aligned with the opening index mark, the third time around;

(3) Rotate dial to the LEFT, stopping when "50" is aligned with

the opening index mark, the second time around;

(4) Rotate dial to the RIGHT, stopping when "0" is aligned with the opening index mark, the first time around;

(5) Hold the dial with "0" aligned with the opening index mark, and turn the small arrow knob to the RIGHT as far as it will go;

(6) Rotate the dial to the RIGHT until it stops. The bolt is now fully retracted and the safe or cabinet may be opened. The above procedure is used with any three-number combination, substituting the selected numbers for the example numbers 50-25-50.

Locking Procedure:

Rotate the dial to the LEFT, stopping when 0 is aligned with the index. Hold the dial in alignment and turn the arrow knob one quarter turn to the LEFT (as far it will go), then rotate the dial to the LEFT for at least four complete revolutions.

Changing to a New Combination:

Select three new numbers that meet security guidelines for combinations,as defined earlier. CAUTION: Use Change Key 6720 (unless otherwise specified on back of lock) on this series lock, other keys will not function properly.

(1) Using the changing index, dial the existing combination as previously explained;

(2) Hold the dial with the last number at the changing index found 8 1/5 numbers to the left of the opening index. Insert the change key in the keyhole in the back of the lock until the wing is entirely inserted and comes to a positive stop;

(3) Turn the key one-quarter turn to the LEFT. With the change-key in this position, turn the dial four complete turns to the LEFT, stopping when the first number of the newly selected combination aligns with the changing index, the fourth time;

(4) Rotate dial to the RIGHT, stopping when the second number is aligned with the changing index, the third time;

(5) Rotate the dial to the LEFT, stopping when the third number is aligned with the changing index, the second time;

(6) Holding the dial in this position, turn the change-key back to the RIGHT and remove it. The new combination is now set in the lock;

(7) Before closing the cabinet, try the new combination several times, using the opening index.

WARNING: Never insert the change key in the lock when the cover is removed. Always be certain that the wing of the change key is entirely within the lock before turning the key.

If an error has been made in setting a new combination, it is suggested that local Facilities Engineers or supporting Military Intelligence (MI) personnel be notified. Caution dictates that a new temporary storage facility be found until competent assistance arrives. DO NOT shut control drawer or vault door when this error occurs.

S&G MODEL 8470 MODIFICATION:

S&G now manufacturers a new "Locked-Open Latch" which is used on their Model 8470. The back cover plate can be retrofitted on existing 8470's. The latch is designed so that passersby cannot spin the dial when the combination has been dialed, or use back-dialing to recover the combination.

SARGENT & GREENLEAF Model 8470 Combination lock with dead bolt:

The diagram below shows an S&G Model 8470, formerly SM50 Pinch-proof combination lock. It is a reversible, surface-mounted lock for use on locally fabricated doors constructed of either wood or metal. The lock features an automatic deadlock tripper, and an inside release knob allowing the lock to be opened from the inside in the event the door is closed and the combination is spun off. The 8470 can be ordered with either the S&G Model 8400 or 8500 Series Combination Lock; Spyproof Dial (TOP READING) should be specified. In the event the 8500 Series combination lock has been specified, ensure the proper handing of the lock (i.e., left or right) is also designated. In addition, ensure that the lock is equipped with a tube for ease of installation.

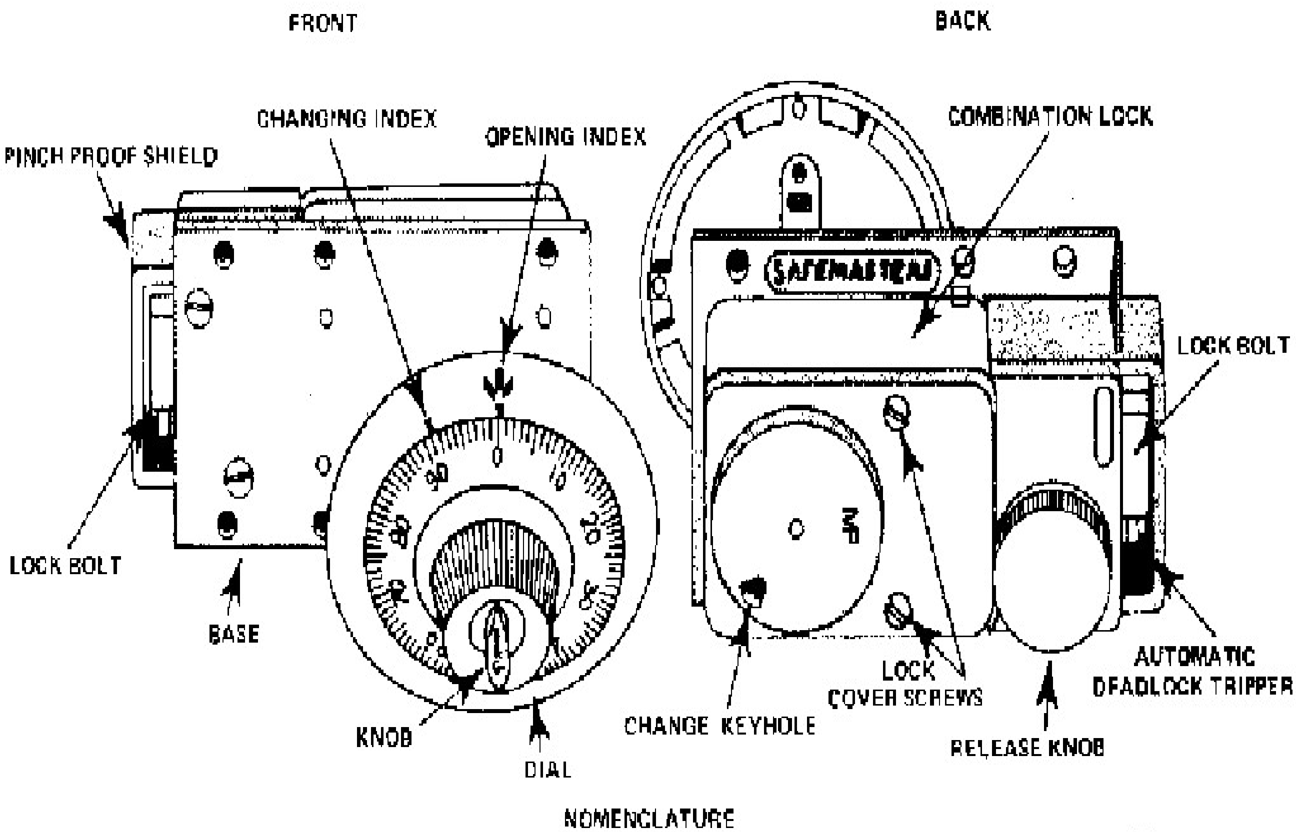


Figure LSS+3420 S&G Model 8470 combination lock with dead bolt.

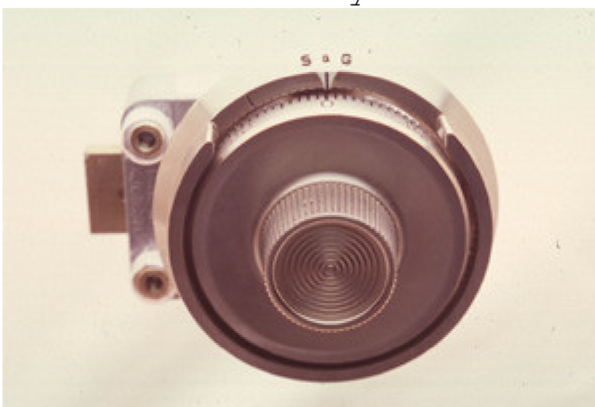
Drill resistant hard plate: A 1/8 inch drill-resistant hard plate should be installed between the S&G Model 8470 and the locally fabricated door. In certain regulations and manuals, this hard plate is a requirement that should not be overlooked. The drill-resistant hard plate should be installed at the same time that the 8470 is installed.

34_7.2.1.3 S&G 8500 SERIES COMBINATION LOCKS

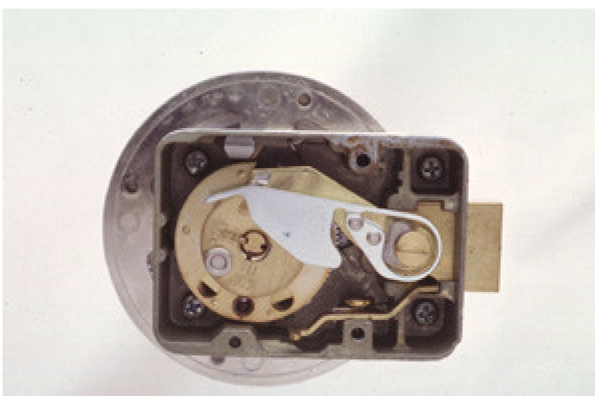
There are several methods of attack to penetrate combination locks. Manipulation Proof (MP) locks produced by Sargent and Greenleaf offer far greater protection than any other lock. The 8500 Series MP locks have been designed to give added security against penetration in light of new scientific instruments and methods of attack. The security offered conforms to UL Groups 1 and 1R.

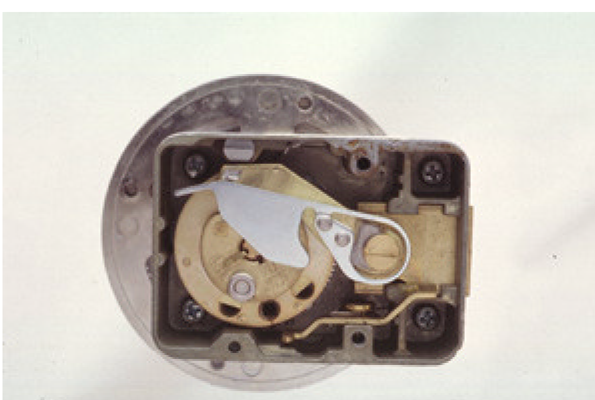
This Series does not have the typical inner spindle thumb turn knob (arrow knob or butterfly) on the dial as used in previous

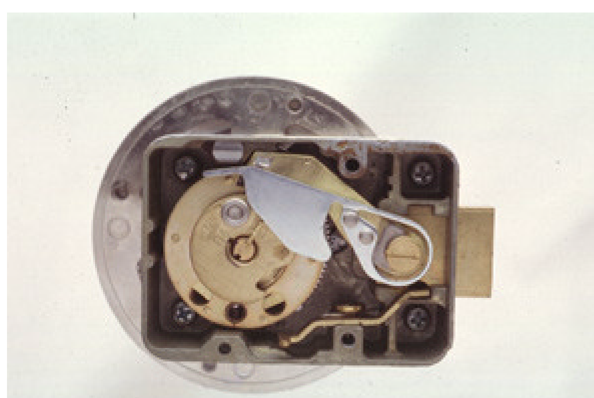
S&G Group 1 and 1R MP combination locks. The 8500 Series may be identified by a plain center dial that can be pushed in at the zero location. This action is spring loaded and causes a definite click to be triggered. It is important to that installation and service personnel appreciate the 8500 Series MP locks' features. A satisfactory installation, requires that these instructions to be followed closely.











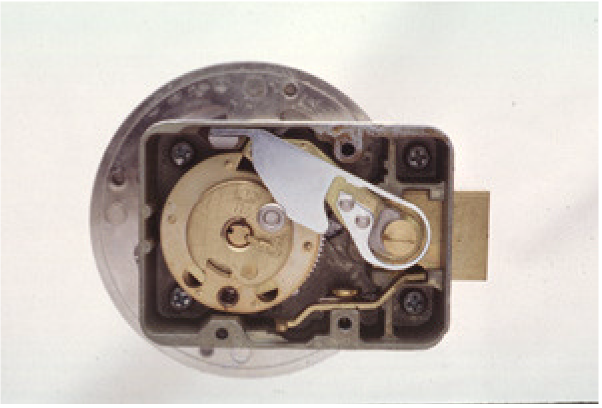


Figure LSS+3421 The S&G model 8550. Photographs show the wheels aligned and the dial at zero (top center), dial has been pushed in, allowing lever to drop (top right), the bolt may be retracted (bottom left), when the dial is rotated to extend the bolt, the roller on the drive cam contacts the accelerator spring (bottom center), and lifts it back onto the shelf (bottom right). Courtesy of Mark Bates, Modern Safe Locks.

IMPORTANT: Tolerances must be maintained and related components must be used to achieve overall satisfactory performance. The lock is designed for right-hand, vertical-up or vertical-down use. Left hand operation was originally achieved with a true left-hand model. A Universal Model has superseded these, and is the present model offered. All locks feature a relock trigger as a standard security feature. The 8500 Series Combination Lock is available in four models. They are:

8550: Three brass wheels, no tube
For: Universal: 8550-UNI (Present Model)
For: Right Hand Vertical Up or Vertical Down: 8550-COM Obsolete (ref. only)
For: Left Hand: 8550-OLM Obsolete (ref only)

8555: Three brass wheels, with tube
For: Universal: 8555-UNI (Present Model)
For: Right Hand Vertical Up or Vertical Down: 8555-COM Obsolete (ref only)
For: Left Hand: 8555-OLM Obsolete (ref only)

8560: Three x-ray Proof Wheels, no tube
For: Universal: 8560-UNI (Present Model)
For: Right Hand Vertical Up or Vertical Down: 8560-COM Obsolete (ref only)
For: Left Hand: 8560-OLM Obsolete (ref only)

8565: Three x-ray Proof Wheels, with tube

For: Universal: 8565-UNI (Present Model)
For: Right Hand Vertical Up or Vertical Down: 8565-COM Obsolete (ref only)
For: Left Hand: 8565-OLM Obsolete (ref only)

Dialing Combination to Unlock:

On the dial ring, there are two indices. The index at the top is for normal dialing and opening. The index to the left is provided for use only when changing the combination. Rotate the dial slowly and steadily. After turning the correct number of revolutions, should any number be turned beyond the index mark, the entire series of combination numbers must be redialed. Do not turn back to regain proper alignment with the numbers. Each time a selected number is aligned with the opening, index a revolution is counted. To unlock on a factory setting (50-25-50):

(1) Rotate the dial to the LEFT, stopping when "50" is aligned on the opening index the fourth time around;

(2) Rotate the dial to the RIGHT, stopping when "25" is aligned the third time around;

(3) Rotate the dial to the LEFT, stopping when "50" is aligned the second time around;

(4) Rotate the dial to the RIGHT, stopping when "0" is aligned the first time around;

(5) With "0" aligned in the index, push dial in to activate lever assembly, release dial;

(6) Rotate the dial to the RIGHT for a right hand and Universal lock and LEFT for a true left hand lock, until the bolt is fully retracted. Then the combination lock can be opened. NOTE: True left hand locks are no longer made, but early 8470 deadlocks used these for left opening doors. This procedure is used with any three number combination selected. CAUTION: Dial should not be pushed in and released at "0" until all three numbers have been dialed.

Procedure to Lock:

Rotate the dial LEFT or RIGHT at least five complete revolutions in one direction.

Changing to a New Combination:

Select three numbers. Do not use digits between 90 and 10 for the last number.

NOTE: Only use Change Key 6720 on these locks; others will not function properly. When using new locks and new change keys, the change key may be difficult to turn at first. This situation may be eliminated by removing the lock cover, inserting the change key through the hole in the cover and turning it several times. Then remove the key and replace the cover on the lock.

WARNING! Never insert the change key into the lock itself when the cover is removed. Also, always be certain that the change key is entirely within the lock before turning.

(1) Using the changing index, dial the existing combination as explained previously, substituting charging index;

(2) Leave the dial with the third number at the changing index, insert the change key in the key hole in the back of the lock until the wing is entirely inside the lock and stops;

(3) Turn the key one quarter turn counterclockwise. With the change key in this position, dial your newly selected combination to the change index;

(4) When the third number is aligned with the changing index the second time, hold the dial in the position, turn the change key one quarter turn clockwise; this will relock the wheels with the new combination set;

(5) Before closing the container, try the new combination several times using the opening index.

NOTE: Read complete instructions on each style of lock before installation.

General Installation Instructions for S&G 8500 Universal (UNI) Series Locks to be followed when replacing locks in security containers.

(1) Remove the lock cover. Put the lock bolt in the extended position and the accelerator spring in the loaded position.

CAUTION: DO NOT remove the drive cam;

(2) Mount the lock in place with four 1/4 x 20 attaching screws;

(3) Attach the dial ring, lightly tighten the attaching screws to hold the dial ring in place for alignment. The dial ring opening index should be at 12 O'clock center position. Before installation of the dial ring, the plastic bearing insert should be pressed into the opening in the back of the dial ring. The insert must fit flush with the dial ring;

(4) To install dial, hold the drive cam in place with one hand and thread the dial into the cam until the dial comes to a stop against the surface of the dial ring;

(5) The alignment of the dial and dial ring is critical to the operation of the lock. Perfect alignment must be obtained. The dial should be flush and centered with the surface of the dial ring for true center;

(6) Measure the excess spindle that projects beyond the drive cam;

(7) Remove the dial, cut off excess spindle and remove burrs;

(8) Tighten the dial ring screws;

(9) Place a washer, compression spring and washer on hub of dial;

(10) Insert the dial into the lock. Holding the drive cam in place (to receive the nose of the drop lever) with one hand, thread the dial into the cam until the dial stops;

(11) Rotate the dial counterclockwise a MINIMUM of one full turn until the spline in the spindle is aligned with the proper spline in the cam, the cam is positioned to receive the nose of the drop lever, and the dial is on zero. NOTE: If the lock is mounted in the vertical-up or vertical-down position the properly aligned spline should be marked VU/VD on the drive cam. For right or left hand mounting RH/LH should be aligned;

(12) Insert the spline key with lip toward edge of cam. Tap in lightly. The dial must turn freely with no rubbing or interference. (NOTE: Before attaching the cover to the lock,

check for proper in and out travel of dial for operation of accelerator spring.);

(13) Rotate the dial at least one complete revolution and stop at "0". The accelerator spring should now be in the loaded position;

(14) Hold the cover in place on the lock and push the dial in at "0". Release the dial. Remove the cover and check the position of the accelerator spring (the spring should be in the released position). If the accelerator spring is not in the released position, the dial has not been backed out of the cam far enough. This condition must be corrected;

(a) Repeat step (11);

(b) Rotate the dial at least one complete revolution and stop at "50". The accelerator spring should not release. (If the accelerator spring does release, the spindle must be turned clockwise into the cam one revolution and this step repeated.);

(c) Hold the back cover in place on the lock and push the dial in at "50". The accelerator spring should not release. (If the accelerator spring does release, the spindle must be turned clockwise into the cam one revolution and this step repeated.);

(15) Dial the set combination (50-25-50) on the lock and observe the drop lever falling into the drive cam at least three times;

(16) When the accelerator spring is opening properly, the cover may be attached to the lock and the new combination set;

Special Instructions for S&G 8500 Series Tube Locks:

(1) Fasten the lock to the mounting plate. Place the dial ring on the tube;

(2) Measure the tube excess. Remove the lock and cut off excess. Leave 3/16" to insert in dial ring;

(3) Remove any burrs from end of tube. Replace the dial and ring on the door.

Torque Adjustment:

The torque adjustment feature allows the feel of the dialing of the combination to be adjusted for individual preference. With the cover removed, insert an Allen wrench into the adjusting screw. Turn clockwise to tighten or counterclockwise to loosen. NOTE: Adjustment should not be less than eighteen inch-ounces of dialing torque, i.e., slight drag on the dial.

Disassembly for Servicing:

Periodic servicing will extend the life of the lock and is essential for maintaining proper security. To do a proper servicing job, follow the disassembly carefully (see Diagram of Disassembled Lock).

(1) Remove lock cover;

(2) Remove lever screw and lever assembly. Be sure to remove the lever control tension spring so it is not misplaced;

(3) Using a pair of side cutters, grip the head of the spline key as close as possible to the surface of the drive cam. Lift straight up, being careful not to bend the head. The edge of the case may be used for leverage;

(4) Unscrew the dial from the lock. Remove cam;

(5) Remove Spirolox washer from wheel pack carefully with a sharply pointed instrument;

(6) Remove wheels and associated parts and place them in sequence so that they can be replaced in proper order;

(7) Remove the lock bolt, do not misplace the detent ball or ball spring;

(8) Remove dial and spindle assembly from dial ring;

CAUTION: Remove the washers and spring from the dial ring and carefully place them in sequential order for reassembling later. The lock is completely disassembled and ready for servicing.

Service and Reassembly:

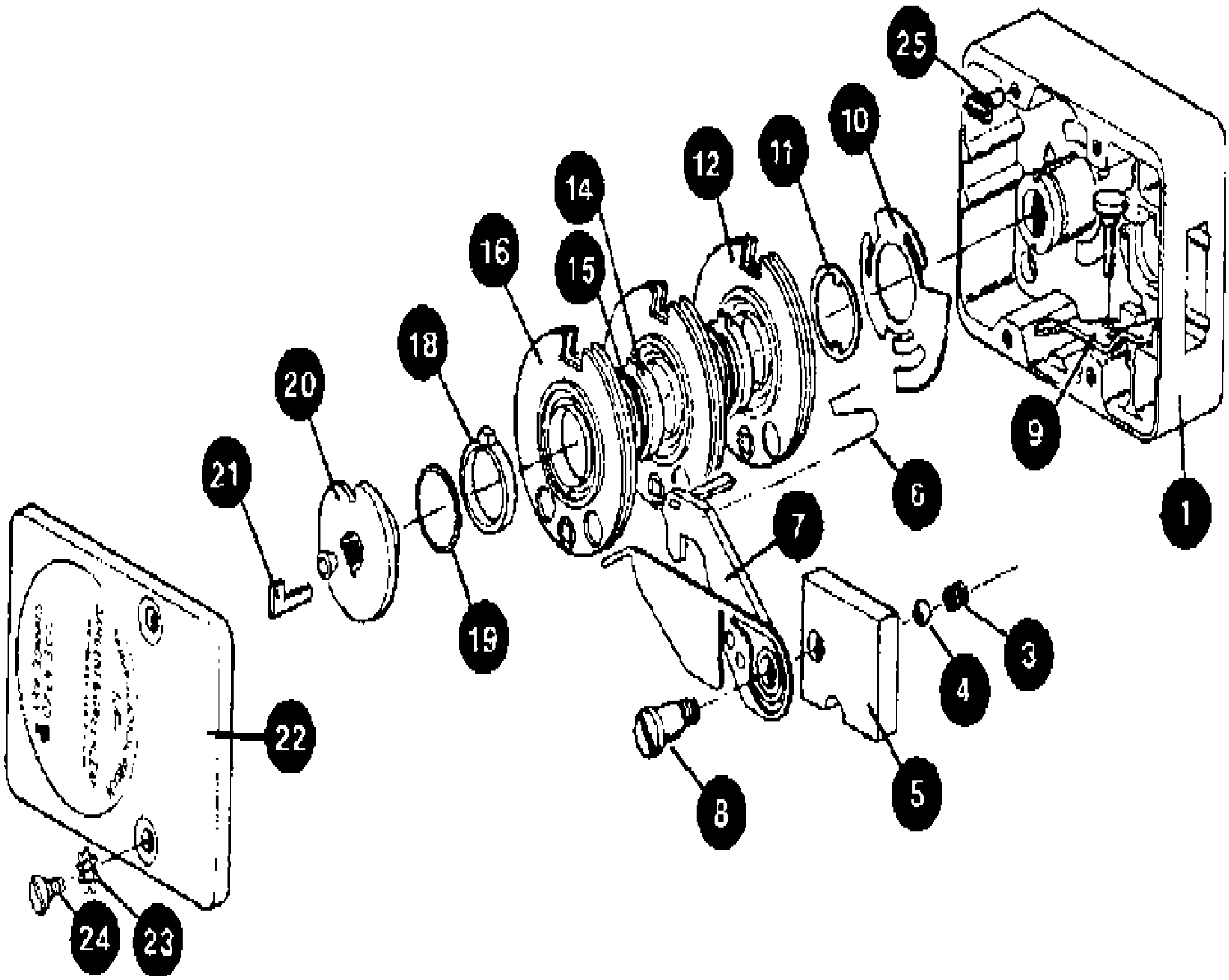


Figure LSS+3405 Diagram of disassembled lock

(1) Tighten the attaching screws on the dial ring and lock;

(2) Wipe each wheel, the wheel post and other bearing surfaces clean. Wipe complete interior of the lock case clean;

NOTE: S&G recommends that GE-322L Lubricant be used. If this lubricant is not available, use a thin film of white petroleum jelly;

(3) Lightly grease the bolt holding up the relock device and insert the bolt;

(4) Be sure to examine each wheel part, the cam, and lever

assembly carefully to make sure nothing is worn or damaged. Replace the wheels and parts exactly as they were before disassembly;

(5) Lightly grease the bearing surfaces of the wheel post and drive cam bearing, then screw the dial and drive cam together until snug. Hold the cam and turn the dial back one complete turn, then align the spline keyway. Insert the spline key. IMPORTANT: It is recommended that a new spline key be used each time the lock is serviced;

(6) Grease the lever bushing and install the lever. Tighten the lever screw snugly, and carefully position the lever control tension spring. Be careful not to bend the actuator spring;

(7) Install the lock cover. Make sure the cover screws are tight and secure;

(8) Reset the combination;

(9) Check the combination at least three times before locking the safe.

Errors:

The most frequent error during the changing procedure is dialing the number on the wrong index. Occasionally, all the numbers may be dialed to the opening index rather than the changing index. More often, dialing part of the combination to the changing index and part to the opening index occurs. As long as the container or door is open, the error is easily corrected.

Recovery Procedure in the Event of Error:

(1) Remove the back cover of the lock;

(2) Insert a straightened paper clip or similar instrument in the square keyways in the wheels;

(3) Rotate each wheel until all keyways are in perfect alignment directly over the small hole in the bottom of the case. There are two holes in the case, the keyway in the cover generally tells you the correct location;

(4) Replace the cover and screws, then insert the change key. NEVER INSERT THE CHANGE KEY INTO THE LOCK WHEN THE COVER IS REMOVED. Always be certain that the wing of the change key is entirely within the lock before turning the key;

(5) Turn the change key one quarter turn and dial the new combination using the changing index;

(6) Remove the key with the combination now set;

(7) Try the combination at the opening index at least three times before closing the door.

34_7.2.1.4 Mosler Model 300-400 and 301-401 MR Series Locks

There are four models of the Mosler combination lock. Although the detailed instructions in this text only deal with the 302-402 MR and MRK series, the following series of locks might also be encountered in the field:

The Mosler Model 300-400 hand-change combination lock is the forerunner of the Manipulation Resistant (MR) series that Mosler currently manufactures. The wheel pack is constructed of a light gray plastic material, which includes the inner disc that is employed to set the combination. This lock was usually supplied with a bright chrome dial and dial ring.

The Mosler Model 301-401 MR is also a hand-change lock and was usually supplied with a bright chrome dial and dial ring. The wheel pack consisted of the same light gray plastic material as the Mosler Model 300-400. The inner disc of each wheel is constructed of metal.

34_7.2.1.5 Mosler Model 302-402 MR and 302-402 MRK Series Locks

The Mosler Model 302-402 MR is the current model of the Mosler Hand Change Combination Lock. This lock can be identified from the exterior by a brushed chrome dial and dial ring. The wheel pack is constructed of a black plastic material with a metal inner disc. The Mosler Model 302-402 MRK is the newest combination lock that Mosler manufactures. The "K" in the model designation signifies that this lock is a key-change variety. When the MRK was first introduced, the dial and dial ring

remained the same as the 302-402 MR hand-change lock.

Because these dial rings did not have a separate changing index, the operator had to use the opening index as the changing index to change combinations. This was accomplished by adding 10 numbers to the selected combination. The 302-402 MRK now has both a changing index and opening index inscribed on the brushed chrome dial ring.

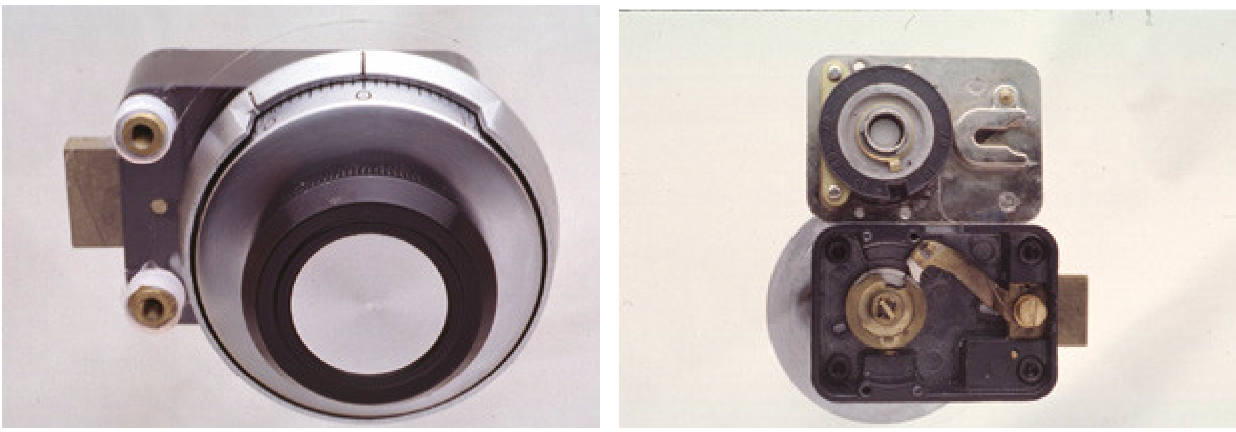


Figure LSS+3406 Mosler 302 MR Hand Change Lock

(1) Rotate the dial for a minimum of four times to the LEFT. This clears all previously dialed numbers. Stop EXACTLY at the opening index mark the fourth time that the first number of the combination has reached the opening index mark;

(2) Rotate the dial to the RIGHT. Stop EXACTLY at the opening index mark the third time that the second number of the combination has reached the opening index;

(3) Rotate the dial to the LEFT. Stop EXACTLY at the opening index mark the second time that the third number of the combination has reached the opening index mark;

(4) Rotate dial to the RIGHT, pausing a moment at zero, and then continue rotating to the RIGHT until the dial stops. The locking bolt is now retracted. This enables the handle of the drawer or door to be "thrown", thus allowing it to be opened. Always rotate the dial slowly and evenly. Spinning the dial is unnecessary, and may cause loosening of component parts which could cause a lockout.

To Change Combination MOSLER MRK 302 Series (Key Change):

(1) Open the drawer or door and release the bolts to the locked position. (If unit is equipped with a locking bolt interlock, it will be necessary to depress the interlock plunger before the bolts can be thrown.) Dial the old combination exactly as normal in the opening instructions; however, stopping at the changing index mark, which is (approximately 10 digits) left of the opening index mark;

(2) Insert the proper change key in back of the lock. Be sure it is inserted all the way up to the shoulder. Turn the key to the limit of its travel in the direction indicated by the arrow marked on the lock cover;

(3) Select the new combination within the parameters given below, and write it down;

(a) Keep numbers above 13,

(b) Below 90, and

(c) Ten digits apart.

(d) Use high-low-high or low-high-low.

(4) Dial the new combination on the changing index mark (using proper turns), being certain of preciseness when stopping at the index. When uncertain of the correctness of the dialing, start over again. This will save time in case of error. After dialing the last number of the combination, do not disturb the dial;

(5) Turn the change key to the limit of its travel in the direction opposite to arrow. REMOVE CHANGE KEY;

(6) Try the new combination, using the opening index at least twice before closing the container in order to be certain that the combination is set properly and operates smoothly;

If New Combination Fails to Operate:

If the lock cannot be opened on the new combination, it can be assumed the new numbers were not set properly. It will then be necessary to remove the cover from the lock case. Proceed as follows:

(1) Remove two screws and the back cover plate. This will expose the wheels on the back plate;

(2) Rotate the dial until the fence disengages from the gate of the drive cam;

(3) Turn the wheels so that all change keyholes line up. Keeping holes in line, turn wheels until the change keyholes in the wheels align with the change-key hole in the lock cover;

(4) Carefully replace the cover to the lock case so as not to disturb the wheels. Before attaching the cover to the lock case, check to see that the change-key holes in the wheels are aligned with the change-key hole in the cover;

(5) Insert the change-key and proceed.

To Change Combination, Mosler MR 302-402 Series (Hand Change).

When selecting numbers for the new combination, use recommended method as listed in 302 MRK Key Change procedure.

(1) Open the container as previously described. The locking bolt must be extended to the locked position to remove the cover. Turn the dial several revolutions, stopping at approximately the number "50";

(2) Remove the cover plate screws from the rear of the lock and detach the cover plate from the case. (On some containers, it may be necessary to remove a panel or small circular cover from the inside of the door to expose the lock.;

(3) Remove the retainer clip from wheel post. Remove the wheels and spacers. Wheels are numbered on outer plastic ring in order that they can be replaced on the post in the proper sequence. The number-one (1) wheel is set at the first number of the combination, and is the first wheel on the post;

(4) Hold number one (1) wheel assembly with numbers up and push the center disc upward until it is removed from the outer ring. Rotate center disc until the setting mark on the metal insert is opposite the desired number on the ring. Press the center disc back into position until it's flush with the outer plastic ring.

Observe that numbers increase counterclockwise on wheels. Change the combination numbers on the remaining wheels in the same manner. Remember to keep numbers above 13 and below 88.

(5) Replace parts on the post in the proper sequence. To help identify wheels for proper reassembly, each Mosler wheel has a number 1, 2 or 3 molded next to one side of the gate (cutout). Further confirmation is gained by observing that the gate (cutout) of the middle wheel is 180 degrees opposite zero. There may be more than one tension washer at the base of the wheel post. The numbered side of the wheels are to face up. When the retainer clip is replaced, check to ensure that it is properly seated in the groove on the post, and that all wheels and spacers are properly mounted on the wheel post;

(6) Replace the cover and screws. Tighten screws firmly;

(7) Try to lock at least twice on the new combination with the CONTAINER OPEN to be sure that the lock is set properly and operates smoothly.

34_7.2.1.6 LaGard 1980-ARL Group 1R Combination Lock

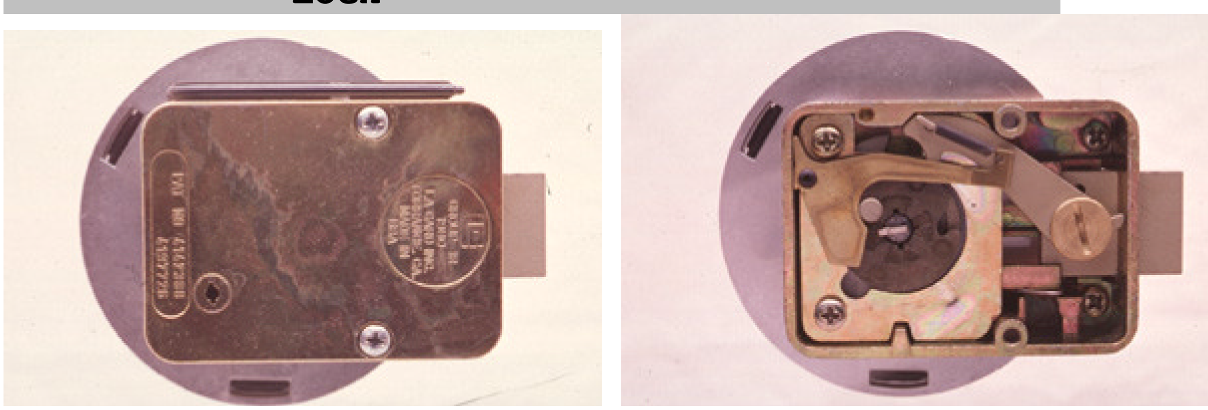


Figure LSS+3422 LaGard model 1980. Courtesy of Mark Bates.

The LaGard Model 1980-ARL has been certified by Underwriter's Laboratories and approved by the General Services Administration as a Group 1R Combination Lock. It may be found as original equipment on Art Metal GSA Approved Security Containers and is only available in a key-change configuration. Combination changing procedures for the Group 1R LaGard are identical to that of the Mosler Key Change Model 302 MRK. Therefore, when combination changing is desired, refer to the procedures listed

for the Mosler 302 MRK. The LaGard Group 1R is easily identifiable by its unique dial and dial ring. You must use the LaGard change key.

34_7.2.1.7 Mas-Hamilton X-07 Group 1R Electromechanical Lock

Opening the X-07:

The X-07 lock has been shipped preset in the Single Combination Mode with the combination set to 50-25-50. Practice opening the lock several times before setting a new combination. The X-07 uses sophisticated computer security and makes dialing much easier than that of traditional combination locks. The X-07's computer recognizes a number as being part of a combination when you stop dialing on that number and then reverse the dialing direction. If at any time the dial remains stationary for more than forty seconds, the computer will reset (LCD will go blank) requiring the operator to redial the entire combination.

The X-07 has protective software that detects robotic dialing. If robotic dialing is detected, the X-07 will not open even if the correct combination has been dialed. The user should dial with complete full wrist turns. This helps the X-07 distinguish between human and robotic dialers. The X-07 may mistake a human for a robot if the user:

- Dials more than 1.3 revolutions in either direction with no pauses in dialing activity;

- Dials with very short, quick repetitive turns, producing very short pauses in dialing activity;

- Dials the combination in less than fifteen seconds (ten seconds in newer version).

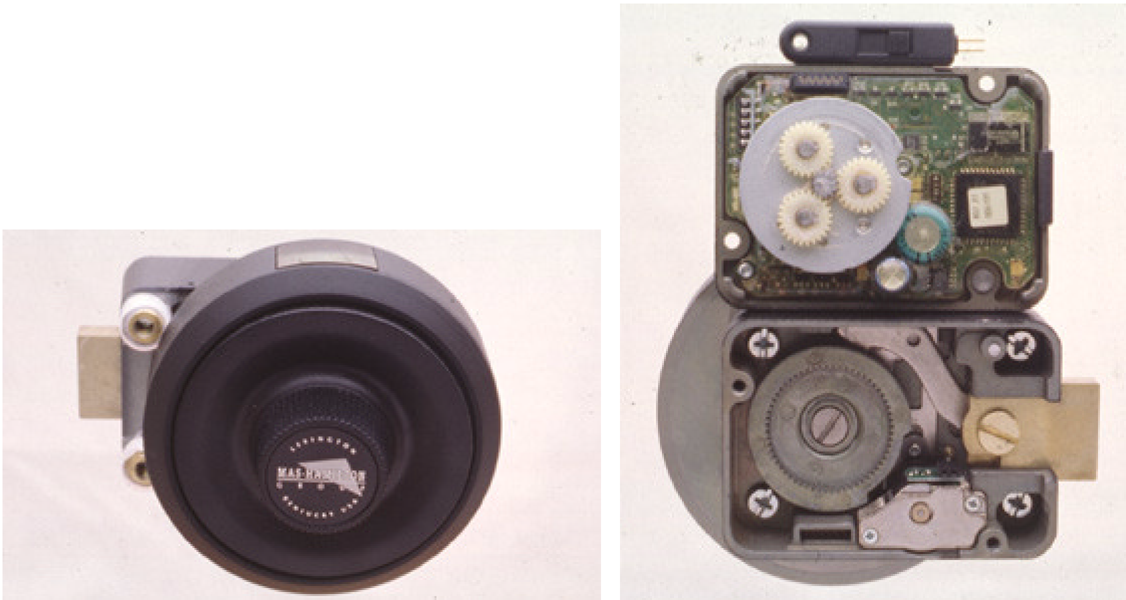


Figure LSS+3407 Mas-Hamilton Group X-07 Electromechanical Lock. Courtesy of Mark Bates.

Opening the X-07 using the Preset Combination:

(1) Dial left (counterclockwise) 4-6 turns to "power up" the lock. Numbers will appear on the LCD display screen;

(2) Continue dialing left to the first number in the combination (50). Stop; the number 50 will be displayed on the screen;

(3) Now dial in the opposite direction (right, clockwise) to (25). Stop;

(4) Now dial left (50). Stop;

(5) Now dial right. After "OP" (Open right) appears on the display screen, continue dialing slowly to the right to pull the lock bolt.

NOTE: If you pass your target number by four or more numbers, continue to dial, but if you pass the target number by no more than three numbers, you may reverse direction slowly and the display will "jump back" four numbers. Now you may dial slowly in the original direction to the target number. If at any time you see a Lighting Bolt, you have made an error in dialing the combination. At this time you must allow the X-07 to "go to

sleep" and redial.

Setting the Operating Mode and Changing Combination:

Before a new combination can be set, select and set a mode of operation.

(1) The X-07 has three modes of operation:

(a) SINGLE COMBINATION MODE: The X-07 will open when one three-number combination is successfully dialed;

(b) DUAL COMBINATION MODE: Two separate combinations are required to open the X-07. Either combination may be dialed first; however, the operator must begin entering the second combination within forty seconds of entering the first combination;

(c) SUPERVISORY/SUBORDINATE MODE or SUPER/SUB MODE: Two separate combinations are required to open the lock, with the Supervisory Combination controlling access of the Subordinate Combination. The Supervisory Combination must be entered first. There can be unlimited delay between entering the Supervisory Combination and entering the Subordinate Combination. There can also be unlimited openings by the holder(s) of the Subordinate Combination until the Supervisory Combination is redialed;

(2) Retract the bolt by entering the correct current combination(s). In Dual Combination or Supervisory/Subordinate modes, both combinations must be entered simultaneously;

(3) Insert the Change Key into the slot on the back of the lock;

(4) Dial to the left (counterclockwise). The Change Key Symbol will appear in the display. The lock is designed not to open when the Change Key symbol is displayed. (Technique when the drawer is locked with the key inserted.;

(5) Enter the current combination(s) again;

(6) Dialing right, the symbol "SL" (for Select Mode) will be displayed. Now dial left to select mode of operation:

1 -for Single Combination Mode

2-for Dual Combination Mode

3-for Supervisory/Subordinate Mode

(7) Stop on the number of the selection. Now dial right to set the mode. The symbol "EC" (Enter Combination) or "E1" (Enter First of Two Combinations) will be displayed depending upon the mode selected;

(8) If Single Combination Mode (Selection 1):

(a) The symbol EC will be displayed. Enter the desired combination by dialing the numbers in the correct sequence. LEFT (counterclockwise) to the first number. Stop. RIGHT (clockwise) to second number. Stop. LEFT (counterclockwise) to third number. Stop. RIGHT (clockwise) until display flashes new combination;

(b) The display will flash the new combination three times and then display the symbol PO (for Pull Out Change Key). Remove the Change Key. This will cause the Change Key symbol to disappear. The display will show the symbol CC (Confirm Combination(s));

(c) To confirm the combinations, redial the new combinations. When the OP (Open right) appears on the display, continue dialing to the right to retract the bolt. The combination is now set;

(9) If Dual Combination Mode (Selection 2) or Super/Sub Mode (Selection 3): (NOTE: For Dual mode, either combination may be entered first; for Super/Sub mode, the Super combination must be entered first.);

(a) The "E1" symbol will be displayed. Enter the first new combination. Dial: Left to the first number. Stop. Right to the second number. Stop. Left to the third number. Stop. Right until display flashes new combination. The display will flash the new combination three times then show the symbol "E2" (Enter second combination);

(b) Dial the second new combination in the correct sequence, in the same manner as the first combination was entered. The display will flash the new combination three times, then display the symbol "PO" (Pull Out Change Key);

(c) Remove the Change Key. This will cause the Change Key symbol to disappear. The display will show the symbol "CC" (Confirm

Combination(s));

(10) To confirm the combinations, redial the new combinations:

(a) In Dual Combination Mode: dial either of the new combinations. The symbol "E2" (Enter second combination) will be displayed. Enter the remaining combination;

(b) In Super/Sub Mode: dial the Supervisory combination first. The "E2" (Enter second combination) will be displayed. Dial in Subordinate combination;

(c) When "OP" (Open right) appears, continue dialing right to retract bolt. The new combinations have now been set.

Alternate Method of changing the Combination:

This alternate method replaces steps 1 - 4. If you have lost or forgotten the current combination and have access to the back of the lock, you can select a mode of operation to set new combination(s) using the serial number found on the inside cover of the lock. This serial number will not open the lock, it will only allow you to set a new combination.

(1) Dial an incorrect combination to obtain the Lighting Bolt error symbol;

(2) Insert the Change Key into the back of the lock;

(3) Enter the serial number as the current combination. Dial:

(a) Left to first 2 digits of the serial number. Stop.

(b) Right to second 2 digits of the serial number. Stop.

(c) Left to third 2 digits of the serial number. Stop.

(d) Right to "SL" (select mode will be displayed continue with Step 5 from above.

Lockout Prevention:

If the door of the container is shut and the X-07 accidentally locked with the Change Key still inserted in the Change Key slot:

(1) Allow the lock to power down. (After forty seconds the display will go blank; wait an additional minute for full power down.);

(2) Turn the dial to the RIGHT until power-up occurs (numbers appear);

(3) Dial the current combination in correct sequence;

Using the Audit Feature of the X-07:

The X-07 keeps count of the number of successful openings. It will also alert the user if there have been three or more unsuccessful attempts to open the lock.

TO CHECK THE NUMBER OF SUCCESSFUL OPENINGS: Dial RIGHT when the lock is powered down (screen blank and no dialing for two minutes). After the lock is powered up, it will alternately flash two pairs of numbers. The number with the arrow flashing left represents the first two numbers of the successful opening count. The number with the arrow flashing right represents the last two numbers in the opening count. The successful openings count does not reset. The number will reflect the total number of times the X-07 has been opened since it was manufactured. When the X-07 has been opened 9,999 times, the count will begin again at 0 and continue to increment.

TO CHECK UNSUCCESSFUL ATTEMPTS COUNT: Dial LEFT when the lock is powered down (screen blank); or Dial left after checking successful openings count. The count will be represented by a two digit number with a Lighting Bolt symbol. When the count is displayed, stop. After you have seen the count continue dialing left to enter combination. The unsuccessful attempts count will be displayed only when three or more incorrect combinations have been entered. The count resets to 0 whenever the correct combination is entered. If the number of attempts exceeds 99, the count will remain at 99 until reset.

34_7.2.2 Radiographic (X-Ray or Gamma Ray) Attack

Radiographic analysis of combination locks is more thoroughly discussed in **Chapters 32** and **36**. It is a technique developed by the intelligence services of the United States and the Soviet Union that allows the extrapolation of gate position for each wheel. The process relies upon the production of an image using electromagnetic waves that are directed at the wheel pack.

Harry Miller was the first to conduct experiments using x-rays to open locks in 1947 at the University of Rochester. The prime focus was to learn if a manipulation-proof lock was subject to this method of attack. The government was not concerned about the problem until 1953 when an isotope became generally available that made portable x-ray machines practical. Group 1 locks that contained low-density delrin wheels were patented about the same time.

In order to prevent the use of radiation to read wheel packs, Harry Miller patented (**3024640(395)**) the integration of lead bearings at the back of the dial. These had the effect or deflecting and absorbing energy from the source. Miller conducted tests by setting a camera seventeen feet from the radiation source to expose a box containing film. Each of the wheels were rotated individually and synchronized with the film to determine gate positions. Since the original work by Miller, there have been many studies conducted by the National Laboratories in the U.S., including Livermore and Argon. Russia has also been involved in radiographic imaging for a very long time.

Traditionally, a source is placed at the back of a safe and film at the front. A series of exposures are made in order to determine individual gate positions. Today, radiation imaging can be accomplished with computers and liquid crystal displays for real-time output. Portable x-ray devices are now available that can be carried in a briefcase and operated without danger of exposure to radiation. They will produce a real-time image of the internal mechanism of locks and explosives. Harry Miller also designed a neutron- resistant lock for which he received approval from the government.

34_7.2.3 Mechanical Security

Today, almost every combination lock provides 100 segments or divisions per wheel. This allows for theoretically 1,000,000 different or unique permutations to which a three-wheel lock can be set. Many locks have four, five, or six wheels, thus reducing the potential for deriving the combination to 1:1,000,000,000,000. Modern locks are highly reliable and require little maintenance. Depending upon whether they are Group 1 or Group 2, their internal tolerances will vary, which in turn directly affects their security. S&G and other manufacturers have implemented strict quality control and testing procedures to

insure reliability.

They utilize robot dialers to study how the consumer operates a lock and the method of entry of combinations. The speed of entry, motion, and delays can all be factored into dialing programs to detect and predict failures. Locks also incorporate devices and safeguards to overcome the natural tendency of employees to ignore security procedures and guidelines in favor of convenience. Thus, day locks, time locks, and scramblers have been integrated into standard combination mechanisms.

Day locking systems prevent the dial from being turned by unauthorized individuals without a key. Medeco and other keyed cylinders are built into the face of the dial to accomplish this purpose. The problem with this enhancement is that employees will utilize the low-security cylinder as a substitute for fully activating the combination lock. S&G introduced a “timbination” lock that triggers a programmed time delay and opening window once the correct combination is entered. This feature is designed to prevent robberies because the safe cannot be opened until the delay period has expired. Additionally, the lock will reset if it remains in an unlocked state longer than a predetermined period.

The S&G Scrambler (**2625032(396)**) will randomly turn each wheel when the dial is spun to a locked status. This is intended to prevent the practice of rotating the dial slightly past the last number of the combination. Unfortunately, many employees do not completely spin the dial to reset all wheels when the safe is locked. Rather, they move the dial slightly so as not to reenter the entire combination. It is convenience, rather than security. Although the Scrambler partially solves this problem, numbers can often be read back within a few digits after the mechanism triggers. Kromer has attempted to solve this problem by requiring that all wheels be turned before the bolt can be thrown.

Spyproof dials are also utilized to prevent others from viewing the numbers as they are entered into the lock. Their design provides for a perpendicular view of the index marker.





Dust covers are another popular security feature. They prevent the interpretation of fingerprints on the dial. A clear plastic shield fits over the dial and ring, and will obliterate any indicia of finger position and dial rotation (**4404823(397)**).

Clear Plastic Dial Covers: Certain regulations and manuals require clear plastic dial covers be placed on all combination locks. Plastic dial covers are generally supplied with each new security container for the appropriate lock installation.

34_7.2.3.1 Number of Permutations

Although a manufacturer may represent that their locks have from one million to one trillion permutations, such representations are not accurate but only theoretical. Unless the lock utilizes a computer to derive each combination, the number of permutations does **not** equal the total dial segments multiplied by the number of wheels. Only in computer-based mechanisms such as the Mas-Hamilton X-07 will the computation of total possible permutations equal or exceed the theoretical limits of their mechanical counterparts. In the X-07 there are at least 1,000,000 unique and useable codes when the lock is set for a three-digit combination. Depending upon programming and supervisory control options, this number can actually be one trillion or more.

34_7.2.3.1.1 Permutations in Mechanical Combination Locks

The number of theoretical permutations is computed by multiplying the number of wheels by the total number of divisions available for each wheel. Thus, a three-wheel lock having 100 positions per wheel would have 100 times 100 times 100, or 1,000,000 different combinations (100^3). A four-wheel lock would have 100 times 100 times 100 times 100 (100^4), or 1,000,000,000 theoretical combinations. A substantial difference exists between

the number of theoretical and actual permutations. In reality, a 1,000,000-number lock may have only 240,000 useable combinations. This results from the unavailability of some numbers in the forbidden zone, the use of closely spaced combinations, the use of duplicate numbers, and fence-gate tolerance.

34_7.2.3.2 Mechanical Design Parameters

The critical design parameters that ultimately determine the actual number of available combinations relate to the **fence-gate interface** and **fence-gate tolerance**.

34_7.2.3.2.1 Fence-Gate Interface

The fence-gate interface relates to how and where the fence enters the gate and directly affects tolerance of components. In S&G locks, the fence must be centered precisely above the gates. Although the fence can be vibrated into alignment if close to the proper position, this technique becomes harder as the gate angle grows more acute. A tight window will make the job of an auto dialer more difficult and time consuming, because the number of actual combinations that must be entered will increase. Dialers are programmed to take advantage of the “overlap” of unique gate positions; in high tolerance locks, this number is reduced.

34_7.2.3.2.2 Fence-Gate Tolerance

The fence-gate tolerance is determined by the size and shape of the gate, the position of the fence upon entry, and changes in mechanical tolerances occasioned by wear. If the width of the gate is diminished, then the wheels must be more precisely positioned at the drop in point. Wear, resulting from use of the lock, will affect the play between spline and drive cam. When this condition occurs, the lock may be difficult to open because the fundamental relationship between dial marker and gate has slightly changed.

In a Group 1 lock, the tolerance or overlap between the gate and fence is 1.5 - 1.75 divisions, or **±**.75-.875 from center of the gate. In a Group 2 lock, it is up to +-1.25. UL calculates this tolerance from the edge of the gate; S&G from the center.

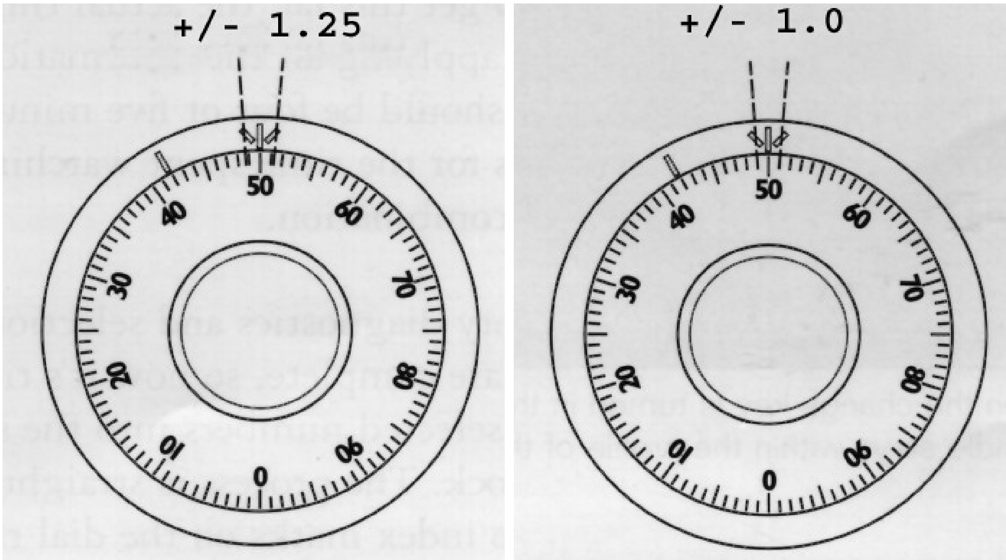


Figure LSS+3424 UL provides for a maximum of +- 1.25 dialing tolerance in Group 2 locks, and +- 1.0 for Group 1 devices. S&G claims it obtains 0.9 for its Model 6730.

Overlap, or fence-gate tolerance, means that the position of the fence can be offset by this number and still is in alignment. An automatic dialing program takes full advantage of these tolerances. In a three-wheel lock, the probability percentage of opening increases as more numbers are dialed. With tolerances factored into the equation, as few as 100,000 unique numbers must be dialed to open the lock. Although there is a very low probability of opening with the first combination, the curve is linear as the dialer progresses. In a Group 1 lock, for example, there is a probability that the lock can be opened in twenty hours.

An example illustrates how fence-gate tolerance can reduce security of the lock. The actual combination, in a Group 2 lock, is 10 20 30. With a tolerance factor of ±2.5, the following numbers within the defined ranges **will** open this lock:

FIRST NUMBER	**SECOND**	**THIRD**
8.75-11.25	**18.75-21.25**	**28.75-31.25**
#1	**#2**	**#3**
9	**19**	**29**
9	**19**	**30**
9	**19**	**31**

9	20	29
9	20	30
9	20	31
9	21	29
9	21	30
9	21	31
10	19	29
10	19	30
10	19	31
10	20	29
10	20	30
10	20	31
10	21	29
10	21	30
10	21	31
11	19	29
11	19	30
11	19	31
11	20	29
11	20	30
11	20	31
11	21	29
11	21	30
11	21	31

A minimum of 27 permutations of the original combination will open the lock, based upon whole integers. If fractions are included, then that number will be increased significantly.

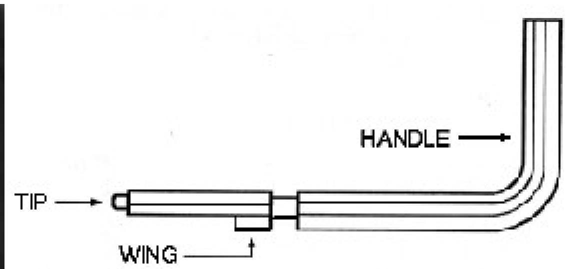
34_7.2.3.3 Electronic Combination Locks

Electronic combination locks such as the X-07 do not suffer from any of the limitations of conventional mechanical devices. They can provide true 1,000,000 single-sequence entry permutations without any restrictions. If dual or sequential control is implemented, then this number can exceed one trillion different useable numbers. Later in this chapter, a detailed discussion of the X-07 is presented because of its uniqueness and wide-ranging patent claims. It was the first electronic lock approved for high-security containers and remains the premiere computer controlled lock in the world.

34_8.0 Combination Changing

Every lock must provide the means to alter the relationship between wheel position and gate in order to facilitate combination changing. A special change key is employed for this purpose. The number sequence used to open the lock is often entered to a **change index marker** on the dial ring, rather than the standard marking. This will cause the discs to align to a different position, allowing the entry of the change key into openings in each wheel. Some locks utilize a **zero change** index system, whereby the same marking is used for both opening and combination change. In such cases, the number sequence can be changed whenever the lock is opened.





The change key is inserted into the rear of the lock and turned. This will release the inner and outer portions of each wheel, thereby allowing the gate location to be altered with respect to the spline key position. Most wheels are designed so that the inner and outer portion of the discs mesh together like a gear. When the spring bias is released, the outer wheel is free to move in direct relation to the turning of the dial to a new combination. When the change key is removed, the spring bias on each disc is reintroduced, thus locking the two segments of the wheel together and fixing the wheel- gate relationship.

CHANGE KEYS: The manufacturers of Mosler and Sargent & Greenleaf locks have advised that their keys are available through sources listed below. However, Bode-Panzer no longer manufactures the change key necessary for their lock.

Sargent & Greenleaf Source:

Sargent & Greenleaf, Inc.
Corporate Headquarters
1 Security Drive
Nicholasville, Kentucky 40356
Telephone: (606) 885-9411
Fax: (606) 887-2057

Mosler Source:

Mosler Government Sales
1401 Wilson Boulevard
Arlington, Virginia 22209
Telephone: (703) 525-5800

34_8.1 Procedures for Changing Combinations

Each manufacture specifies different procedures for changing the wheel-gate relationship within their combination locks. However, there are certain basic principles that must be adhered to in order to successfully alter the wheel-gate relationship without causing maintenance or lock-out problems.

There are four actions that must be accomplished:

Determine the combination;
Select a new combination;
Set the new combination;
Test the new combination with low and high numbers.

In order to properly set a new combination, the technician must:

1. **Have the proper change key;**
2. **Have knowledge regarding dialing tolerance, forbidden zones, wheel pickup for the specific lock;**
3. **Perform routine maintenance at the time of change;**
4. **The lock must be in good working condition; there should be no end-play.**

The technician must determine certain preliminary information prior to changing the combination:

1. **Obtain the current combination from the customer;**
2. **Wiggle the lock case to make sure there is no play;**
3. **Insure that the dial ring is tight against front of safe;**
4. **Determine the dial end play by pushing and pulling on the**

dial.
There should be no more than .050"; preferable is .025."
5. Be certain the dial ring is properly aligned;
6. Determine the number of wheels within the lock;
7. Ascertain the level of friction in wheel pack;
8. Determine the condition of moveable flys;
9. Determine the amount of rotation from wheel pickup to wheel pickup;
10. Ascertain the location of the contact points;
11. Determine the location of forbidden zone.

The lock must be first tested by the technician before proceeding to change the combination. This is accomplished by moving all wheels left for five turns, stopping at 50. This will park all wheels in the same position.

Then turn the dial to the right. During first full revolution, only the dial, spindle, and drive cam will actually be moved. The technician will detect any binding between the dial and ring. There should be no friction.

As the dial is turned right from 20 to 0, two subtle bumps should be felt. These are the contact points. Although they are not always between 20-0, this is the most common area.
Keep dialing right. More resistance should be encountered near 50, as one of the wheels is picked up. This will occur from 1.0 to 1.5 numbers from 50, based upon the tolerance of the lock.
Note: if pickup occurred several numbers **before** 50, then there is a stuck fly on that wheel.

Continue to rotate the dial in order to pickup additional wheels. After three revolutions, there should be no change (unless it is a four wheel lock). If the lock is in proper mechanical order, the dial should never drag during rotation. Two contact points should be identified. Each wheel should pickup within +- 1.5 of its marker. There should be no significant binding if the dial is riding within the dial ring. There should be no stuck flys.

Specific rules should be followed for picking an acceptable combination:

1. The last number must not be in the forbidden zone;
2. The numbers should be +- 5 from the contact points;
3. No easily guessed numbers should be used;
4. Do not use numbers that all end in 0 or 5;

5. Do not use ascending or descending sequences;

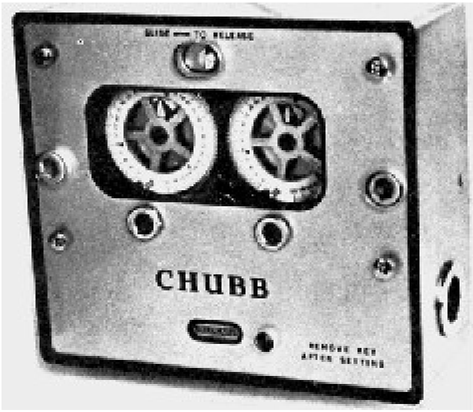
To change the combination, the following guidelines should be followed, after **covering the opening index** to avoid errors in alignment. Be certain that parallax errors are eliminated by viewing the dial straight-on.

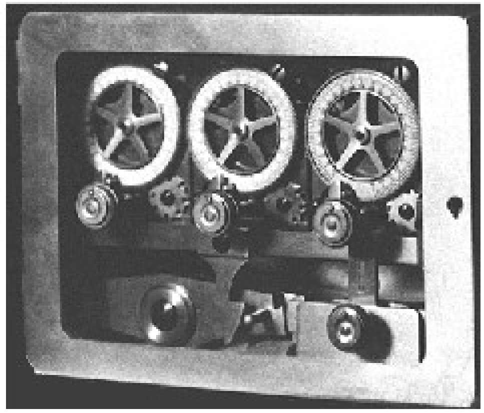
1. **Dial the number to the change index;**
2. **Insert change key;**
3. **Turn change key;**
4. **Dial new combination to the change index;**
5. **Turn the change key, then remove it;**
6. **Check the combination;**
7. **Test the combination by subtracting and adding 1 digit to each number. In Group 2 locks, the permutations should open the lock. This provides assurance that the wheels are meshed properly and that no parallax error in viewing the combination has occurred.**
8. **Verify that there is not a manufacturing error between the change and opening index on the dial ring, by insuring that the markings coincide with the dial position.**

34_9.0 Time Locks

The time lock is a mechanical or electronic device that is integrated into the bolt works of a safe or vault to block actuation except during a designated window of time. The time lock consists of a case, locking mechanism, and one or more chronometers. They operate independently of the combination lock and provide for no external controls.

They were developed over 150 years ago in response to the drastic increase in armed robberies.





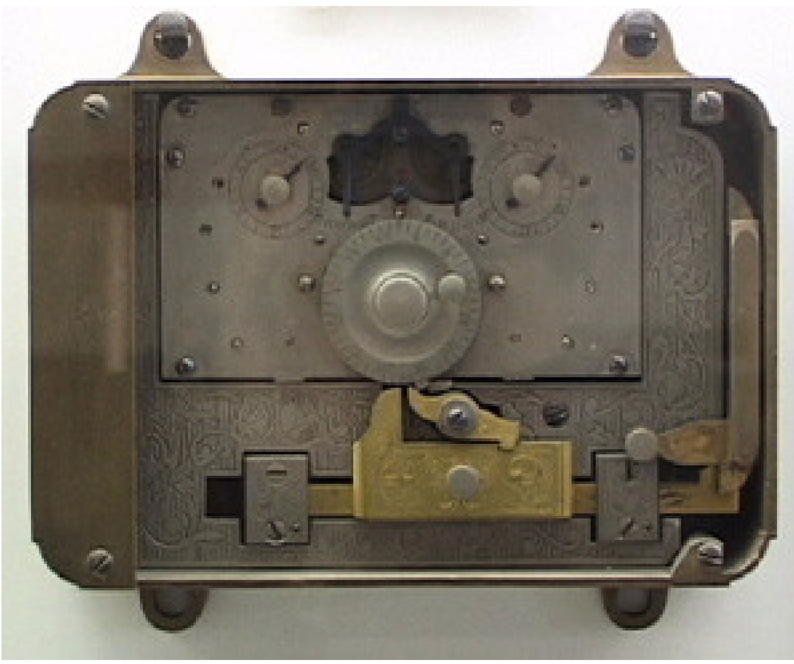


Figure LSS+3423 The Pillard time lock

In the 1870s, a new form of bank robbery became popular. Masked intruders would attack and kidnap bank cashiers, often within their homes, and force them to divulge the combination for the bank vault. Failure to provide this information often led to their death.

Prior to the introduction of time locks, the safe or vault was ineffective as a device to protect valuables because one person with a gun could bypass the most secure enclosure. After the time lock was introduced, the armed robber could not force an opening. Once set, the device would render futile any attempt at bypass. Even with the correct combination, the safe would not

yield until the predetermined time. Although William Rutherford (in Scotland) patented the initial design and concept in 1831, it would not be implemented for another fifty years. The original mechanism consisted of a disc with a notch, driven by one or two clocks. The notch would prevent access to the bolt mechanism until it rotated to the correct position after the specified time had elapsed.

In response to the new wave of crime, James Sargent, a famous American manufacturer and lock picker, invented and patented a new time lock. Sargent & Greenleaf (S&G) began to manufacture the invention in 1873. The inventor fit the original device to the vault door of the First National Bank in Morrison, Illinois, in 1874 for the sum of $500. Thereafter, banks everywhere adopted them, almost eliminating the crime that caused their introduction.

All time locks are set for the number of hours that the container is to remain locked, precisely as the inventor had envisioned. They characteristically contain three independent running chronometers that are either wound or powered. Usually the movements can delay opening from 120-244 hours, and operate in parallel. Some of the newer electronic time locks provide for an audit trail. If there is a failure of one device, the others can still allow the lock to open. The conventional time locks will generally provide a window of approximately forty-five minutes. If the safe is not opened during this time, then it will remain locked until the full delay period expires.

TIME LOCK DEFINITIONS

There are a number of specific terms associated with time locks, to describe their internal components.

Accelerated Active Movement

This component allows power from the spring at "0" hour to accelerate the rotation of the display wheel. This will move the unlocking pin rapidly, thereby forcing the carrier to the unlock position.

Actuator Control Button

Moves snubber to locked position.

Carrier Trigger

Case

Display Wheel (dial wheel)

This displays the numbers for timing.

Escapement

A device that controls the speed of the gear train.

Front Cover

Gear Train

There are a series of different sized gears through which energy is transferred and stored.

Jewels

These provide a bearing surface for frictionless operation.

Main Spring

This is the method of energy storage.

Mainspring Barrel

This provides a housing for the spring.

Mounting Table

This platform secure the clocks.

Movements

Plate

This provide place for movement to be mounted.

Reserve Power

This energy is stored as energy by the mainspring.

Reset Movement

This allows a reduction of time. A clutch on the third wheel allows back winding.

Standard Movement

A time lock with no extra features.

Unlocking Pin

This piece is mounted on the display wheel between the 90-100 hour mark.

Winding Arbor Assembly

This is the winding arbor.

Winding Key

Snubber Locking Bolt

This component blocks the movement of the snubber.

34_9.1 Electronic Time Locks

Electronic time locks will ultimately replace their mechanical counterparts because of reliability and ability to offer complex timing options. These microprocessor-controlled systems, using high- technology, mirror the basic options offered in the older mechanical time locks. They provide the ability to regulate access to the container. All of these devices contain real-time clocks that allow programmed openings and closings for an entire year, if desired. They can account for both holidays and special conditions. One or two-employee entry of the combination can also be required, and a detailed audit log can be generated.

A modification was introduced by S&G, which was called the **Timbination** Lock. This is a time-delay device that provides an opening window of three minutes. The countdown time can be changed in the non-UL listed version from four to thirty minutes. This lock provides a backup if the operator forgets that the combination has been entered and a safe remains unlocked. The mechanism will automatically lock after the timing window expires. Originally, UL specified a fifteen-minute window but has now modified that to five minutes.

34_10.0 Definitions

Discs: See Wheel pack

Anakin Relocker: Once triggered, this type of mechanism causes a bar to pivot that will block the movement of the carriage linkage used to retract locking bolts in a safe.

Arbor: A generic term for a shaft used in handles and dials spindles.

Balance Hole: Wheels in combination locks must be balanced or trimmed in order that their mass is precisely distributed. One or more holes are placed in the outer ring, much like weights on an automobile tire. Balancing is required to prevent induced vibration from slowly rotating the disc to the position that the gate is aligned with the fence. This had been a recurring problem aboard naval vessels, where constant vibrations caused safes to open.

Case: The shell that contains the internal components of a combination lock.

Change Key: A device that is utilized to alter the combination or lever configuration of a lock. The key is inserted into the **change-key hole**, an opening in the lock case. Each wheel contains a **change-key cam** that is a finely geared outer ring that is linked to each of the wheels in the wheel pack. The positional relationship between cam and wheel will determine the location of the gate. A small **pilot hole** in the base of the lock case will provide seating for the tip of the change key. Protrusions or **stops** around the change- key hole will control the amount of key rotation allowed.

Changeable Lock: A mechanism that allows programmable alteration of the fence-gate relationship in wheels or levers in order to effect an immediate change of combination. A change key is inserted into the lock for this function. A **hand change** lock must be partially disassembled for reprogramming.

Changing Index: A marker on the dial ring that provides a reference for gate position. It is used when changing a combination.

Click Lock: A combination lock that provides user feedback in the

form of clicks rather than numbers on a dial.

Combination or Code: The sequence of digits, letters, or symbols that when entered, will open a lock.

Contact Points: The precise location is referred to as the **contact area**, where the nose of the lever touches the left and right side of the drive cam gate. The position of the left contact area is critical when the lock is manipulated open.

Counterspy Dial (Spy proof Dial): The numbers appear at the top rather than facing outward, in order to restrict visibility only to the operator.

Cover: The cover is the removable portion of the lock case that allows access to the internal mechanism.

Curb: In older combination locks, this is the round cover to which the wheels are attached.

"C" Retainer: A C-shaped clip that retains the wheels to the wheel post. Also known as a **Circlip**. A **Truarc** ring is a modified version of the C retainer. A **Spirolox** retainer, in contrast, is a flat ring with overlapping ends.

D.A.T.(Delayed Action Time Lock): A safe lock mechanism that requires a **delay period** before it can be opened and then provides a brief window for activation.

Dead Zone: Older combination locks had areas on the dial where no numbers or increments were printed. These were referred to as dead zones.

Detent Ball (Timing Ball): A spring-biased bearing is placed under the bolt to retain it when in a fully extended position.

Dial Ring: A round plate that is mounted immediately behind the dial and surrounds it to provide an index for dial number and change-key markings. It is also known as a **flange**.

Dial: The round, exterior control mechanism of a combination lock. The dial is utilized to transmit rotational motion to the wheel pack and drive cam to align each gate in sequence as it is turned. The dial, spindle, and drive cam may be referred to as the **dial knob aassembly** (Mosler).

Direct Drive: The action of the dial, spindle, and drive cam are said to be linear, or directly linked.

Double-Bitted: A key with bitting on two opposing surfaces.

Double Dots: The presence of two raised dots between the bolt and top mounting hole in the bottom of the lock case indicate the use of a Spirolox type retainer on the wheel post in S&G locks.

Drill Point: The precise location to drill a hole in order to open a combination or lever lock.

Drive Cam: The drive cam is a modified wheel. It is directly linked to the spindle in all but high-security combination locks. Its function is to transmit rotational energy to each of the wheels (through **flys and drive pins**) and to provide a recess (**drive cam gate**) into which the fence is retracted when all wheel gates are properly aligned.

Drop: The physical location where the nose of the lever actually drops into the gate of the drive cam and wheel pack. The position is usually referenced to a dial position of zero. In the S&G 6730, for example, the drop is at 97.

Escutcheon Plate: A decorative or protective plate that surrounds the dial ring or handle.

Factory Combination: A universal code that is programmed during production that will open the lock. Once the lock is installed, the code should be changed.

Fence: A metal protrusion shaped in the form of a stump or bar that is designed to precisely fit within corresponding slots (gates) in each individual wheel or lever within a lock. The mechanism is designed to prevent retraction of the bolt until the fence is completely contained within the aligned gates. There are several different fence designs. An example is the Yale OC5 **geared roller**. This pivoting arm is allowed to rotate into the gate and is driven by a geared drive cam.

Flys and Drive Pins: Flys and drive pins are the components that form part of the wheels; they are used to receive (**flys**) and transmit (**drive pins**) motion as the individual discs are rotated.

Forbidden Zone: Within every combination lock, there is an area

that cannot be utilized for the third (or last) wheel gate position. This zone encompasses the physical area that is required for the drive cam to retract the bolt. If the last wheel is set to a number within the forbidden zone, unreliable operation will result. A lock with a physical drop of 97, for example, would have a forbidden zone of 0 - 20.

Gate: The corresponding slot in each wheel or lever to which the fence is mated. See **Fence** above.

Handing: The direction to which the bolt extends and retracts from a safe lock with the door open. There are four standard positions: Right hand (RH), left hand (LH), vertical up (VU), and vertical down (VD). Some locks are **true right** or **true left** handed and are made to be mounted in one specific orientation.

Index: A marking is provided on the dial ring as a reference point for the numbers on the dial when entering a combination. This mark is called the **opening index**. A **changing index** is a separate reference that is used for altering a combination.

Inspection Window: An opening is provided in lever locks to view the interaction of the levers with the fence.

Key Changeable: See **Changeable Lock.**

Key Locking Dial: A pin tumbler or wafer lock that is mechanically integrated into the dial to prevent it from turning.

L.O.B.C., "Locked On By Combination," or "Locked On Back Cover": Certain locks require that the correct combination be entered (often to a special index mark) before the back cover can be removed.

Lever: The portion of the lock's mechanism that contains the fence. When all of the wheels are aligned properly, the entire assembly enters the drive cam gate to retract the bolt. The **nose**, which is the protruding portion of the lever, rides on the edge of the drive cam. There are many different designs of the lever assembly, depending upon manufacturer.

Listed Locks: Combination locks that have received a UL security rating are said to be "listed." The 1R manipulation proof is such a device. Many locks are also said to be non-listed.

Manipulation: A technique to determine the combination of a lock,

through interpretation of data from the contact points on the drive cam.

MR: Manipulation-resistant designation

MRK: Nomenclature for a manipulation-resistant lock with a key-change operation.

Nose: See **Lever**.

Physical Drop: See **Drop**.

Relocker: One or more mechanical devices that are integrated into the lock body and boltwork in order to block the bolt in case of forced-entry attempts. A **relock trigger** is a device within the lock case to deadlock the bolt.

Retainer Washer: See C-clip. These devices are utilized to retain the parts of the wheel pack to the wheel post.

Shutter Cam: Within a Mosler manipulation-proof lock, a spring-loaded shutter is engaged while the dial is moved through the drop area. This makes manipulation virtually impossible.

SMNA Labels: The "Safe Manufacturers National Association," was a testing and certification facility until the mid-1950s for burglary and fire containers. SMNA labels can still be found on older safes (see **Chapter 37)**.

Spacer Washer: A flat washer is placed between discs within a wheel pack to prevent friction, touching, or dragging between components. They will also dampen the effects of vibration that can cause wheel movement.

Spindle: The threaded rod that physically connects the drive cam and the dial. A **punchproof** spindle is tapered or shouldered to prevent punching or driving of the shaft into the lock.

Spirolox Retainer: A flat ring with overlapping ends that is used to affix the wheel pack to the wheel post (see also, **C-clip)**.

Spline: The longitudinal groove or slot that runs the length of the threaded portion of the spindle and correspondingly into the drive cam, which allows the spline key to lock them together.

Spline Position: The relative placement of the spline with respect to the rotational position of the dial. Most manufacturers spline the spindles at "50."

Tenite: A synthetic material used by Mosler for dials.

Time Lock: A locking mechanism that is controlled by one or more precision timepieces. The clocks will provide an **opening window,** during which the lock can be activated. It is also known as a delayed action time lock (See D.A.T.).

Timing Ball (Detent Ball): A metal ball and spring are located beneath the bolt to retain it in a locked or open position.

Torque Adjuster: An alignment feature provided by S&G to adjust the amount of torque on the wheel pack.

Tube: A shroud that surrounds and protects the spindle from insulation and contaminants. It aligns the dial ring for proper installation.

UL Rating: A designation relating to many aspects of security and established by Underwriters Laboratories. UL is a private testing organization.

VdS Rating: Verband der Sachversicherer is a designation for safe locks.

Wheel (Disc): A group of rotating parallel discs, together with drive pins (pegs) and flys, that comprise a wheel pack within a combination lock. Each disc will individually prevent the bolt from retracting until the fence has entered its corresponding gates. The relative position of each gate will determine a lock's combination. Wheels can be made of metal or plastic and are connected by the spindle.

Wheel Pack: The wheel pack is comprised of three or four individual wheels that form the critical operating components of the combination lock. Each of the parallel rotating discs is connected to the others and the **drive cam** through the **spindle.** Their actions are mechanically linked through interconnecting **flys** and **drive pins**. A wheel pack is said to have an **indirect drive** if the spindle and drive cams are not directly linked. Generally found in high-security locks, gears are employed to transmit motion in such mechanisms.

X-Ray-Resistant Gate Patterns: Radiographic imaging can be frustrated by a raised pattern of gates on the bottom of a lock case. This technique will cause shadows to appear on the film, making the determination of gate position difficult and unreliable.

Zamak: An alloy of zinc and aluminum that is utilized for lock cases and components. The material has good casting qualities and tensile strength and can be sanded, filed, drilled, and tapped.

Zero Change: Changeable combination locks that do not require a separate changing index mark.

34_11.0 Computer-Controlled Combination Locks

Computer-based locking systems are gaining wide acceptance in many diverse industries. They can meet any security requirement and have been certified by the United States government for use on containers holding top secret information. They are also quite prevalent in the hotel industry in both door locks and in-room safes (**4745784(398)**). The utilization of electronic locks is widespread; they can be found in many military, government, and business requirements as well as residential, recreational, automotive, and vending. Motor vehicles, gun cabinets, lockers, storage containers, safe-deposit vaults and hundreds of other applications utilize the technology.

These locks began to appear in the 1980s. Since then, they have taken many forms during their rapid evolution. The original devices were quite simple but quickly gained sophistication as the technology of microprocessors virtually exploded. While the conventional combination lock has been evolving for the past one hundred years, the relatively short life span of its counterpart has been remarkable. Harry Miller was the first to patent what can be identified as an “electronic lock.” Although these early devices could really be classified as electromechanical in nature, nevertheless they relied upon crude “digital” data to perform their tasks. Actually, similar electromechanical devices were utilized in conjunction with cryptography during World War II and the Korean War.

Since the introduction of the Mas-Hamilton X-07 in 1992, a new standard in security, functionality, and reliability was

established for electronic locks. The integration of electronic combination locks is inevitable for all but the most rudimentary of containers. These devices are immune from normal maintenance problems, such as mechanical wear and changing tolerances, and all of the limitations inherent in mechanical components. The locks are secure if properly engineered and are virtually immune from traditional manipulation techniques.

34_11.1 Comparison of Electronic and Mechanical Locks

There are critical differences between conventional and electronic locks. These distinctions relate to:

- **Overall theory of operation;**
- **Mechanical reliability;**
- **Fence-gate relationships;**
- **Wheel packs;**
- **Drive cam;**
- **Lever and bolt actuation;**
- **Security and manipulation resistance;**
- **Theoretical and actual permutations;**
- **Audit control and accountability;**
- **Optional configurations.**

34_11.2 Theory of Operation: An Overview

Electronic locks replace the wheel pack and associated lever and fence with a microprocessor. The computer is utilized to perform the functions normally associated with conventional mechanical hardware. Specifically, the processor accomplishes the following tasks:

- **Provides a method for the entry and programming of numbers that constitute the combination of the lock;**
- **Stores, in non-volatile memory, one or more sequences of numbers that must be input by the operator to open the lock;**
- **Provides a sensing mechanism to allow the entry of numbers by the operator;**
- **Processes the information as entered by the operator and determines if:**

- **The entered numbers match those of the combination;**
- **Incorrect numbers were entered as part of the sequence;**
- **More than a specified number of attempts were made to enter numbers;**
- **Manipulation was attempted;**
- **A defined timing parameter was met;**
- **The correct sequence was entered and whether it shall actuate the bolt mechanism.**

Within the computer-based lock, there is no wheel pack, lever, fence, drive cam, or flys. Rather, there is an entry device (dial or keypad), a processor to store the reference and input data, and an output solenoid or similar mechanism to control retraction of the bolt.

34_11.3 Mechanical Reliability

The mechanical reliability of electronically based locks is superb because there are few moving parts. Generally, they are the dial or keypad, bolt, and solenoid control. Most common failures are electronic contacts, cable interconnections, memory batteries, displays, and solenoids.

34_11.4 Fence-Gate Relationship

Electronic locks do not have fences or gates; the processor replaces their function. Number sequences are programmed when the lock is installed or subsequently and can be set to any value. As will be detailed in the description of the X-07, multiple combinations can be entered to enhance security and control. Virtually all microprocessor-based locks are instantly programmable.

34_11.5 Security and Manipulation Resistance

There is a wide diversity of security and manipulation resistance of electronic combination locks and their susceptibility to countermeasures. Security is a direct function of the sophistication of the processor and the amount of research and development upon which the lock is based. The author has been able to compromise some of the solid-state locks presently on the market, either electronically or through mechanical means. The

ability to bypass is dependent upon many factors involving both the mechanical configuration and circuitry.

Even the X-07, probably the most secure and sophisticated lock in the world, required certain redesign. The author, other technicians, and a government testing and research laboratory independently determined that there was the potential for bypass using certain techniques. This, even though eleven government security agencies could find no defect in the lock prior to certification by GSA. If properly designed, the electronic combination lock, such as the X-07, will offer superior manipulation and surreptitious entry protection. Extremely high reliability and sophisticated audit control will guarantee that these locks replace their conventional counterpart in the future.

34_11.5.1 Theoretical and Actual Permutations

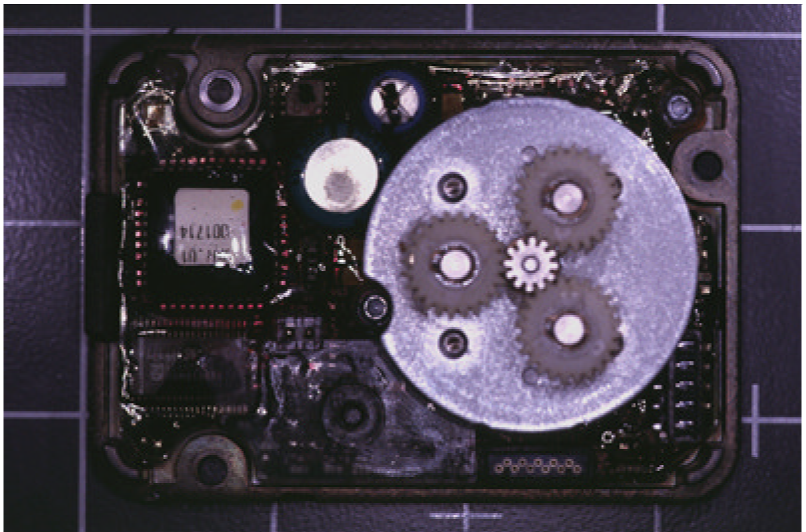
Electronic locks do not suffer from the problems associated with the "forbidden zone" and "drop in" or "contact points." Thus, they can offer true 1,000,000 permutations that are not diminished by mechanical limitations. These locks can also require two different sequences to be entered simultaneously for supervisory control. Thus, one trillion actual different combinations can easily exist for one lock.

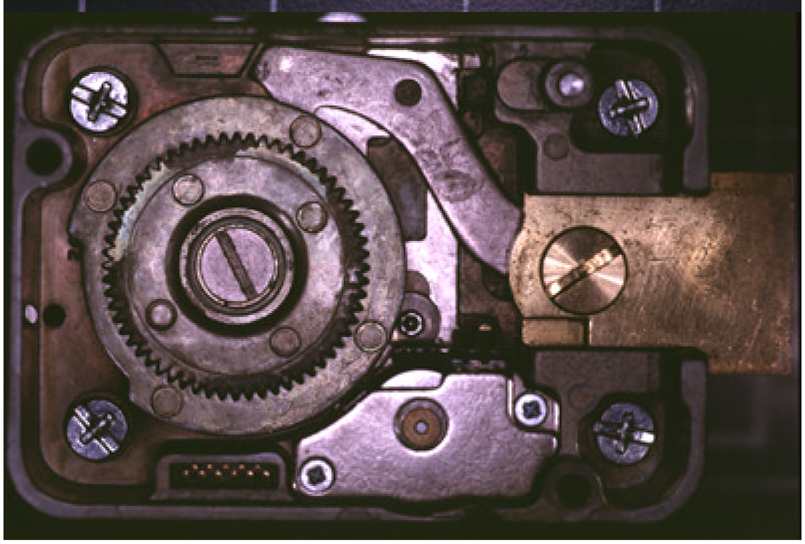
34_11.5.2 Audit Control and Accountability

Audit control and accountability is not possible in the conventional combination lock but is standard in computer-based systems. The X-07 will store and display invalid attempts and the fact that certain manipulation techniques were employed. These locks will shut down for a predefined window of time if successive manipulation attempts are sensed.

34_12.0 Mas-Hamilton X-07 Electronic Combination Lock

34_12.1 Introduction





LSS101: Discussion of the X-07 and X-08 with Joe Cortie

The Mas-Hamilton Group in Lexington, Kentucky set out to create the worlds most sophisticated electronic combination lock. The design team consisted of the brightest engineers from IBM, together with a world-renowned security expert from the government. In 1991 after almost three years of development, the X-07 made its debut in government service. The X-07 was the first self-contained lock to be certified by GSA to protect top secret containers. The device, which appears in a standard footprint, meets UL 768 and Federal Specification FFL 2740. See **chapter 37** for the full text of this specification. The inventors were granted over thirty patent claims (**5061923(399)**).

The critical and extraordinary functions included a computer-controlled lock and magneto power system. Although the system is microprocessor-based, the lock contains no batteries or other power source.

As with all high-security government locks, the X-07 relies upon the safe manufacturer to protect it from attack. The primary advantage of this system is the sophisticated functionality to prevent surreptitious entry through manipulation. A second generation of the Mas-Hamilton system made its debut within three years of the introduction of the X-07, and since the printing of the hardbound edition of this text. The X-08 is also described here. The X-07 set the standard by which all microprocessor-based locks will be measured for many years to come. This is in part due to the patent claims that will preclude other manufacturers from implementing the same innovations. For this reason, a detailed description of the X-07 is provided here.

There have been other patents granted for electronic combination locks, but none of these devices have attained the security and sophistication of the X-07, X-08, and derivative Mas-Hamilton products. See the Gartner electronic combination lock that was patented in 1994 (**5307656(400)**).

34_12.2 Design of the X-07

The X-07 comes in a standard footprint and can easily replace most conventional combination locks. Actually, the configuration comes in two parts: the dial with LCD, and the lock body that contains the electronics and bolt mechanism. A ribbon cable interconnects the two components. The dial has no markings but rather uses a liquid crystal display. It shows numbers as it is turned, together with rotation direction. The operator moves the dial in a left-right-left sequence, stopping as the correct number is displayed for each segment of the combination. When all three numbers are entered correctly, the microprocessor causes a magnetic pin to release, allowing the bolt to be retracted. If an incorrect digit is selected, the lock will not open and certain security traps are set. These are discussed subsequently.

Within the lock case is housed the magneto power system, Intel designed microprocessor, and bolt-release system. The lock body and case cover are mated through an integrated connector. The dial, containing the liquid crystal display, is connected with a ribbon cable to the processor. All systems are potted with Dymax,

a high-dielectric material (1800 volts/mm) for environmental protection and security. The special compound is impervious to moisture, fungus, and electrostatic shock and incorporates a reddish material randomly scattered in the compound. This provides a unique luminescent fingerprint when exposed to a UV light source. This signature will provide evidence if the lock has been tampered with or replaced.

34_12.3 Power System

Perhaps the most unique aspect of the X-07 design is the power generation and storage system. The lock requires no external electricity and will never go dead regardless of the interval of inactivity. The dial is gear-linked to three stepper-motors that act as alternators to provide power to the processor. These charge a capacitor upon being rotated.

Once the capacitor is fully charged, the microprocessor is initialized. This causes numbers to display on the LCD, beginning in a random sequence. Turning the dial as the combination is entered keeps the processor alive. Sufficient energy is generated to power the CPU, display, memory, and the bolt-release magnetic assembly.

The function of the power system is to generate alternating current that is rectified and stored. This power (up to 3.2 volts) will initialize the system, power the memory, processor, and all active components. The lock will actually operate at 2.5 volts. The alternator is actually a three-phase motor that computes direction of rotation and will tell the microprocessor what speed to display numbers.

34_12.4 Testing Standards

The X-07 was probably subjected to the most rigorous testing protocols ever for a combination lock. Eleven government security labs as well as UL evaluated the Mas-Hamilton design for almost a year. The result: the lock could not be manipulated by any known means. Because the X-07 was to be utilized to protect data of the highest sensitivity, tests involving electronic countermeasures, spectrum analysis, random number generation, atomic particle saturation, electromagnetic bombardment, and radioscopy were performed together with the more traditional forms of attack. Some of the procedures that were conducted to insure the reliability, integrity, and viability of this lock included:

- **The lock case and dial was subjected to static electricity of repeated strikes of up to sixty times at 250,000 volts without effect. Eddy currents were created on the potting compound to test for the skin effect;**
- **UL salt test, simulating 40 years of exposure on the deck of a battleship in a 100 percent salt environment;**
- **UL life test required 10,000 cycles. Actually, the lock was tested for 430,000 cycles;**
- **No adjustment or calibration during life cycle testing;**
- **Magnetic disturbance utilizing 1000 amps through a coil; no effect;**
- **Spray, temperature and humidity: -25C-+70C (UL is 0C-50C; Federal is -23.4C-70C). Storage temperature, -40 to +90 with all electronics operating -40C to 85C;**
- **Relocker temperature threshold: 70C will trip;**
- **EEPROM memory one 100-year test or 100,000 write cycles;**
- **EMI tests to determine effects of radio frequency and electromagnetic interference;**
- **Spectrum monitoring in order to determine if any useable information is radiated from the lock. Based upon Tempest specifications, no useable emissions were present and all noise transmission was under -100 dbm.**

34_12.5 Standard Features

There are certain standard features incorporated into the X-07 that are not available in any conventional combination lock. These were implemented to correct problems associated with mechanical designs. They include:

- **Dial direct to the number in the sequence. It is not relevant how many times the correct number is passed so long as the proper digit is correctly entered;**
- **No dialing tolerances or contact points resulting**

from the design of conventional wheel packs and lever fence;

- **No index lines;**
- **Display indicates direction of rotation of dial;**
- **Commands and prompts provided to user through the display;**
- **Allow back dialing of up to three digits if the correct number is inadvertently passed;**
- **Allow three user modes:**
  - **Sole responsibility (three numbers in sequence);**
  - **Dual responsibility (two three-number different combinations within forty seconds);**
  - **Supervisory/subordinate mode (toggled) requires each combination to be entered in sequence;**
- **Eliminate back dialing for day use;**
- **Automatic combination reset after forty seconds;**
- **Day locking;**
- **Audit features;**
- **Successful opening count (cannot be reset);**
- **Display of invalid digit-entry sequences and number of occasions. Attempts are defined as a dialing sequence with two changes of direction without entry of the correct combination. This number count is reset every time there is a successful opening. Tracking will not exceed 99 attempts.**

34_12.6 Security Features of the X-07

In a conventional lock, there is no way to learn about unsuccessful opening attempts, nor the capability to capture information regarding the fact that an attempt was made or how often such an event occurred. The Mas-Hamilton design team considered many security deficiencies in mechanical locks, as well as how they could be remedied in their electronic counterpart. The following critical problems were identified in traditional locks that would ultimately be corrected in the X-07:

- **The relationship between the dial position and number displayed is always fixed. Therefore, once a lock case was opened, it could be examined to determine the combination;**

- **Tolerances of moving parts substantially reduces the actual number of combinations;**
- **Only one number sequence can be set for a given wheel pack: sequential combinations are not available to enhance security;**
- **Robot dialing is impossible to detect;**
- **Locks are not user-friendly with respect to the number of turns required and direction or rotation (L-R-L or R-L-R);**
- **It is impossible to determine if the lock has been exchanged.**

The X-07 has been designed to thwart every known form of attack. Consequently, there are many advanced security features integrated into both the hardware and software of the X-07. These include systems to prevent robot dialing, audit trail functions, and to thwart interception or extrapolation of the combination. Because this lock was primarily designed for use in top secret containers, the most important criteria is the knowledge that an attempt or surreptitious entry has been accomplished. In the X-07, several safeguards have been implemented to make known any unauthorized occurrences. These include:

- **Failure to complete the entry of a combination within 40 seconds will reset memory and require the reentry of all digits;**
- **Day-locking is impossible;**
- **Continuous movement of the dial at a speed of over 600 RPM, caused by the use of a robot dialer, will cause a zener diode to blow. There is a 5:1 gearing ratio between the dial drive cam and power generation system. Thus, if 3000 RPM is applied to the dial, then 600 RPM will appear at the internal generator. Once the zener is triggered, it will cause a permanent short circuit and deprive the super capacitor of the ability to charge;**
- **Total scramble of random-number generation and display, making back-dialing impossible;**
- **Provide audit feature to record and report the number of opening attempts;**
- **Impossible to observe the combination while it is being dialed;**

- **True one million permutations; no dead numbers resulting from tolerance of moving parts as in conventional lock;**
- **Single and dual combination mode entry for a possible one trillion unique combinations;**
- **Prevent robot dialing;**
- **Each time that the user enters a digit, a new series of random numbers are generated to make manipulation impossible;**
- **Each dialed number is stored in memory;**
- **Processor can operate from 3.5 MHz.-25 MHz and is not affected by temperature;**
- **Redundancy in electronics (70%) to eliminate failure potential of component and to allow close tolerance in timing parameters;**
- **Potting compound is utilized to prevent access to the electronics. There is no way to read or write the device without the correct software;**
- **Eleven data lines connect the dial with the microprocessor. No useable information can be derived from these circuits;**
- **Relockers are incorporated to deadlock the bolt. If the lock cover is moved 1/10" or the case is heated to over 158 F, a magnetic pin will be drawn into the bolt.**

34_12.6.1 Anti-Manipulation Features

The fatal design parameter of every Group 2 mechanical lock is the ability to attach a robot dialer and open the lock in thirty hours or less. If one of the numbers is determined through manipulation, then the process can be reduced to forty-five minutes. As detailed in **Chapter 36,** a Group 2 (and perhaps some Group 1) mechanical locks can always be manipulated with an automated dialer because of the following inherent design parameters in all wheel packs:

- **There is always a constant physical correlation between the position of the dial and the location of the left and right contact points;**
- **There is a definable mechanical tolerance or play in all locks that will allow a wide latitude (up to**

±1.25 numbers) of variance from the index marker to the actual combination digit;

- **The manufacturing tolerance for every lock is known;**
- **A three-number 100-segment lock with a theoretical 1,000,000 combinations may actually have 240,000 or less useable permutations.**

The X-07 cannot be manipulated open, because sophisticated programs have been integrated into the operating system to insure that the lock does not function like its conventional counterpart. The following security programs have been implemented to insure that robot dialers are totally ineffective:

- **The data representation of the number sequence is changed each time the dial direction is reversed;**
- **The number generator seed is encrypted and the key is changed each time the dial is turned;**
- **There is a free-running counter in the processor that is re-encrypted each time the lock is opened;**
- **The seed for the algorithm changes each time the lock is reprogrammed: it is random and free-running;**
- **The memory location for the seed changes when the lock is reprogrammed;**
- **The serial number of the lock is utilized in generating the seed. This will prevent the use of a logic analyzer to sample memory locations of different locks in an effort to determine the algorithm;**
- **It is impossible to decipher any data stored in the memory to learn the combination.**

The profile of a robot dialer will be met and appropriate countermeasures initiated if the following conditions occur:

- **Continuous dialing without a pause of at least .250 seconds every 1 1/3 turns will cause the combination to be ignored;**
- **If an entire combination is entered in less than 15 seconds;**
- **If continuous dialing occurs for more than five minutes without letting the lock power-down;**
- **Dialing ten incorrect combinations in sequence**

requires a two-minute power-down and blanking of the display until power reset.

A robot dialer utilizing the most sophisticated sensing technology, including optical character recognition, sound, and video, would be expected to accomplish an opening based upon half of the combinations, in 190 days. In dual-combination mode, the robot dialer would not know if one of the combinations had been entered incorrectly until both were dialed. In reality, there is no such thing as surreptitious entry of an X-07. If one statement can summarize the security of the X-07, it is this: "if you do not have the combination, you will not open the lock."

34_12.6.2 Future Security Enhancements

Later models of the X-07 are expected to contain a clock to provide greater audit detail and increased functionality, with respect to entry control. Remote control for alarms as well as authorizations for opening and changing of combinations will also be incorporated. It is also expected that future locks will store up to 50 or more different combinations, one for each employee. With additional memory, every opening and closing can be retained. Expect memory size to increase to 1,000 or more bytes (from the present 100 bits) and stored data to be encrypted.

34_12.7 Programmability (Changing Combination)

The X-07 is field programmable for all options and number sequences, including supervisory control functions. To change a combination, the user places a two-pronged plug into the back of the lock that short-circuits the contacts. When the proper combination is dialed, the lock will display (SL) for change-key mode. The lock will not open in the change mode, so the bolt cannot be withdrawn nor can the door be shut.

A series of commands will allow the operator to enter and verify a number sequence for single or dual-combination modes. If the lock cover is accessible and the combination has been lost, the serial number may be entered through a specific sequence to place the lock into programming mode. This security feature will prevent someone from covertly obtaining the combination. Presently however, there is no audit trail with regard to removing the back cover, although such a feature is planned for later models, together with different code change procedures.

CHAPTER THIRTY-FIVE: FORCED ENTRY OF SAFES

Destructive Entry of Safes: Tools and Techniques

Master Exhibit Summary

access point to remove layers of metal.

Figure LSS+3510. In this figure, peeling was accomplished from the corner using a cold chisel.

Figure LSS+3511 This was a peel and punch attack to access the bolts (left). A classic peel attack is shown (right)

Figure LSS+3512, examples of peeling of the outer skin on the top of the container and the rivets popped.

Figure LSS+3513 Prying and wedging.

Figure LSS+3514 A safe that has had the door pulled loose by the application of extreme pressure.

Figure LSS+3515, (ISP 38-3563 left, and 39-3563 right). The result of pounding of components.

Figure LSS+3516, Bolts were sheared from shock waves through the use of the welded bar to the front of the door.

Figure LSS+3517. Example of punching. Pressure was applied to the hinge side.

Figure LSS+3518. This was a pound attack. The door was pounded with many hits.

Figure LSS+3519, An attack by the use of a wedge to pry apart and separate portions of the container.

Figure LSS+3520, The top of the safe was cut into to provide access to the bolt works.

Figure LSS+3521 Attacks by torch. In the middle picture, an inept attempt to open the safe by cutting through the side.

Figure LSS+3522. Attack using a torch where there was obviously no knowledge of where to cut.

Figure LSS+3523 Additional examples of the use of a torch. In the photographs, the lock box is burned out.

Figure LSS+3524 Lines scored by an oxyacetylene torch in the outer shell of a Chubb safe.

Figure LSS+3525, examples of torch attack. Incorrect tools were utilized on the side of the safe.

Figure LSS+3526, attack by torch that did not result in an opening.

Figure LSS+3527, A torch attack where burglars cut a portion from the door for access.

Figure LSS+3528, Examples of attack by oxyacetylene.

Figure LSS+3529. The thermic lance develops high temperature and can be utilized virtually anywhere.

Figure LSS+3530 An example of a safe attacked with a thermic lance.

Figure LSS+3531 An example of arc welding with cutting rods.
Figure LSS+3532, A free-standing Chubb safe was attacked with explosives.

Figure LSS+3533 A safe was open with explosives, after being filled with water.

Figure LSS+3534 A fixed drill rig.
Figure LSS+3535 A burglary where it is suspected that a drill rig caused the fracture of the outer skin of the door.

Figure LSS+3536 Core drill can produce a large hole for access to the bolt works or lock box.

Figure LSS+3537 Critical drill points are shown. This is a rear view, with the lock case removed.

Figure LSS+3538 (ISP 23-2963) Deflector plates made of angle iron are added to deter drilling.

Figure LSS+3539 (ISP 104-3563) The bolt is punched out of the way in order for the handle cam to be rotated.

Figure LSS+3540 Burglars drilled into the side of the safe to punch and drive the bolt out of the way.

Figure LSS+3541 A scope is inserted to obtain a view of the wheel pack.
Figure LSS+3542 The fence is a prime target for drilling, either the soldered link or the actual fence material.

Figure LSS+3543 Progression of movement of the fence into the gate of the wheel pack.
Figure LSS+3544 A 90 degree angle view with a borescope using a mirror on a Mosler MR 302.

Figure LSS+3545 Locating the fence for drilling.

Figure LSS+3546 A lever fence that has been drilled, and then removed.

Figure LSS+3547 Drilled relockers and zoom view.

Figure LSS+3548 Mosler MR-302 point of penetration.
Figure LSS+3549 Hole drilled through cover plate.
Figure LSS+3550 Side drilling and scoping the lock case.

Figure LSS+3551 Floor safe that has been angle drilled to view wheel pack.

Figure LSS+3552 Safe drilled from the top of safe to lock box to view the wheel pack.

Figure LSS+3553 Many burglaries are simulated.

Figure LSS+3554 The burglar uses a drill without much knowledge of the safe.

3563-15 Individual must have knowledge

3563-16 Tool knowledge of the burglar

3563-17 Time limit for burglary

3563-1819 Proficiency in burglarizing types of safes

LSS201: A primer on the burglary of safes, Courtesy of Bill Sherlock.

LSS201: Forensics and locks, Courtesy of Bill Sherlock.

LSS202: Steve Mattoon on the use of explosives to gain entry.

Use of the change-key hole for reading wheels, by Harry Sher

LSS204: Owe Bengtsson on opening safes

LSS204: Owe Bengtsson introduction to opening safes

LSS204: Owe Bengtsson on the forced entry opening of safes

LSS204: Owe Bengtsson on the opening of high security safes

35_1.0 Introduction

This chapter describes the accepted methods for penetrating safes by force that are used by professional technicians. The traditional and modern techniques utilized by criminals are also described, together with the evidentiary aspects of safe and vault burglary. In the experience of the author, any safe can be opened; this chapter explores those methods. The wide array of tools, both general and specialized, is described together with guidelines for their use. Particular emphasis is placed on drilling technology of hard plate barrier materials. See **Chapter 5** for a more technical discussion of metallurgy as it relates to locks and safes. Covert and non-destructive-entry techniques, including manipulation, are described in **Chapter 36.**

The subject of safe and vault penetration is quite complex and involves many disciplines. As the reader will learn, opening a security container is both a science and an art, and can be hazardous. Successful penetration requires the correct equipment, coupled with accurate information and knowledge of the art. Patience and extreme attention to detail are essential if the mission is to be accomplished without danger to the technician.

Remember that safes in a perfect world are **designed so that they cannot be opened by anyone who is not authorized to do so**, regardless of the methodology employed. In the real world, most safes **can** be opened, either covertly or through force. Depending upon one's point of view, this is either good or bad. Whenever a safe must be opened by other than normal means (combination or key), it is usually because the lock or boltwork is inoperative due to mechanical malfunction of critical components, including relockers. The cause may also be a failed burglary, complex maintenance problem, obstruction in the doorjamb, triggered relocker, sabotage, or a previous penetration attempt that was unsuccessful. An opening may also be required for a security or intelligence operation or for evidence.

Although television and the movies portray techniques of safecracking as a relatively simple task, the process is anything but that. In fact, penetrating a high-security safe can be likened to battlefield surgery: you only do it after all other methods have failed. Safes are not meant to be opened except by the use of a key or combination. Any other procedure entails risks. It is not a simple decision to drill or apply any form of force to a secure container to effect an opening. It is a technical procedure that requires extensive information about the lock and the construction of the safe. All other methods of entry must first be exhausted.

Statistically, few safes are attacked and fewer actually opened. Most customers believe safecracking to be a rare crime; thus, any money spent on quality containers is wasted. In reality, the only reason that a safe is not successfully compromised is due to quality in its design and construction. Drills, hammers, levers, thermic lances, torches, and explosives are the tools of the trade. Their use will be described in order to provide a detailed summary of proper procedures.

All safes are normally secured and opened through a mechanical or electronic combination lock, a lever lock, or both. As described

elsewhere in this text, these locks can provide an extremely high level of security against manipulation. The container, however, always has the job to protect the lock from physical compromise. In some cases, safes are penetrated through surreptitious means. The term "surreptitious" is often misunderstood and is therefore defined here. It is "a means of entry which would leave evidence, but would not be detectable by a user during normal use, but would be detectable during inspection by a qualified person." The General Services Administration (GSA) in 1989, in A-A-F-358G, Paragraph **6.4.3**, promulgated this definition.

35_1.1 The Art of Safecracking

The history of safecracking is rich with examples of innovation, initiative, and ingenuity upon the part of burglars. One axiom always has held true with regard to security containers: “If there is a way that they can be opened, they will be, and often.” See the discussion in **Chapter 33**. Criminals and technicians have always sought to develop methods to circumvent all of the mechanical design innovations, engineering talent, and production technology that could be incorporated into a container to keep its contents secure. A tremendous reservoir of knowledge has been gathered since the Industrial Revolution relating to container security, and all that that concept entails. Every time a safe is to be penetrated or a lock manipulated, two centuries of experience is placed as an obstacle to one attempting that which is supposed to be impossible. The reader may also wish to review the discussion by Alfred Hobbs regarding this subject in **Chapter 14** of his book.

35_1.2 Container Security: Early Problems and Solutions

Safecracking has been going on for hundreds of years and has always been a contest between manufacturers, technicians, and burglars. Safe makers have sought to produce containers and locks that could not be compromised by anyone through any means. Every part of a safe has been designed in response to some form of attack or threat. The shape, design, mechanism, metals, and even the paint is a product of security.

Manufacturers have gone to extraordinary lengths to protect their containers. Great advances in metallurgy, chemistry, physics, and manufacturing processes have combined to produce the most secure locks and containers on earth. Likewise, methods of

attack that were once primitive and rudimentary are now sophisticated. They include the use of high- tech tools and computers.

Burglars began with crude tools, such as jimmies, levers, pickaxs, sledgehammers, pry bars, and wedges. The use of drills, torches, lances, and explosives soon followed. Safe makers responded to each method of attack with various enhancements that contributed to safe and vault technology today. Manufacturers have logically focused their design efforts to barrier materials, bolt works, locks, hinges, and construction techniques. In response to each new method of entry, they have refined their products and processes. The more relevant advances can be found in technical specifications in the Chubb archives:

- **The methods of fixing steel plates together to form the body of a container;**
- **The construction of comb and dovetail joints with extra fillets at the corners;**
- **The development of sophisticated metals to act as barrier materials, with Rockwell C ratings exceeding 90;**
- **Changes in bolts and locks to protect against drilling, manipulation, temperature, and explosives;**
- **The development of complex and fail-safe relocker systems, utilizing mechanical, thermal, vibration, and glass materials to prevent compromise of locks, bolt works, and barriers;**
- **Introduction of many enhancements in mechanical and electronic combination locks;**
- **Introduction of time locks, time-delay locks, and automatic scrambling locks;**
- **Isolation of wheel pack from the bolt. In older safe designs, the discs were directly connected to the boltwork. This allowed feeling and hearing the fence-gate positions as pressure was applied to the bolt;**
- **Implementation of reinforced lock mounting and protection of the keyway, in order to prevent the practice of pushing a strong steel threaded rod into the keyhole and driving it backward with a sledgehammer;**
- **Sealing of cavities to prevent gunpowder from being**

directed into the safe with a bellows or straw, allowing the safe to be blown apart;

- **Reduction or elimination of sharp, square edges on walls and doors. Only safes with rounded, welded edges would resist lever or wedge attack;**
- **Advances in riveting, attaching, dovetailing, and welding of metal plate to increase strength;**
- **Prevent ripping and peeling through the use of steel bands and supplemental enforcement;**
- **Use of manganese steel and other sophisticated alloys to prevent cutting;**
- **Reduce the tolerance gaps in square doors to prevent the use of nitroglycerine to seep into these areas. The round door in the Corliss safe was a direct result of this practice;**
- **Develop a crane hinge to provide closer tolerances than was possible with traditional hinges that required rotation around the radius of the pin. The crane hinge provided for a direct straight-in fit, much like a bath plug fills a drain;**
- **More secure door and door mating designs to reduce tolerances and make them more secure. Locking and sealing was accomplished in one motion, borrowed from the design of the breach locks of big guns. For a time, the doors were designed as a large plug with interrupted threads that actually constituted a screw thread with slots cut into the frame. To engage these doors required a partial turn to lock secure. They were extremely effective but eventually were compromised;**
- **The thickness of walls and barrier materials was increased. Steel that is less than ¼" thick will provide no resistance to attack from drilling, ripping, and explosives because it cannot resist pressure;**
- **Sophisticated barrier materials have been developed to resist drilling, especially around the lock. More than one inch of material may be considered as drillproof. Several layers of different metals may be employed to protect against the effects of drilling, temperature, and pressure;**
- **The physical weight of safes was increased for**

structural integrity, rigidity, and protection from concussion. Over 800 pounds is considered the minimum requirement.

35_1.3 Terms of Art: The Original Safecrackers

Many terms came into the lexicon in England and then America almost two centuries ago to describe the tools and techniques of the **Peterman** or **Boxman.** This jargon attests to the uniqueness and mystique of the craft. Some of the terminology is included here to preserve the tradition, and provide a flavor of the art for the reader:

Bellmen: Users of explosives;
Bellows: Device utilized to create a pressurized airflow to force explosives into a safe;
Blower: Safecracker;
Box: Safe;
Boxmen: Safecracker;
Dets: Detonator for explosives;
Grease: Nitroglycerine;
Gut Box: The locking mechanism

Gutshot or Spindle Shot: Nitro can blow a lock after the dial has been removed and the safe is laid on its back. An eyedropper is employed to drip the nitro onto the dial, where it will follow a path into the lock. A detonator is required to set off the explosion.

Jam Shot: This method of opening a safe requires some skill. Nitro is poured into the crack around the edge of the door, allowing the fluid to trickle in and fill the doorway. It will blow the door open and allow it to remain on its hinges once detonated. To accomplish this technique successfully, two critical items were required: a bar of kneaded soap and a strip of cellophane tape ½" wide. The tape was first pressed into the crack around the door and then the soap was used to create a sealed track over the cellophane. The tape was then removed and the nitro poured around the door. Manufacturers have since introduced tighter tolerance and a small lip around the door to catch the nitro and stop the practice.

Jimmies or **Jemmies:** Levers;

Kiester: Smaller safe within a larger one;

Knocker: Detonator;

Mit: Handle of the safe;

Nitro: Nitroglycerine. This is actually glyceryl trinitrate, which is used for the treatment of angina in cardiac patients. It expands blood vessels and reduces the work load of the heart;

Peter Cane: A lever that is used to open a jammed or distorted safe door after an attack that succeeded in creating a gap between the door and frame;

Peterman: Safecracker;

Powder: Gunpowder;

Punching a Cam: Forcing the lock mechanism away from the bolt by driving a rod into the lock case, then applying pressure to release it from its anchor;

Rag Shot: This involved boring a small hole directly above the dial. Then, a rag was saturated with a solution of nitro, pushed into the hole, and covered with kneaded laundry soap. A wire connected the detonator to a battery;

Shooting for Space: Introduction of nitroglycerine into crevices and tolerance gaps within a safe;

Space Shot: This involved dropping a safe on its back, then building a soap cup on the center of the door and detonating an explosive contained in the cup. The aim was to “dish the door”;

Yeggs: Traveling safecrackers;

35_1.4 About Opening Safes: Things You Should Know

Experienced safe technicians who have spent many years learning the craft open most safes. A competent "safe tech" is invaluable because without his skill, the safe will either not be opened or it and the contents will be destroyed in the attempt. Time is generally a critical factor in most openings: the professional safe technician will require the minimum amount of time to do the job right. Finally, when the safe is opened it will be restored

to its original security rating. It will not be left vulnerable to future attacks that have been made simpler by the previous penetration procedure.

Most professionals in the world are members of both the **Safe and Vault Technicians Association (SAVTA)** and the **National Safemans Organization (NSO).** Many have attended schools on safe penetration and manipulation conducted by either Mark Bates or Lockmasters. Information regarding NSO and SAVTA, specialized schools, and a master index of articles and bulletins can be found at **security.org**. Opening a safe, especially for the first time, can be an awesome experience. It is usually remembered for quite some time by the technician, often with accompanying nightmares!

35_1.4.1 Reference Material and Courses

Many books on the subject of penetration contain a great deal of valuable data. Hopefully, this will be one of them. However, no text or school can properly prepare the technician to open a difficult container. Only experience and making many mistakes can do that. There are so many variables, unexpected circumstances, and conditions that can occur that every opening is a challenge and fraught with peril.

Courses in safe penetration may be valuable. A knowledgeable instructor with a recognized curriculum must teach in a facility capable of properly demonstrating various techniques. Basic and advanced classes, manufacturer seminars, and resident classes may all be helpful. In the first instance, be certain of the accuracy of the reference material that is being relied upon as the basis for drilling or other forced-entry techniques. If the diagram or drill point template was not drawn by Ed Willis or a craftsman with similar competence and experience, then the data may not be reliable. Information published prior to 1970 regarding drilling procedures should be read quite critically. Prior to the mid-1980s, carbide-tipped drills were not available for penetrating hard plate, and thus some of the procedures that were published were slightly different than today.

35_1.5 Remember the Basics

Always remember that the lock controls access to the safe. Open the lock, and the safe will follow. The manufacturer of the container is largely irrelevant and of secondary importance if the lock can be bypassed. The vast majority of malfunctions that

require that a safe be penetrated are lock related. See the discussion below about lockout diagnostics.

In almost every penetration, drilling is accomplished within the dial ring area, although this may not be the case in high-security containers with glass relockers. Do not be easily intimidated by the size, complexity, or security of a container. Simply respect it. To do otherwise will ultimately occasion errors in judgment and lead to failure. Remember that every manufacturer touts its products in technical terms, calculated to act as a deterrent to anyone contemplating penetration.

Most design engineers working for safe manufacturers are not particularly clever, and few think as a burglar does. In the author's view, they have little understanding of how to “break” a safe, only to design it. Quality during production and the proper research and development make a safe secure. A UL rating simply confirms the security level of a container and provides an index as to the difficulties that may be encountered in an opening. It does not guarantee that the safe cannot be opened.

Other basic guidelines for safe technicians that are often forgotten or misunderstood include:

- **Do not be intimidated by any safe. Have respect for the potential difficulty of the task and the engineering that is incorporated into the container. It is designed to keep from being opened without the key or combination;**
- **A safe or vault lock is no more complicated than a pin tumbler or lever device;**
- **The proper knowledge of the design of the container is essential and can compensate for a lack of confidence;**
- **Safe manufacturers require that their products can be serviced. They are generally cooperative with a professional safe technician and law enforcement agency in providing information about opening their product;**
- **Possess all of the correct tools to do the job, understand their function, and know their limitations. An opening should not be undertaken without the proper implements;**
- **Tools are expensive, and there is no substitute for**

quality. A serious safe tech should spend the required amount on the finest tools after careful research to determine what best meets his requirements.

35_1.6 Hazards in Opening Safes and Vaults

Many hazards can be encountered in the process of opening a safe. They may cause physical danger, legal liability, economic loss, and injury to reputation.

35_1.6.1 Documentation: The First Step

It is important that the proper documentation be maintained regarding the opening of any container. This includes:

- **Any impact upon security;**
- **Cause of the lockout;**
- **Complete description of the work performed;**
- **Complete identification of the safe: color, make, model, generic type, and serial number;**
- **Date and time;**
- **Information regarding repairs, including drilling, for insurance claims and UL certification of the container. This data can be used to rebut claims of negligence should burglars using the same drill point compromise the safe;**

- **Information regarding the specific job, which includes:**
    - **Insurance coverage for negligence, property disappearance, and business interruption;**
    - **Maintenance data for future service;**
    - **Maintenance records regarding service and combination change, including documentation of details regarding the job. (This may be very important in the case of a lockout that occurs shortly after the work was performed);**
    - **Method of opening;**
    - **Parts installed;**
  - **Services performed;**
- **Signature of individual in authority, both prior to**

and after acceptance of the work performed;
- **Verification of the authority of individual requesting the services of a safe technician, so that charges of theft and conspiracy cannot be lodged against the technician;**
- **Warranty data regarding work performed;**
- **Witness to opening, in order to verify that contents have not been removed by the technician;**
- **Written contract for work to be performed.**

35_1.6.2 Dangers to Life or Property

Although rare, there are dangers that can occur while working on safes and vaults. An assessment should always be made prior to any opening or performance of service. This should include:

35_1.6.2.1 Explosives

If a safe was burglarized using explosives, extreme caution must be exercised because active non-detonated charges may be present. This is especially true where nitro was employed. If nitroglycerine is present, it can be detected by the presence of a soapy substance. In fact, soap is actually used to contain the "grease." Safes may also be booby-trapped with other forms of explosives.

35_1.6.2.2 Tear Gas

Tear gas was first introduced in 1871, and was developed by Graebe. Its chemical composition can take several forms, the most common of which are chloroacetophenone, phenacyclchoride, Chemical Mace, and CN. Perhaps the most popular was chloroacetophenone, which is a solid crystallization produced by chlorinating acetophenone and benzene.

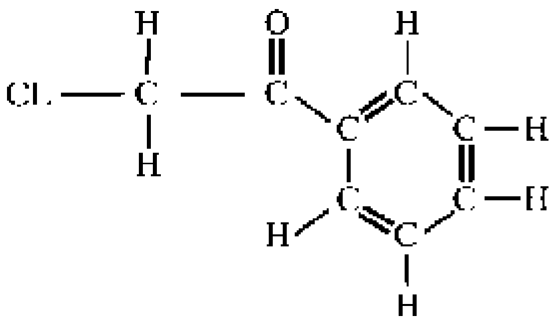


Figure LSS+3501 Chemical composition of the most common form of tear gas.

The presence of tear gas can be lethal, especially if the material was produced and installed many years ago. Tear gas was routinely placed in safes and vaults used in federal buildings and banks, between 1935-1970. Discharge can cause evacuation of a building and be dangerous to those with heart or respiratory conditions.

If the safe is quite old, the tear gas may have deteriorated and can become toxic or even deadly. This is especially true if cyanide was utilized as a primary ingredient. Companies that produced tear gas systems for safes included Badger Safe Guards (New Jersey), Detour Safe Protector (Minnesota), Night-Hawk (Oregon), Chicago Tear gas Company, Pro-Tex Laboratories (Chicago), and Lake Erie Chemical Company (Cleveland).

Tear gas may be released during a failed burglary attempt. Glass vials containing the chemical can be exposed to breakage during the search for evidence and present an additional risk. The use of a torch to open a burglarized safe after the fact can also trigger tear gas relockers.

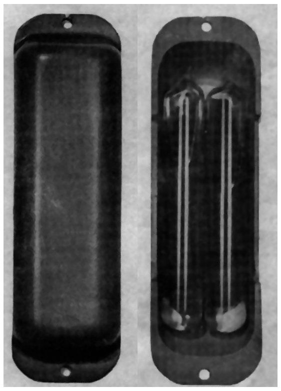


Figure LSS+3502 A typical tear gas container with two glass vials containing the active material. Upon the triggering of a relocker, shock, or vibration, the vials are broken and the gas released.

35_1.6.2.3 Smoke Bombs

Smoke bombs were popular in safes produced at the end of the nineteenth century. They were contained in a metal canister mounted within the door and activated by a tensioned relocker.

35_1.6.2.4 Dangerous Contents

Safes can contain dangerous materials that may cause injury or death. If the safe is opened by grinding, hammering, prying or with a torch, the problem can be more pronounced. This is especially true if blasting caps, ammunition, fuel, or explosives are contained within. The safe may also be booby-trapped with a bomb.

35_1.6.2.5 Burglarized Safes

There are several hazards associated with opening a burglarized safe. The search for evidence must be preceded with an investigation into possible dangers relating to contents and physical condition, including:

- **Electrical wires, conduit, or outlets that are in contact with the container;**
- **Stability and anchoring of the container. Pay particular attention to broken casters or mounting pads;**
- **Door and hinges are secure and will not fail when dislodged or opened;**
- **Temperature of the container;**
- **Corrosive chemicals on the surface of the container;**
- **Sharp edges;**
- **Explosive residue, especially nitro.**

35_2.1 Security of Safes and Vaults

There are many ways to compromise or penetrate a safe. In addition, certain very basic measures will help to prevent losses from fire and burglary.

35_2.1.1 Buy a Quality Safe

There is no substitute for quality. Manufacturers such as Chubb, Mosler, and Diebold have been in business for over a hundred years and have developed extremely sophisticated technology to protect valuables. There is a reason why good safes are expensive. Research, development, and precision construction come at a price. Safes can be subject to many quite sophisticated forms of attack; advanced metallurgy, chemistry, and physics are required to insure a high-security rating and effective resistance to such measures.

35_2.1.2 Access to the Safe

Hide the safe or encase it in concrete or other barrier material to prevent access. In commercial establishments, place the safe where it can be observed from the outside. Utilize reliable internal and external alarm systems including door trips, motion detection, and proximity sensors. Alarm devices should protect against movement, temperature, and vibration.

35_2.1.3 Obtaining the Combination

Prevent anyone from obtaining the combination by using spyproof dials and obstructing remote viewing. Do not leave the combination where it can be found, and do not utilize predictable sequences of numbers such as birth dates or telephone numbers.

35_2.1.4 Locks

Utilize high-tolerance combination or key locks. Electronic locks such as manufactured by Mas-Hamilton have set the world standard for computerized high-security control. Mechanical locks should have at least 1,000,000 theoretical permutations, with a maximum of ±1.0 number tolerance for fence and gate. False notches should be incorporated to deter manipulation. Group 1 locks are generally required for military, government and high-security installations. Time locks should be utilized on vaults to control access, especially whenever holdup or hostage taking is a potential threat.

35_3.0 Methods of Entry for Opening Safes and Vaults

There are many techniques for opening safes and vaults and for

bypassing safe locks. The procedures can be divided into non-destructive (covert or surreptitious) and destructive means. Within each classification, there are several options. These depend upon a complex array of factors based upon the lock, safe, or vault to be opened. Several alternatives may be applicable for any job and are in part dependent upon the skill of the technician, tools available, window of opportunity, and conditions at the time of the opening. Non-destructive entry involves the bypass of locks and other mechanisms in a manner that cannot be detected. Such techniques do not cause any alteration or damage to a component. An entry that causes damage or a change to any mechanical component of the lock or safe is said to be destructive, regardless of whether the change is fully repaired.

Although there are many approaches described in this text, drilling is the primary method of destructive entry. Major emphasis will be placed on that technique and all of its facets. The following summary analyzes and categories the available options for effecting an entry by both non-destructive and destructive means.

35_3.1 Summary of Non-Destructive-Entry Techniques

Non-destructive entry occurs by obtaining useable information about critical locking components without their disassembly or destruction. Nine primary methods for obtaining such information will ultimately lead to an opening.

35_3.1.1 Combination Deduction

The original factory combination or number sequence is deduced by using tryout numbers or other means. Numbers can be obtained from a variety of sources if the proper security measures have not been implemented. Perhaps the easiest approach is to test the lock using known factory-default combinations. Many times, locks are replaced and never reprogrammed. Using a list of test numbers from the manufacturer, the lock can be opened.

Unfortunately, convenience can take precedence over security. Selection of combinations based upon birth dates, social security numbers, telephone numbers, easily remembered sequences, or patterns are too often used. The burglar can sometimes guess these. Combinations are often written on pieces of paper and left

in desk drawers, on bulletin boards, blotters, in notebooks, or on the container itself. In one bank theft investigation worked by the author, the combination to the main vault had been written on a file card in the security director's desk. It had been missing for nine months without the combination having been changed. There should have been no surprise when the money finally disappeared!

35_3.1.2 Employee Compromise

Information regarding combinations may be obtained from employees, with or without their knowledge. Numbers may be written down and recorded by employees for safekeeping or to facilitate recollection. If an unauthorized person such as a janitor or coworker locates that information, then the contents of a container can be compromised without the ability to identify the perpetrator. Employees may unwittingly provide information about a combination to third parties through innocent conversation. They may also sell the information or provide it while in collusion with criminals.

35_3.1.3 Surveillance

The combination sequence can be derived through surveillance while the container is being opened. This can occur through direct or remote observation. Techniques for obtaining information through surveillance include:

- **Secrete persons or cameras in ceilings;**
- **Observe safe being opened at close range;**
- **Audio or video plants in order to derive the combination or information about it. Devices will include video, film cameras, or audio recorders. Some older locks emit clicks for each number division. These can be recorded and deciphered later;**
- **Long-range lenses, telescopes, or binoculars;**
- **Simulated burglary in order to force maintenance of the safe. This can lead to information being obtained or overheard from locksmiths or safe technicians about the problem;**
- **Paper under safe dial to record rotations.**

With the availability of extremely small video devices, a camera

can be placed in such a position as to afford a direct view of the dial. This information can be recorded, or directly seen. The results of surveillance can yield partial or complete data regarding the combination. Obtaining one of three numbers in a combination sequence can reduce the time required to open a lock to less than forty-five minutes.

35_3.1.4 Manipulation

Extrapolation of the combination through the manipulation of the dial can be accomplished on most Group 2 and non-listed locks. Manipulation is not detectable once it is performed. It is a precise process and thoroughly described in **Chapter 36**. Although manipulation has traditionally been a manual process, Mas-Hamilton has introduced an extremely sophisticated computerized system to automate the task for certain popular combination locks. The Soft Drill is detailed in **Chapter 36**.

35_3.1.5 Vibration

Older combination locks can be opened with vibration. As has been noted previously in **Chapter 33**, this design problem in certain mechanisms was particularly prevalent on ships where constant engine tremors were transmitted to wheel packs through the metal of the vessel. In the older designs, no balancing mechanism was integrated into the wheel structure. Because there was less material at the top of the wheel (where the gate required the removal of metal), there was a corresponding imbalance or weight difference.

If the wheel vibrated, the heavier portion at the bottom would find its natural position based upon the action of gravity. All that was required was to introduce enough vibration so that all three wheels would align their lightest portion (gates) at the twelve O'clock position beneath the fence. Vibration could cause the lock to be opened without a trace that an entry had been made. This was such a pervasive problem that safes would open themselves on some ships.

35_3.1.6 Day-Locking

Safes are often day-locked using a second locking mechanism integrated into the dial. This provides little protection from picking or other methods of compromise. Day-locking may also be accomplished by turning the dial a few divisions past the correct number to expedite the opening process. Employees will often

engage in this practice in order to eliminate the requirement for entering the entire combination.

Obviously, a thief can also back dial the number to open the safe without having any direct knowledge of the combination. In certain cases, the number sequence in locks using wheel pack scramblers can be derived.

35_3.1.7 Robot Dialers

Robot dialers can be an extremely effective means to open a lock. They are computer-controlled devices that are programmed to dial every possible combination while exploiting the tolerance errors of a specific lock. See **Chapter 36** regarding current technology.

35_3.1.8 Radiographic Imaging

X-ray and gamma ray imaging may also be employed to provide a representation of the position of wheels and gates.

35_3.1.9 Touch-Sensitive Materials

Fingerprint powder, ultraviolet indicators, and other materials may be utilized to show which buttons have been touched on a push button lock. Dust covers on dials and keypads can eliminate the practice.

35_3.2 Summary of Destructive-Entry Techniques

Destructive entry occurs whenever a container or its lock is physically penetrated using tools, temperature, or concussion. The principal methods of forced-entry can be divided into four major categories: **cutting**, **blunt force penetration**, **concussion**, and **drilling**. Each of these techniques is explored in detail in subsequent sections of this chapter, with special emphasis on drilling.

35_3.2.1 Cutting

Cutting is a less precise form of attack, often used by burglars and unskilled technicians. The technique encompasses sawing and grinding, employing common power tools to physically remove or penetrate barrier materials. Cutting may also be accomplished through the use of more sophisticated techniques including lasers, high-pressure water cutters, a thermic lance, torch,

creation of high-temperatures through the use of chemicals, or application of acids.

These tools are employed to melt, vaporize, alter, or remove protective metal barriers. Hinges, handles, or locks can be destroyed or large holes can be made to create openings through which access to contents can be obtained.

35_3.2.2 Blunt Force Penetration

Techniques of blunt force penetration are most often employed by burglars; they generally denote a low skill level. The techniques will include **punching, peeling, ripping, and chopping**.

35_3.2.3 Concussion

Concussion requires the application of pressure, generally created by an explosive such as nitroglycerine, gelignite, dynamite, plastic, or primer cord.

35_3.2.4 Drilling

Drilling is the generic process of making a hole at a precise location (drill point) somewhere in the safe or lock body. The ultimate purpose or use of the penetration will vary, depending upon many factors. Generally, a hole is created in order to allow a view or manipulation of vital components using a borescope or similar optical device.

35_4.0 Destructive Entry: Primary Tools and Techniques

LSS204: Owe Bengtsson on opening safes

LSS204: Owe Bengtsson introduction to opening safes

LSS204: Owe Bengtsson on the forced entry opening of safes

LSS204: Owe Bengtsson on the opening of high security safes

In this section, a historical overview of the tools and methods of forced penetration is summarized. Then, an inventory of basic and specialized tools is provided. The various types of drill bits, their proper use, and related drilling equipment, including drill rigs, are also described in detail. Finally, the penetration of hard plate is analyzed.

35_4.1 Historical Overview of Tools and Techniques

Enhancements in security containers during the past two centuries have most often been a response to the development and use of tools and techniques by criminals for defeating safes and vaults. In virtually every instance, once a manufacturer has introduced an improvement, the burglar has initiated a successful counter offensive.

Two centuries ago, the common safe-breaking tools were a crowbar, axe, steel wedge, pick, or bolt cutter. Protection generally meant heavier metals, with sophisticated linings. Later, manufacturers adopted techniques of poured metals that created seamless corners, joints, and bonds that offered additional protection against these forms of attack. When drills became an accepted means of penetration, then anti-drilling barriers were incorporated into doors. These took many forms, as described later in this Section, and spawned an incredible array of hard plate metals.

35_4.2 Common Methods of Attack

LSS201: A primer on the burglary of safes, Courtesy of Bill Sherlock.

LSS201: Forensics and locks, Courtesy of Bill Sherlock.

There are many tools, devices, and options available to the thief. Some are rather crude and merely require brute force. Others are more exotic and sophisticated and utilize temperature, concussion, or other methods to alter the molecular structure of metals. The following discussion summarizes the most common methods of entry, beginning in the early eighteenth century. They are based upon the construction of the container and will usually be successful if enough time and effort are expended.

35_4.2.1 Punching

Punching is a technique that is as old as the wheel pack itself. The dial is first removed, then the spindle or dial shaft is driven into the lock case. This will cause the tumblers to fall out of the way of the bolt. Bolts can also be punched, either from the front or side in order to move them out of the way of obstructions.

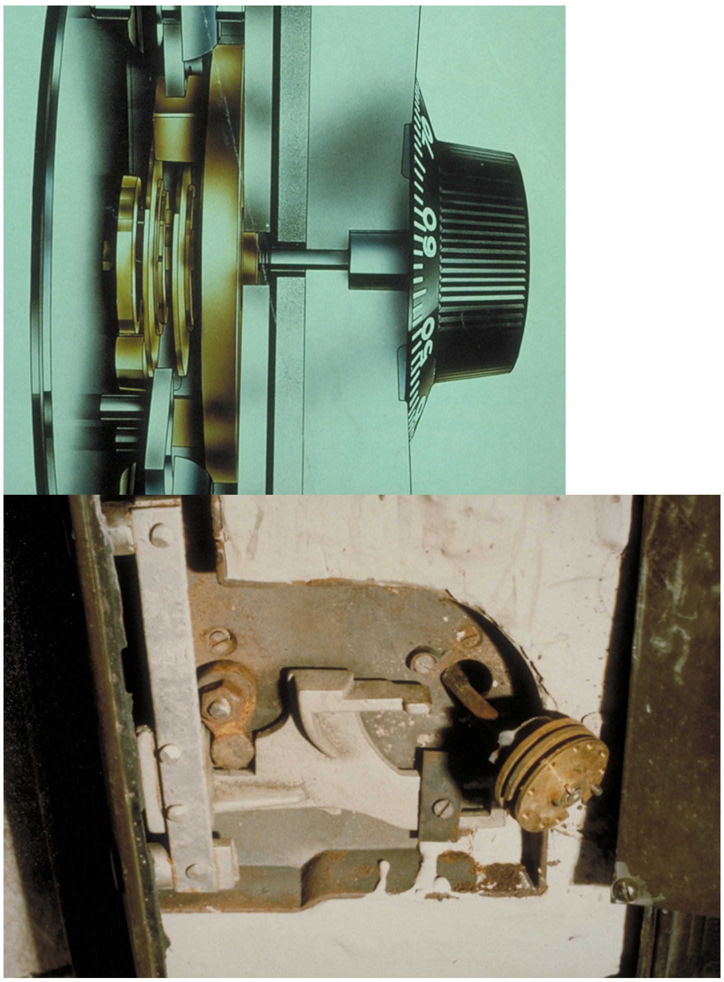
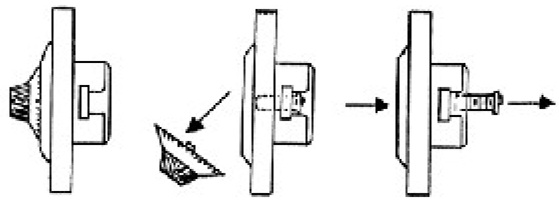


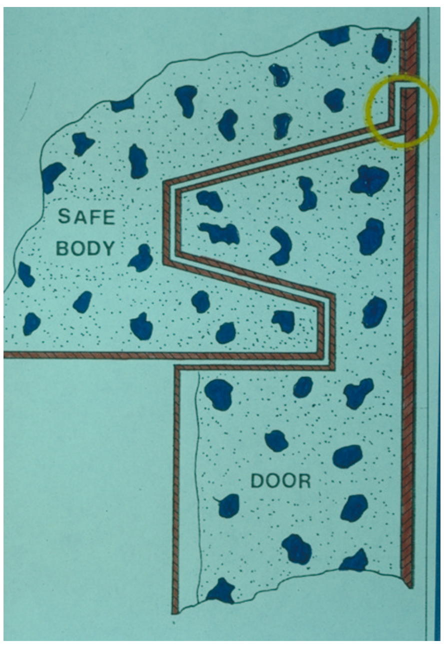
**Figure LSS+3508. Punching involves the wheel pack being forced inward (left,
ISP 35-3563), as shown in the photograph (ISP 34-3563). Courtesy of Illinois State Police, Bill Sherlock.**

In older safes, there were no internal relock devices to prevent

this practice. Due to the vulnerability of early lock designs, various countermeasures were applied. These included the use of relockers and placing a bevel on the spindle into the wall of the door. Safes that utilize locks with a UL classification of 1, 1R, and 2 are generally not subject to the practice.



35_4.2.2 Peeling



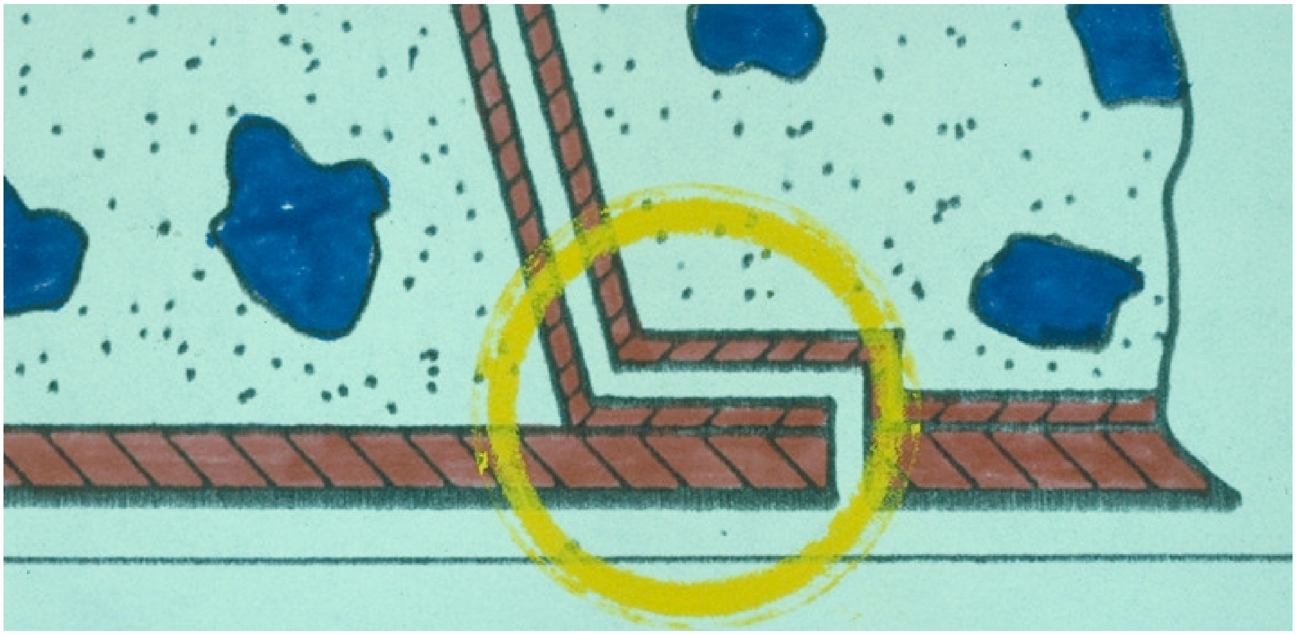


Figure LSS+3509, diagram showing how a safe is peeled by gaining an access point to remove layers of metal (left, ISP 23-3563, right, ISP 24-3563). Courtesy of Illinois State Police, Bill Sherlock.

Peeling or stripping is a brute force method of entry that usually indicates little expertise. The technique is employed with older and less expensive safes and is usually effective on containers manufactured prior to the 1960s. This form of entry requires the stripping of laminates of metal apart until the body of the container is penetrated. Generally, the edge of a square corner of the safe near the door is attacked. An axe is utilized to break the laminate bond. Then, with a lever or pry bar, the layers of metal are separated. Each exposed sheet is removed in succession, much like peeling an onion. This can be a very time-consuming and labor-intensive method of entry.



Figure LSS+3510. In this figure, peeling was accomplished from the corner using a cold chisel.



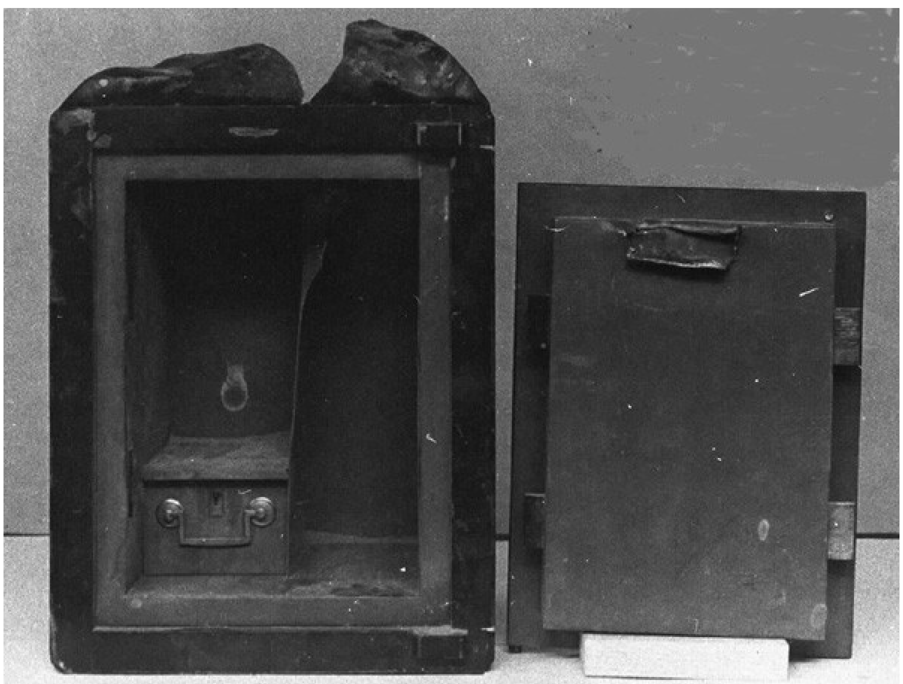


Figure LSS+3511 This was a peel and punch attack to access the bolts (left). A classic peel attack is shown (right)





Figure LSS+3512, examples of peeling of the outer skin on the top of the container (left), and the rivets popped through peeling (right).

35_4.2.2A Prying and Wedging

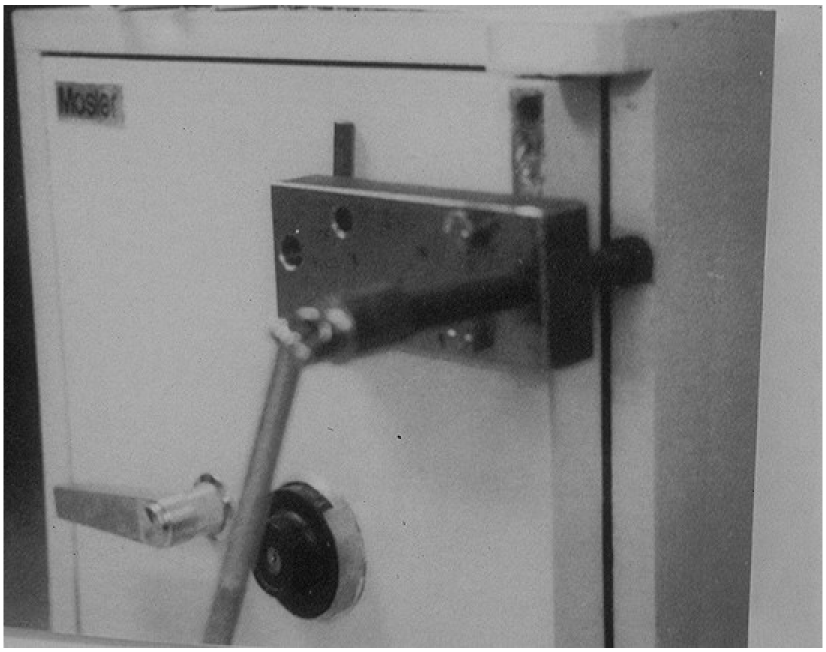


Figure LSS+3513 Prying and wedging. (center, ISP 29-3563, and right, ISP

30-3563). Courtesy of Illinois State Police, Bill Sherlock.

In this mode of attack, wedges and pry bars are utilized to attack the door, or sides of the container. The procedure differs from peeling, in that layers of skin are not removed, but rather plate is separated from the structural support.

35_4.2.2B Pulling



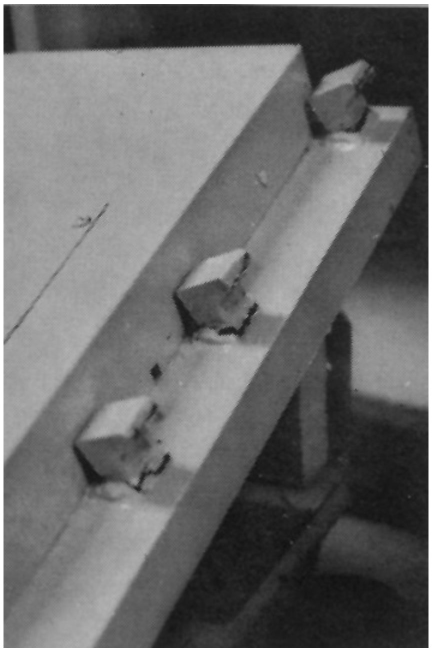


Figure LSS+3514 (ISP 31-2963 left, 32-2963 right). A safe that has had the door pulled loose by the application of extreme pressure.

35_4.2.2C Pounding

Punching involves another form of brute force attack, designed to deform the metal in order to destroy the structural integrity of the container.

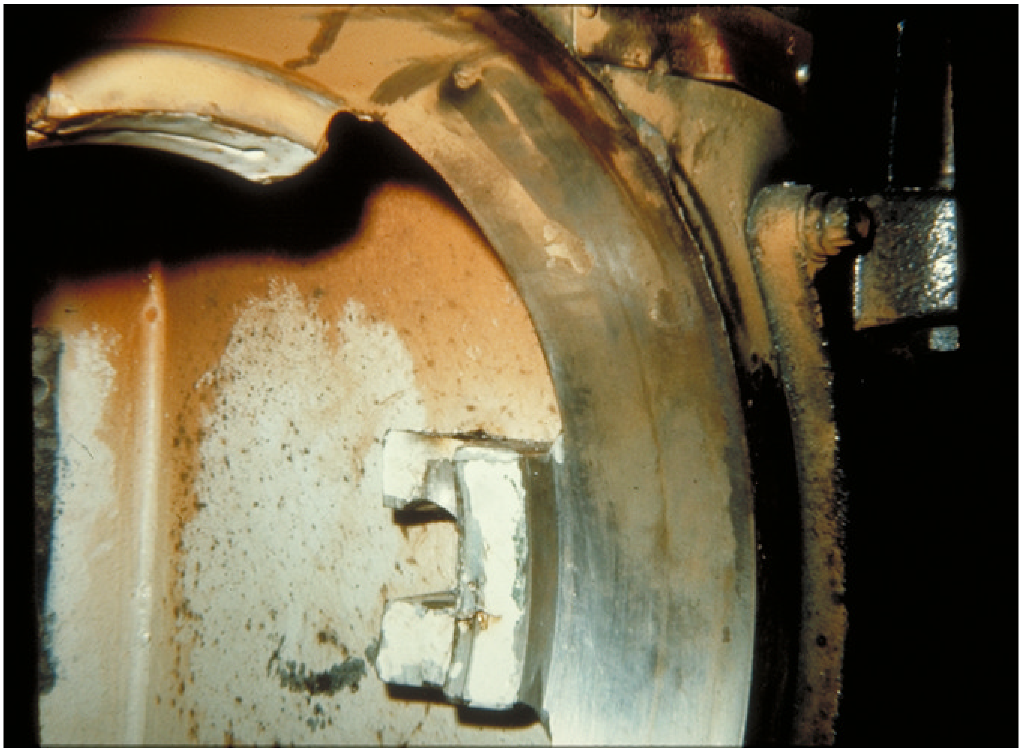
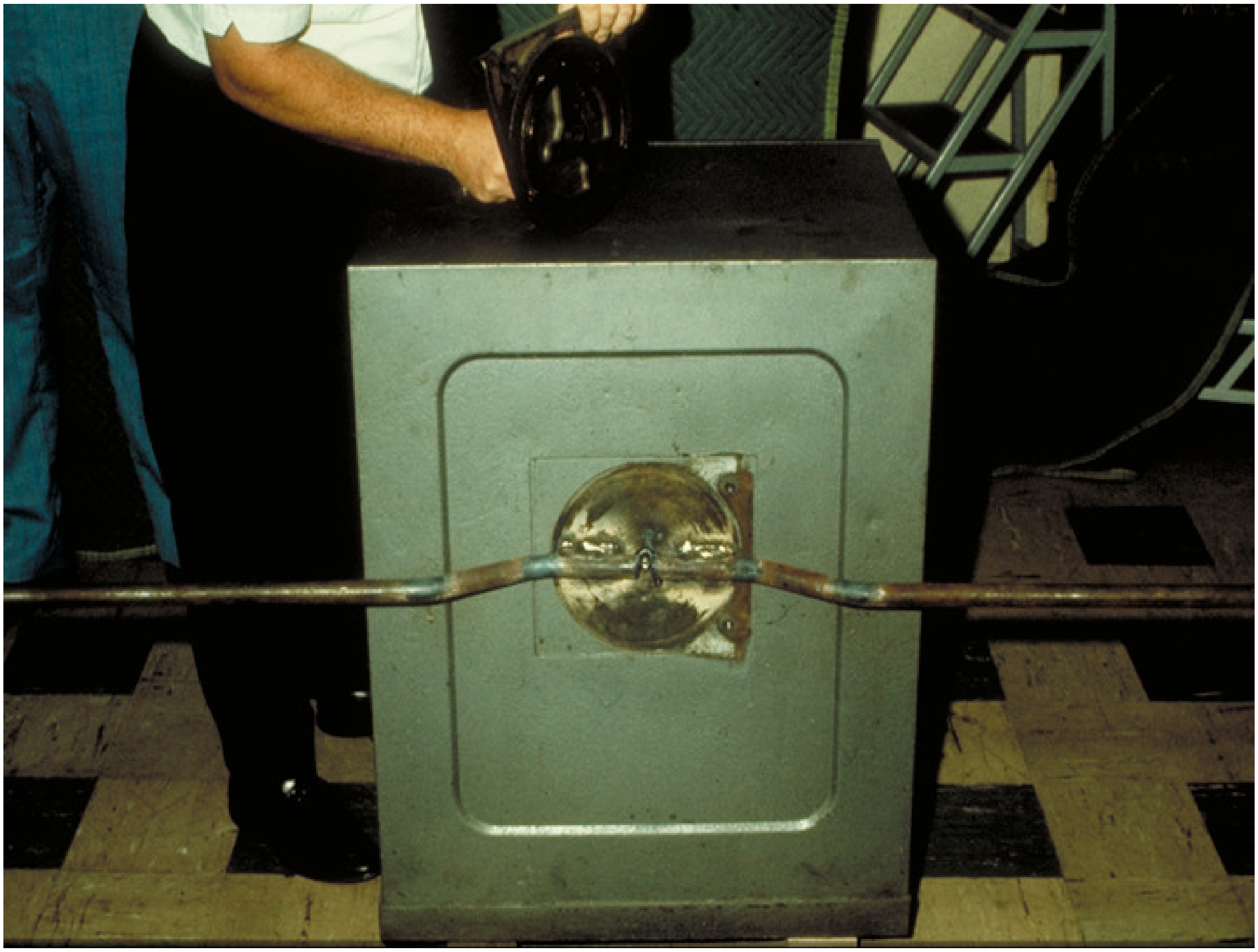




Figure LSS+3515, (ISP 38-3563 left, and 39-3563 right). The results of a pounding of components.





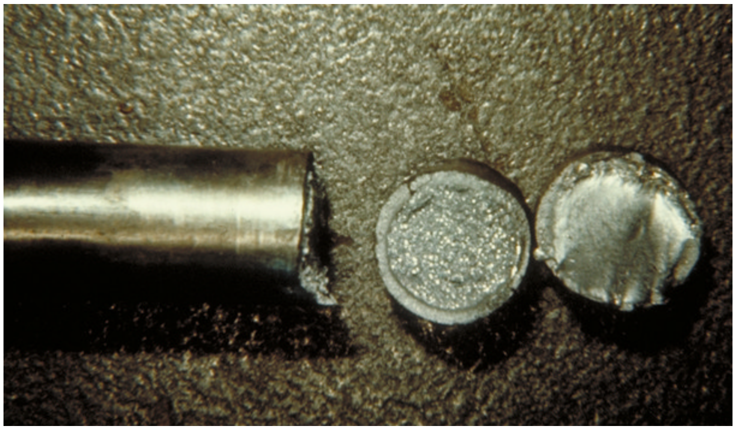




Figure LSS+3516, (top, ISP 40-3563, left, ISP 41-3563, middle, ISP 42-3563, and right, 43-3563). In this attack, the bolts were sheared by causing severe shock waves through the use of the welded bar to the front of the door. This attack changed the design of the round door from hardened to soft bolts . Courtesy of Illinois State Police, Bill Sherlock.



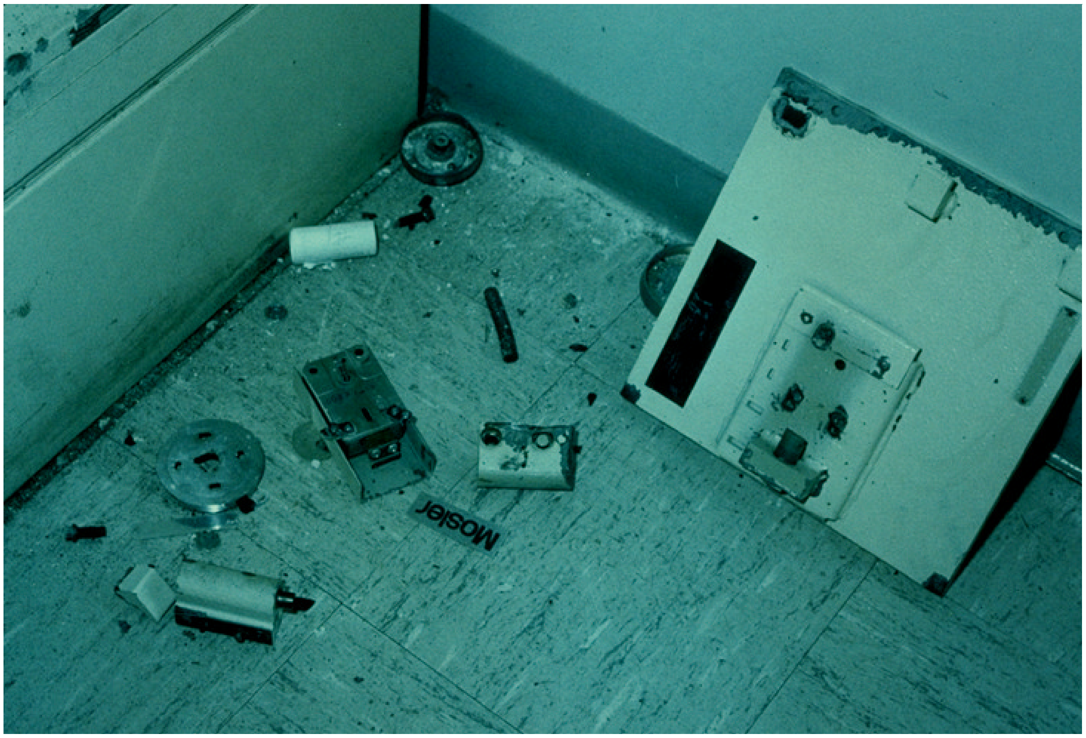


Figure LSS+3517. Another example of punching (left, ISP 47-3563, right 48-3563). Pressure was applied to the hinge side (47), all the welds were broken (48).


Mosler

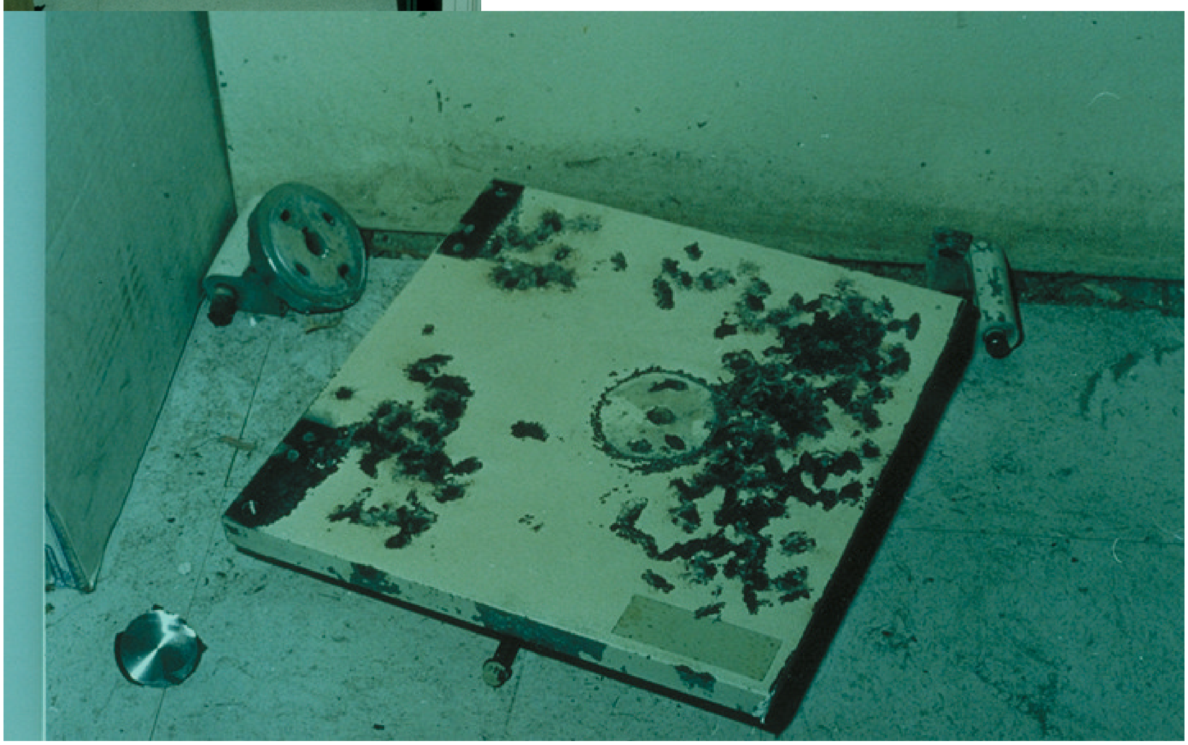




Figure LSS+3518 (top left, ISP 44-3563, top right ISP 45-3563, and bottom ISP 46-3563). This was a pound attack in a pattern burglary in four locations having the same layout. The door was pounded (45) with many hits. The parts shown inside (46), including the door stop after the tack weld was broken.

35_4.2.2D Wedging






BANANAS



Figure LSS+3519, These photographs show an attack by the use of a wedge to pry apart and separate portions of the container. (top left ISP 51-3563, center 52, right 55, lower left, 54, right 53). Courtesy of Illinois State Police, Bill Sherlock.

35_4.2.3 Chopping

Chopping is an extremely primitive technique, applicable to older containers that are thin-walled or made of softer materials. An axe, sledgehammer, pick, or other sharp pointed heavy tool is used to deform metal plates and make holes in the top, sides, and bottom of the container. Often, metal sheets would pull away from rivets once struck.

Another popular technique, called the “can opener” features the

use of a sledgehammer and axe to break open a container. This procedure requires a great deal of force, noise, and time to accomplish. In response, manufacturers employed thicker metals and framing.

35_4.2.4 Hinges

In older containers, the destruction, removal, or shearing of hinges was a favorite method of attack. In many of the early doors, only one bolt was utilized. This practice was a natural way to compromise the enclosure. Manufacturers responded with multiple bolts linked to the primary locking system to prevent the technique from working.

35_4.2.5 Cutting, Sawing, and Grinding

Disc cutters, grinders, and hole saws can be utilized to penetrate containers, especially fire safes. Equally effective is the reciprocating saw, such as manufactured by Makita. High-speed grinders placed at the appropriate cutting angle and location will penetrate most containers. The exception is the Chubb Planet safe, constructed of an elastomer that is extremely resistant to grinding and drilling. As described elsewhere in this text, Chubb received a patent for their unique plastic fire and burglary-rated safe. Any attempt to burn through the material will result in the formation of a hard crust, creating an even wider barrier. Attempts to cut the barrier will wear a disc in about fifteen seconds once the aloxite layer is reached.



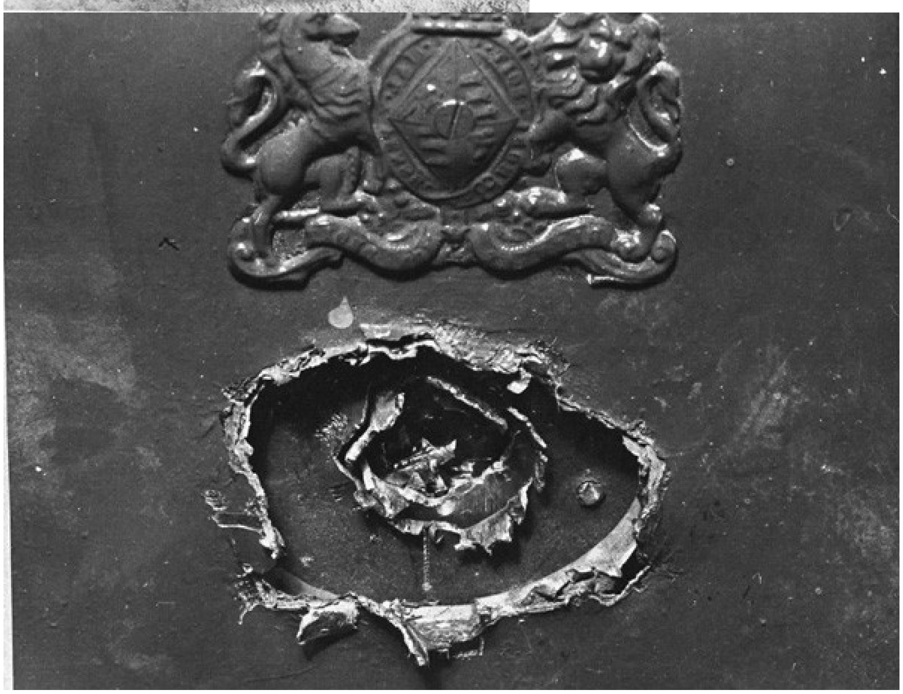


**Figure LSS+3520, examples of cutting. In the photograph (left), the top of the safe was cut
into to provide access to the bolt works. Shown (right) is a cold chisel attack.**

35_4.2.6 Use of High Temperature

The application of high temperatures to defeat barrier materials was described in **Chapter 32.** The process involves the molecular alteration or destruction of metals and plastics with an electric arc, torch, thermic lance, or chemicals. This particular technique has become popular because of the availability of equipment, low skill level, ease of opening, and absence of noise. The prime target is usually the lock for obvious reasons.

The first documented use of heat to alter metals probably involved a process of reverse hardening or annealing. This technique was developed to remove the temper from a metal in order to make it softer. As detailed in **Chapter 5**, the process required the temperature to be raised and then quickly lowered. Safe makers utilized metals that were more resistant to heat and incorporated layers of copper to act as a conduit for high temperatures. In fire safes, concrete is effective in the dissipation of heat. If the safe technician is utilizing high temperature penetration, care should be taken to insure that tear gas is not incorporated within the container and that the internal temperature does exceed 350^{o}.

35_4.2.6.1 Blowpipes

In the nineteenth century, criminals developed a device known as a blowpipe. It was used for concentrating a gas flame directed at the face of a safe or vault. The resulting high temperatures could be used to penetrate one-inch-thick steel plate by drawing the temper from the material. A bellows directed and propelled the flow of gas to create a large hole in the barrier.

35_4.2.6.2 Blowtorch

The commercial production and sale of oxygen in 1886 by Brinks Oxygen Company created a new and efficient means for penetrating safes: the **blowtorch.** The theory underlying this new technique was based upon the principle that iron and steel will burn in an atmosphere of pure oxygen.



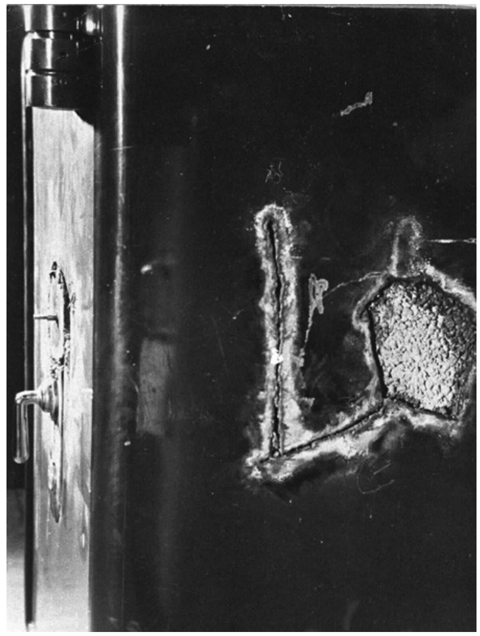




Figure LSS+3521 These photographs show attacks by torch. In the middle picture, an inept attempt to open the safe by cutting through the side. The burglar knew how to use a torch, but had no idea of where to cut. In the photograph (right), a torch attack on the lock box.





Figure LSS+3522. (Left), an attack using a torch where there was obviously no knowledge of where to cut. In the photo (right) the burglars burn and cut the bolt works. The parts are displayed.


FIRE RESIS
SAFE
RATNER
LONDON



Figure LSS+3523 Additional examples of the use of a torch. In the photographs, the lock box is burned out.

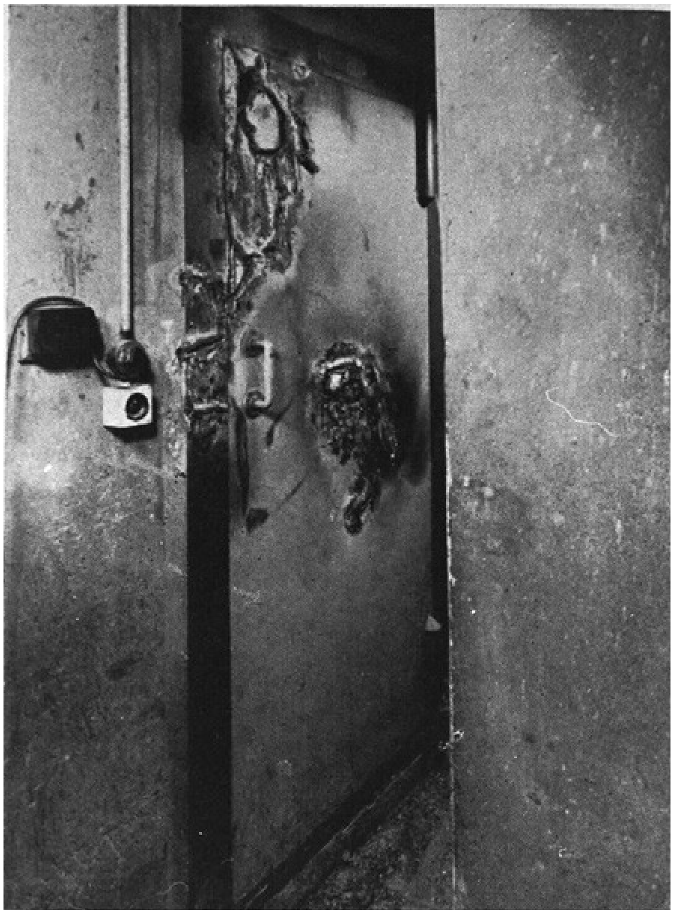




**Figure LSS+3524 (left) photograph showing lines scored by an oxyacetylene torch in
the outer shell of a Chubb safe. The burglars tried to cut the lock out of the middle
of the door. In the photograph (right), a close-up of an oxyacetylene attack of Chubb
safe which was not successful.**

In practice, the skin of the safe was preheated with a gas flame; a stream of oxygen was then forced through a steel tube or pipe onto the surface of the barrier material. The resulting combustion of the metal with oxygen would vaporize anything in its path. The use of oxygen to destroy the molecular structure of a metal would also form the basis for the development of the **thermic lance.**

By 1901, the **oxyacetylene torch** was available to cut metal and was being utilized for the penetration of vaults. It was employed in 1907 in Antwerp, during the burglary of a diamond merchant.





Figure LSS+3525, examples of torch attack. (left) incorrect tools were utilized on the side of the safe. This accomplished nothing. (right) a suspicious burn on the spindle, indicating perhaps an inside job.


CHUBB





Figure LSS+3526, attack by torch that did not result in an opening. Center photograph (ISP 59-3563) involved a torch attack where several million dollars of goods were stolen. A diagram of the theft is presented to show the detail that went into this crime (ISP 58-3563). In the right photograph (57) a typical oxyacetylene rig is shown.

Acetylene, however, was unstable under pressure. In order to make the gas safe to handle, it was dissolved in acetone and the mixture absorbed into kapok or charcoal within a pressurized cylinder.

Today, the oxyacetylene torch is relatively safe to use in the hands of a trained operator. The flame will burn at temperatures between 4,000° F and 5,000° F, and can be utilized to open most of the older safes.





**Figure LSS+3527, (left) a torch attack where burglars cut a portion from the door
for access, and (right) where part of the skin was removed to access the bolt mechanism.**














Figure LSS+3528, Examples of attack by oxyacetylene. Photo ID: top left ISP-61-3563, right, 62; middle row left 63, center 64, right 65; bottom left 67, right 68. Photos 61-66 show that the burglars had a competent knowledge of their tools, but no knowledge as to what to do with them. In 67 and 68, the burglars did not understand how to use their tools and had no knowledge of the container that they were attacking. Courtesy of Illinois State Police, Bill Sherlock.

35_4.2.6.3 Thermite

Thermite is a solid fuel developed in Germany for use in welding. It is a mixture of aluminum and iron oxide, toluene, and sulfur, and is ignited from the high temperatures generated from a burning strip of magnesium. As thermite burns, it feeds itself by producing oxygen. This maintains a very high temperature flame that is capable of melting steel.

The chemical is highly desirable for safe and vault penetration because it is portable, burns rapidly, and is silent. Once a reaction begins, it cannot be stopped until all of the fuel is spent. Thermite has been utilized for covert operations where its special characteristics can be of value.

35_4.2.6.4 Thermic Lance

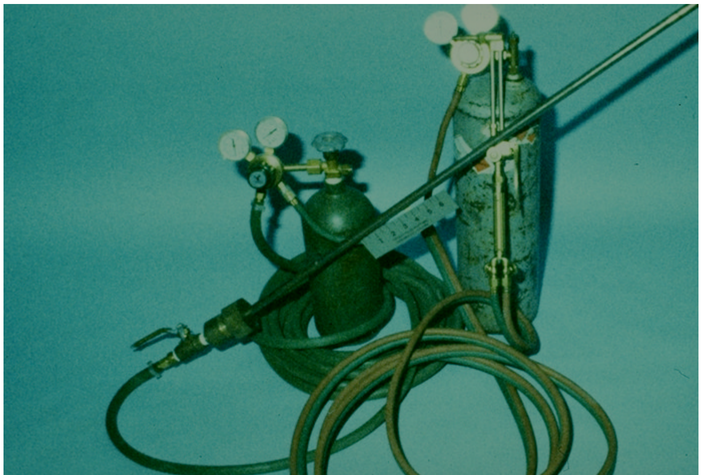








Figure LSS+3529. The thermic lance develops high temperature and can be utilized virtually anywhere. In the above photographs, the destructive power of this technology is shown. Photo ID: top left ISP 72-3563, right 73, bottom left 74, bottom right 75. In photograph 72, an older version of the lance is shown. Today, Broco produces this product in a small configuration that can be carried in a briefcase. Courtesy of Illinois State Police, Bill Sherlock.

The thermic lance or burning bar is discussed in detail in **Chapters 5** and **32.** Today, it does not have much application in safe work, although in difficult situations it can be invaluable and is often the only viable means for penetration. The use of the lance should be considered when it is not possible to drill through the top or sides of a high-security container, or there is not sufficient data available to formulate drill points.

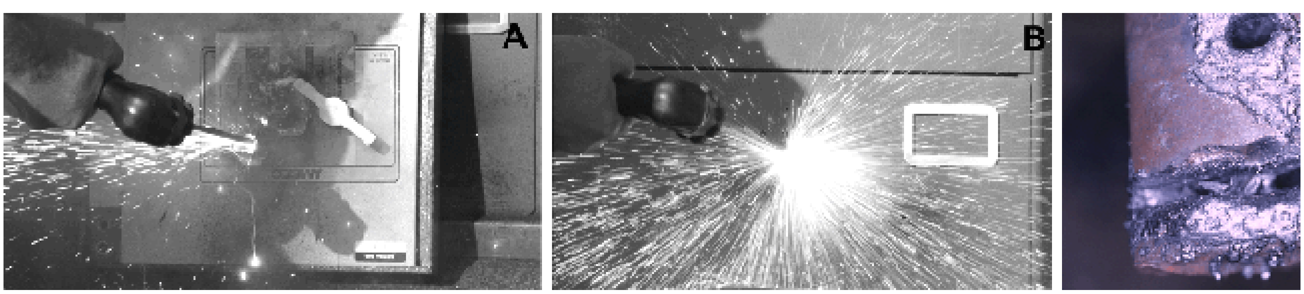




Figure LSS+3530 (ISP-76-3563) An example of a safe attacked with a thermic lance.

The cost of expensive drill bits must always be evaluated especially when doors are particularly thick. If time is a critical factor, these devices can expedite an opening.

The lance was developed in England around 1880, although it did not find widespread use by burglars until the next century. The original burning bar was a cumbersome device, measuring up to ten feet in length. It was awkward and dangerous to handle and required a fair amount of room in order to be manipulated. It would burn for a maximum of about six minutes. Today, the thermic lance can be carried in a briefcase, is relatively safe, and easy to use. The original devices consisted of long metal tubes filled with steel, aluminum, and magnesium wire. The modern version utilizes 18″ rods that are ¼″ in diameter.

The principal operating theory of the lance is the same as the blowpipe. The target metal is brought to its burning temperature in an atmosphere of pure oxygen, which is fed under pressure. As the metal melts, it will act as a flux to accelerate the burning process. The lance is effective with virtually any material including iron, steel, concrete, and granite.

The equipment to construct a lance is simple and consists of oxygen and tubing made of iron, mild steel, wrought iron, or plastic. The tube is filled with metal filings or a thin bundle of rods, having a hollow oxygen channel in the center. In operation, the working tip is heated, using a torch or spark to ignite the oxygen flow. The rod is then forced into the target material until penetration is completed.

The principal value of the thermic lance is its ability to penetrate thick barrier materials within seconds or hours, rather than days. It can be an extremely effective tool against a strong vault door, although a great deal of heat, smoke, and sparks are generated. The lance burns rapidly, requiring long fuel rods for lengthy burns. Generally, an 18" rod will provide a forty-five second burn, or enough to cut 1" of steel for each inch of rod. Temperatures as high as 10,000° F can be produced almost instantly, vaporizing any material. This means that a ¼" thick hard plate can be penetrated in less than five seconds; 3" cast manganese in forty-five seconds, and almost a foot of concrete in less than three minutes.

The lance has seen spectacular success in high-profile crimes, especially in the 1960s and 1970s. In 1965, there was a successful burglary in Knightsbridge, West London. After two minutes, almost two million dollars (one million pounds) was stolen from a safe in Lloyds bank. Then, in 1976, a bank safe-deposit vault was hit in Nice, France, after the burglars had tunneled for seven weeks. The holiday weekend burglary netted millions of dollars worth of valuables.

If a thermic lance is to be used, certain precautions and operating procedures must be observed. Thus:

- **Avoid excessive oxygen pressure that can cause blow-back of molten material, fire hazard, and injury;**
- **There should be no combustible materials in the area of use;**
- **Verify that the materials being consumed during**

burning are not toxic;
- **Insure that there is adequate ventilation;**
- **Do not make more than a five-second burn, and inspect after every burn;**
- **Concentration of heat is intense and focused; thus, there is little danger to surrounding areas;**
- **Relockers will rarely be fired by the use of a lance;**
- **Conventional drilling should be accomplished to the hard plate prior to the use of the lance;**
- **Experience and practice are required for effective penetration;**
- **Protective clothing, gloves, face and eye covering is required;**
- **A gas mask should be utilized;**
- **Smoke detectors should be covered or disabled during use;**
- **Have a fire extinguisher available;**
- **Use a flame and heat-retardant drop cloth;**
- **Never use a lance in the presence of explosives;**
- **No spectators should be present;**
- **Know the contents of any container before penetrating it;**
- **Never penetrate the lock case with a lance.**

The Broco thermic lance that was developed by Brower has received several U.S. Patents (**4182947(401), 4069407(402)**). It is probably the best known in the industry. It is more thoroughly described in **Chapter 32.** The "**Prime Cut**" will cut virtually any material at twice the temperatures of oxyacetylene. Although the technique does not produce a fine cut, it can vaporize anything in its path.

The only required equipment is oxygen and a regulator, the torch valve and rod-holding device, power connector, and cutting rod. A 12-volt battery is used for ignition of the oxygen. A ¼" rod will require from 20-65 P.S.I. of gas, and a regulator with a 1200 CFH rating. An average small oxygen cylinder will hold 55 cubic feet. At 40 P.S.I., 4 Cubic feet is burned for each 18" rod. See the detailed instruction manual for the **Broco Prime Cut.**

35_4.2.6.5 Electrical Burning and Cutting

During the early twentieth century, burning techniques utilizing electric arcs became prevalent. Today, wire welders and cutters can penetrate virtually any material through the application of an arc created by a high electric potential. There are several different cutting technologies, including tungsten inert gas (TIG), magnesium inert gas (MIG), plasma arc, and oxygen plasma. Because of the precise cutting capabilities of plasma technology, it is described in detail here.

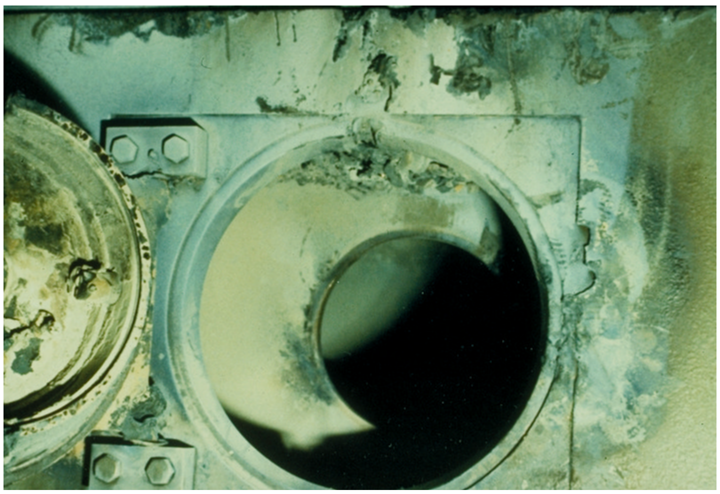
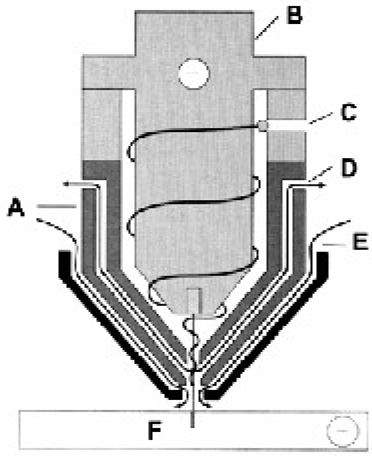
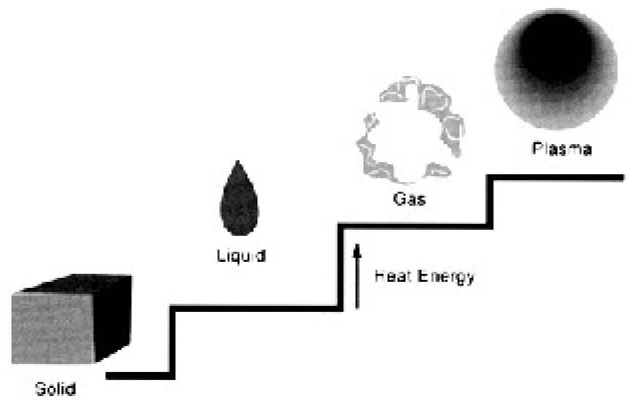


Figure LSS+3531 An example of arc welding with cutting rods. Photo ID: ISP 70-3563.

35_4.2.6.5.1 Plasma Torch

Plasma cutting utilizes high temperature ionized gas. It is created with an electric potential and is used for melting and cutting electrically conductive metals. A controlled nozzle opening is required to constrict and direct the flow of oxygen, nitrogen, or other gas. The device generally has an electrode of tungsten and uses an inert ionized gas such as argon to create plasma around the cutting tip. The torch can allow precision cutting but requires that the material be electrically grounded. Two leading companies that produce plasma torches are Hypertherm (Hanover, NH) and Thermal Dynamics (W. Lebanon, NH).





Exploded view 1, 2.

35_4.2.6.5.1.1 A History of Plasma Cutting

In 1941, World War II created a requirement for a process to bond light metals for the production of airplanes; electric arc welding was thus developed. The new process relied upon an electric arc to melt metals, an inert gas to form a shield around the arc, and the pool of molten metal to displace air. This was known as TIG, argonarc, or heliarc, because argon or helium was employed as the inert gas. At the time, the process was a perfect solution for precision welding and is today referred to as **GTAW**, or gas tungsten arc welding.

Plasma cutting technology began to mature about 1950 with the introduction of TIG welding. Shortly thereafter, scientists at Union Carbide made a significant discovery. They realized that if they reduced the nozzle opening that formed part of the TIG electrode (cathode) for the inert gas and it was electrically active with the work surface (anode), then the properties of the arc could be altered. In essence, the gas flow and arc were constricted. This increased its speed and heat dramatically. Rather than bonding, the plasma jet was now cutting the material.

Then, in 1957, conventional plasma arc cutting using “dry” arc constriction techniques was developed. This allowed the rapid cutting of virtually any metal. In 1965, water was substituted as the shield gas, and three years later water was used to increase arc constriction. Subsequently, advancements allowed underwater cutting as well as oxygen plasma cutting. In 1985, oxygen-injected cutting, using nitrogen as the plasma gas was introduced. Then, deep-water cutting and high-density cutting

that rivaled laser cuts became available.

35_4.2.6.5.1.2 The Physics and Chemistry of Plasma Cutting

There are three traditional states of matter: **solid**, **liquid**, and **gas**; **plasma** is described as the fourth state. Water, for example, is ice, liquid, or steam. The differences in states relate to energy level. The addition of energy as heat will cause a change in state. Thus, ice becomes water that changes to steam, which is actually hydrogen and oxygen gas. If additional energy is added to a gas, then its electrical and temperature characteristics are altered through **ionization**. This is actually the product of free electrons and ions within the gas atoms. The gas, now in the form of plasma, can conduct electrons or electricity.

Plasma and metals share certain common transmission characteristics based upon Ohm's law, and the relationship between voltage (E), current (I), and resistance (R) (I=E/R). Thus, if the conduction area of a metal is reduced, the resistance increases. When this occurs, a higher voltage (EMF) is required to force the same number of electrons across the transmission path. This will create heat through resistance.

Plasma gas follows the same laws. For example, if the plasma is moderately constricted by the nozzle being reduced in diameter, it can operate at twice the voltage. This will produce a much hotter plasma arc than in the equivalent TIG arc. The energy density that a plasma torch produces can be calculated in amps per square inch. This formula is based upon the ratio of current flowing through the nozzle, to the effective area of the orifice through which it passes. Conventional systems that utilize nitrogen, for example, have an energy range of 12,000 - 20,000 amps per square inch.

35_4.2.6.5.1.2.1 Flow of Electrons and Jet Characteristics

Plasma operates in both **transferred** and **non-transferred** modes. In the transferred mode, current flows between the torch electrode (cathode) and workpiece (anode). In the non-transferred mode, the current flows between the electrode and torch nozzle. Transferred mode is generally used in cutting because the heat transfer to the workpiece is greater. The gas type affects the plasma jet, flow rate, arc current, voltage, and nozzle size. These characteristics will determine whether the gas is used for

welding or cutting.

35_4.2.6.5.1.3 High-Density Plasma Cutting

This technology was developed in 1990 to compete with laser devices. The systems have the capability to produce cuts of high quality and accuracy, rivaling that of the laser but at a much lower price. Oxygen and nitrogen systems can cut carbon steels, aluminum, and stainless steels from 3/8" to 1 1/4", with high precision and a cut edge angle of 1-4° off square. For additional information, see **hypertherm.com**.

35_4.2.6.5.2 Laser Cutting

Commercial laser devices are now available that offer precision cutting and penetration to .005". These instruments, however, are not yet suitable for safe and vault work because of lack of portability. They are primarily designed for a factory environment where there exists sufficient operating space, control facilities, and power. Lasers are being utilized by a number of high-security safe manufacturers to produce extremely close tolerance joints between doors and safe bodies.

35_4.2.6.6 Temperature Extremes

The application of extremes in temperature has been effectively employed for opening certain types of containers. The prime example was the cannonball, which had particular appeal for burglars wishing to bypass these extremely secure safes. In this case, the procedure required that the circumference of the door be superheated. Cold water was poured on the metal, which would cause it to harden. Then, a hatchet was driven into the groove that existed around the door. When struck with a heavy hammer, the door would break open.

35_4.2.7 Using Explosives to Open Safes

LSS202: Steve Mattoon on the use of explosives to gain entry.

The application of explosives by criminals to open safes and vaults was natural and obvious and occurred fairly soon after their introduction and availability. Explosives can exist in many forms; they are based upon simple to complex chemistry. These special chemicals would be employed to penetrate locks and the security containers to which they were affixed. Their use can be

particularly attractive, because they can provide the capability to penetrate barrier materials that are 4” thick.

During the nineteenth century, many techniques were developed to open safes. As expected, explosives would become the preferred method of the safecracker, especially in England and somewhat later in America. The primary explosives were gunpowder, dynamite, nitro, and gelignite. Today, although nitroglycerine is still used, C4 plastic is preferred.

There was a constant and furious technological battle between the safe manufacturers and safecrackers, from which design innovations and improvements occurred. The use of explosives by burglars led to implementation of the following features:

- **Development, refinement, and implementation of the chemistry and metallurgy of hardened steel and special barrier materials;**
- **Changes in bolt and lock design;**
- **Introduction of time locks and combination locks;**
- **Design of secure joints;**
- **Welding and banding techniques;**
- **Use of laminates;**
- **Stronger boxes which could withstand explosive forces.**

Manufacturers soon realized that safes made of steel less than ¼” thick were ineffective against explosives; they could not resist the pressures and ripping forces created in a blast. Early safe attacks utilizing gunpowder were crude. They generally involved placing bags of the material next to the doors to cause sufficient distortion upon detonation to allow opening by a long lever. When Nobel made dynamite safe to handle through the addition of nitroglycerine, safe burglars shortly thereafter discovered how to extract that same chemical from dynamite.

Nitro was very useful to safecrackers, because its explosive force was concentrated in a very small quantity of chemical. They also learned how to create their own mixtures with nitric and sulfuric acid and glycerine. Preferred over nitro, dynamite became a favorite and powerful tool of the safecracker. This was because dynamite was solid, fairly stable, and safe to handle.



Figure LSS+3532, a free-standing Chubb safe was attacked with explosives. The violence of the blast blew the mounting plate away from the lock.

Explosives are not as popular today among the modern safecracker as in times past. This is in part because of the noise created, time involved, potential danger inherent in their use, as well as increased criminal penalties. Notwithstanding their limited acceptance, many safes are opened in this fashion. Interestingly, a recent series of safe burglaries in the United States involved a technique developed over a century ago. Holes were first drilled in the top of the safe and then the container is filled completely with water. Blasting caps were dropped through the holes. When the explosive is detonated, the safe will be opened without damage to the contents, because the water has no place to go.



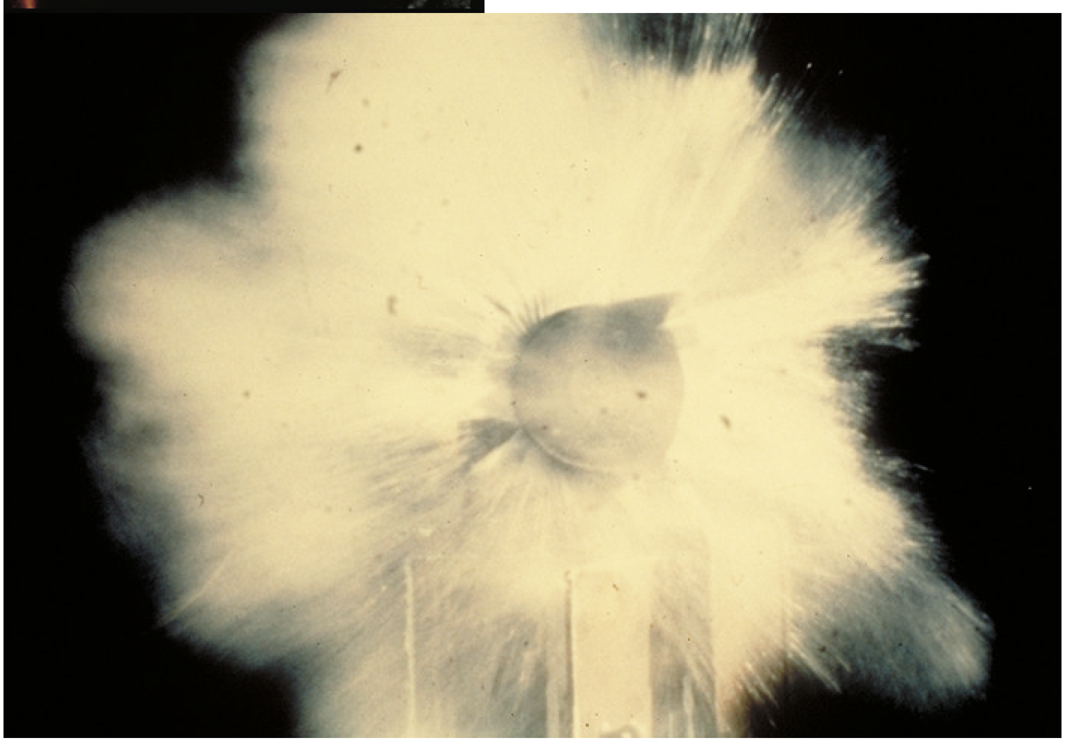




Figure LSS+3533 (Top left, ISP 29-2963, right 28-2963; bottom 26-2963). A safe was open with explosives, after being filled with water.

Many different kinds of explosives are available today, identified by their ability to create pressures and expansion of gasses. These are summarized below. Gunpowder, guncotton, nitroglycerine, gelignite, and the modern, sophisticated castable high- explosive materials, such as C4 putty, Flexible intershape, PETN, RDX, QUADREX, TRIEX, Detasheet (by Dupont, a flexible explosive) and TNT, have different potential for causing destruction. These materials will easily blast through 3/4" or thicker steel plate when properly applied.

Explosives are rated in terms of their measure of violence,

computed by the volume and speed of gas produced and displaced by a specific quantity of material. A high explosive will produce gas more quickly than a low explosive.

NAME	ALTERNATE NAME	COLOR	MAJOR USES	REMARKS
LOW EXPLOSIVES				
Black Powder	Schwarzpulver	gray to black; cocoa brown to black	safety (time) fuse; reloading (time) fuse	Very sensitive to friction, heat, a
Smokeless Powder	nitrocellulose	light brown to black	small arms, mortars, rockets, reloading of small arms	Very sensitive to friction, head, a shock. Normally deflagrates and a low explosive; wh initiated by a bl cap, may detonate as a high explosi
PRIMARY EXPLOSIVES				
DDNP	di-azodinitrophenol; dinol; diazol	greenish yellow to brown	detonators, priming compositions	Very sensitive to friction, heat, a shock. Has largel replaced mercury fulminate in blas caps
lead azide	lead hydronitride	white to buff to gray	detonators, priming compositions	Very sensitive to shock, and fricti
lead styphnate	lead tri-nitroresorcinate; trizinate	light orange to reddish brown	priming compositions	Very sensitive to shock, and fricti Relatively poor i in comparison wit primary explosive
mercury fulminate	fulminate of mercury; mercuric fulminate	white to gray or light brown	detonators, priming compositions	Very sensitive to shock, and fricti Largely replaced azide. Should be moist until used.
tetracene	-	pale yellow	detonators, priming compositions	Sensitive to shoc heat. Not efficie initiating high explosives; used sensitizer with c high explosives. used alone.

SECONDARY EXPLOSIVES				
amatol	-	buff to yellow to dark brown	main charge for bombs, projectiles	Developed during to conserve limi supplies of TNT.
ammonal	-	gray	projectile filler	Similar in compos Minol.
ammonium nitrate	-	white; my be dyed other colors	ingredient of explosive mixtures, dynamites; also used in fertilizer	Very insensitive shock. Must be ke Must not be worke tools of brass o
ammonium picrate	ammonium trinitrophenolat e, dunnite, Explosive D	yellow to orange to red	armor piercing projectiles and bombs; organic fule in composite propellants	Relatively insens shock and frictic Moisture reduces sensitivity to initiation.
Astrolite	(a) Astro-Pak (b) Saf-T-Pak	-	demolition	Two components a until mixed. Do r with tetryl boost to possibility o spontaneous igni
Composition A-3	-	white to buff	projectile and shaped charge filler	-
Composition B	see cyclotol	-	-	-
Composition C-3	plasitite	yellow to brown	plastic demolition explosive	Putty-like materi stains the hands used underwater. explode if burned large quantities
Composition C-4	Harrisite	white to light brown	plastic demolition explosive	Putty-like materi sensitive to impa slightly more bri than Composition be used underwate
cyclotol	tritolite, Composition B	buff to yellow to brown	fragmentation bombs; projectiles; grenades; bursting charges	Excellent for bla effects.
Explosive D	see ammonium picrate	-	see ammonium picrate	-

Flex-X	Detasheet, sheet explosive	olive-drab ; red, may be dyed any color commercial ly	cutting charges for irregular or curved surfaces	Flexible, easily very insensitive shock.
Go-4	-	tan	fracturing oil and gas well formations	-
HBX-1, HBX-2, HBX-3	HBX (= high blast explosive); Torpex-3	gray	main charge filler for underwater bombs and torpedos	Excellent for bla effects. When desensitizer is a Torpex, the U.S. the product HBX, British retain th Torpex.
HMX	cyclotetra- methylene- tetranitramine, homocyclonite	white	(a) used alone or (b) mixed with TNT or octol to form explosive filler for high blast warheads	By-product of RDX manufacture.
Kinepak	-	powder is white, liquid is pink	demolition	Two components ar until mixed.
Minol-1, Minol-2, Minol-3	-	gray	filler for bombs and depth charges	An ammonal contai less TNT and more ammonium nitrate aluminum; compara TNT in sensitivit initiation.
nitrocellulos e	cellulose nitrate, NC, guncontton, nitrocotton	white	blasting explosives, smokeless powder, propellants	Mixed with nitrog to form flashless
nitroglycerin e	glyceryl trinitrate, NG, blasting oil	thick pale yellow liquid	propellant ingredient, demolition ingredient, dynamite ingredient	Patente by A. Nob 1864. Liquid is r absorbed through inhaled vapors ca severe headache.

nitroguanidine	picrite	white to yellow	propellant composition ingredient, bursting charge ingredient	One of the least sensitive militai explosives.
nitrostarch	starch nitrate, grenite	white	bursting explosive, mortar shells, grenades	Another form of nitrocellulose.
octol	-	buff	projectile and bomb filler	Excellent for bla effects.
pentolite	pentritol (when 8 percent wax is added)	white to yellow to gray	shaped charges, demolition blocks, boosters	Presence of rust increases impact sensitivity.
PETN	pentaerythritol tetranitrate, penta, pentrit	white, sometimes dyed green	detonating cord, blasting caps, priming compositions, boosters	Presence of rust increases impact sensitivity.
picratol	-	yellow to brownish yellow	armor piercing projectiles and bombs	As insensitive to initiation as Exp D.
picric acid	melinite, lyddite, pertite	light yellow to lemon yellow, yellow red	used in manufacture of Explosive D	Stains skin.
RDX	cyclotromethylene trinitramine, cyclonite	white, may be died pink	detonating cord, blasting cap base charge, projectile and bomb filler ingredient, ingredient in Composition A and Composition B	Used on large sca explosive ammunit WWII.
tetryl	tetralite, pyronite, CE	yellow	boosters, blasting caps, ingredient of explosive mixtures	Causes dermatitis skin reddish brow Colorless when fr prepared and pure acquires to yello when exposed to l Addition of graph during loading ca to turn gray.

tetryl	tetratol	buff to light yellow	bursters, demolition blocks	Ranks between tet TNT in sensitivit heat and initiati
TNT	trinitrotoluene, trotyl, tolite, triol, triton, trilite	light yellow to brown or light gray	bombs, projectiles, demolition charges, grenades, propellant composition	Standard military explosive against others are measu
Torpex	TPX	gray	depth charges bombs, warheads, mines	Excellent for bla effect.
Tritonal	-	silver gray	bombs	More powerful anc sensitive to shoc TNT.

Figure LSS+3503 Table of explosives

35_4.2.7.1 Gunpowder

Gunpowder was a mixture of charcoal, saltpeter, and sulfur, and was developed around the thirteenth century by the Chinese. It would remain the primary propellant and explosive for the next six hundred years. It appears that it was first used for the penetration of containers in the seventeenth century in Hungary.

The early use of gunpowder was crude and imprecise. Bellman (users of explosives), boxmen, or petermen (safecrackers) developed a popular method of attack that involved **blowing powder** into the keyhole of the lock so that drilling would not be required. English safe makers combated this procedure by covering the cavity created by the keyhole with wood. Later, the use of the keyless combination lock frustrated this method of attack.

Another technique was known as the "puff and rod." It required drilling into the casing of the cast iron or mild steel box, then applying a bellows to blow a charge of gunpowder into the safe. The introduction of hardened steel ended this practice.

35_4.2.7.2 Guncotton

This substance was very popular for blowing safes. It was a combination of nitric acid, sulfuric acid, and glycerine impregnated into cotton cloth. A German chemist named Schonbein

invented the mixture when he spilled nitric and sulfuric acid in his kitchen. After using a cotton apron as a mop to clean up the chemicals, he set the wet cloth on the stove to dry. It blew up! As early as 1846, guncotton was used in simple blasting.

35_4.2.7.3 Nitroglycerine

In 1846, Sobrero, an Italian, created liquid glyceryl trinitrate. This mixture, known as **nitro**, was the first high explosive. **Grease** (as it was called) could be produced by placing dynamite in a sack and compressing it, so that an oily yellow liquid would ooze through the fabric. It was used by safecrackers in a concentrated form to blow safes.

Nitroglycerine was a versatile tool of penetration and provided many options for forced-entry of safes and vaults. For example, it could be used to blow a lock (known as **gunshot** or **spindle shot**) by dripping the substance into the lock after the dial had been removed and the safe was laid on its back. A similar technique (the **rag shot**) required that a small hole be bored directly above the dial. A rag was saturated with nitro, pushed into the hole, and sealed with laundry soap.

The material could also be contained within moldable material such as fels naphtha and fashioned like a funnel. This particular substance is very malleable, yet it will not permit the nitro to leak through it. A soap cup dam would be located on the center of the door after the safe had been placed on its back. Known as the "**space shot**," this technique would "dish the door," or cause a deformation of the barrier metal. Finally, the chemical could be seeped into the crack around the edge of the door (**jamb shot**). If done correctly, this would cause the door to blow open, still remaining on its hinges.

35_4.2.7.4 Dynamite

In 1867, Nobel turned nitro into dynamite. **Guhr** dynamite was a mixture of nitro and kieselguhr (diatomaceous earth) that was produced as a solid. It was completely safe to handle. Dependable control of the explosive reaction was achieved when Nobel utilized gunpowder and mercury fulminate to apply a shock rather than a flame to the charge. Because of the work of the Nobel family, dynamite would be the primary explosive until the middle of the twentieth century. Ironically, explosives directly or indirectly killed two of the Nobel family members.

35_4.2.7.5 Gelignite

This material was developed at the end of the nineteenth century and would be popular for about thirty years. It was a mixture of guncotton and nitro, and formed a blasting gelatin resembling Jell-O. Gelignite could be configured in putty-like blocks, cut into pieces, and formed in any required shape. The chemical was stable and powerful.

This material was popular for use in blowing locks and bolt works. When gelignite was utilized, it would be forced into the lock and held in place by plasticine, soap, or modeling clay. It could also be contained in a balloon or condom. The detonator was placed around the substance.

In some cases, two holes were drilled next to the locking bars. A balloon filled with gelignite would be inserted into the body of the safe so that it would hang over the boltwork. Opening then became a simple task.

35_4.2.7.6 Castable High Explosives

Today, sophisticated explosives are available that can be shaped and precisely controlled with respect to the energy they produce. These are known as **castable** high explosives, as noted in **4.2.7** above. They are mainly used for emergency entry operations rather than safe and vault penetration. Resources for explosives include Explosive Technology (Fairfield, California), Jet Research (Arlington, Texas), and Dupont. Barret (Australia) makes a bomb bag to contain explosives that are found at a crime scene, for detonation.

35_4.2.7.7 Definition of Conventional Explosives

The following definitions apply to conventional explosives, and were obtained from the United States Defense Threat Reduction Agency. They were cited in the ***Weapons of Mass Destruction Terms Handbook.*** *There are several federal statutes dealing with explosives:* ***18 USC 2332a Weapons of mas destruction; 18 USC 921 Destructive Devices;(403) 18 USC 831 Explosives and Other Dangerous Articles.(404)***

Ammonia Dynamite

A portion of the nitroglycerine content is replaced by ammonium nitrate in ammonia dynamite. It is lower in cost and less sensitive to shock and friction than straight dynamite. It is probably the most widely used explosive of the dynamite family.

Ammonia-gelatin dynamite

This dynamite retains most of the characteristics and qualities of gelatin dynamite, but derive a portion of their strength from the use of less costly ammonium nitrate.

Ammonium nitrate

Ammonium nitrate is one of the least sensitive and most readily available main charge high explosives. It is usually found in the form of small compressed pellets called prills. It is used extensively as a blasting agent, by the military as a cratering charge, an ingredient in certain dynamites, and widely employed as a fertilizer. Its use as a commercial fertilizer makes ammonium nitrate readily accessible to anyone.

ANFO

While the grade of ammonium nitrate used as fertilizer is naturally inferior as an explosive charge, it can be sensitized by the addition of fuel oil. This mixture is referred to as "prills and oil" or ANFO, and its use is fairly widespread because of its low cost. Car or truck bombs using ANFO are large in size and lethal to structures at a considerable distance.

Black Powder

The typical composition of black powder is saltpeter (potassium nitrate) or sodium nitrate 75 parts by weight; sulfur 10 parts by weight; and charcoal, 15 parts by weight. The form may range from a very fine powder to granules over ½ inch in diameter. The burning speed of black powder is controlled by the size of the granulation. Large grains of powder burn more slowly than fine grains.

Blast effects

When a high explosive detonates, the solid or liquid explosive material is converted into mostly gaseous product. These extremely hot gases expand immediately and compress the air

around the charge to form a blast wave. The strength of the shock at a given distance from the explosion is a function of the type explosive, the weight of explosive, and the distance from the point of detonation.

Blasting agents

A blasting agent is an insensitive chemical composition or mixture, consisting largely of ammonium nitrate, which will detonate when initiated by high explosive primers or boosters. Since they contain no nitroglycerine, blasting agents are relatively insensitive to shock, friction, and impact and are, therefore safer to handle and transport.

Blasting cap

A device used to initiate an explosive train. Commonly referred to as detonators, they contain primary explosives. May be either electrically or nonelectrically fired. Blasting caps are extremely sensitive and will explode unless handled carefully.

Blasting cap crimpers

Used to squeeze the shell of non-electric blasting caps around safety fuse or detonating cord to prevent separation.

Blasting machines

A device designed to deliver electric current directly into an explosive firing circuit. There are two types available: condenser discharge (DC) and generator. booster High-explosive boosters, also called Primer explosives, or simply primers, are explosives that provide the detonation link in the explosive train between the very sensitive primary explosives (blasting caps) an the comparatively insensitive main charge high explosives. It amplifies the detonation wave of the primary explosive.

Booster

High-explosive boosters, also called primer explosives, or simply primers, are explosives that provide the detonation link in the explosive train between the very sensitive primary explosives (blasting caps) and the comparatively insensitive main charge high explosives. It amplifies the detonation wave of the primary explosive.

Chemical bombs

Devices in which a chemical reaction takes place within a confined space, such as a bottle, the pressure is greatly increased. When the maximum pressure per square inch (p.s.i.) is exceeded, the container ruptures with enough force to shatter glass, destroy mailboxes, and split metal cans. The dangers come from fragmentation and burns to skin from the chemicals. The following are the most common types of chemical reaction bombs.

a. Acid Bomb. Common ingredients are hydrochloric acid and aluminum foil that chemically reacts to give off heat (exothermic), ultimately producing hydrogen gas and sufficient pressure to burst the container. Commercial sources for hydrochloric acid are toilet bowl cleaners (Sno Bowl or "The Works") and Etchant Solution (a commercially available solution for etching).

b. Caustic Bomb. Alkali based devices mixed with water and aluminum foil. The most common ingredient is sodium hydroxide (lye), a corrosive in both liquid and solid forms that can immediately cause serious burns to skin on contact. Commercial sources of sodium hydroxide are Drano toilet bowl cleaner and Red Devil Lye.

c. Dry Ice Bomb. When dry ice evaporates, carbon dioxide gas is released. It usually takes 30 to 45 minutes for enough pressure to build to rupture the container depending on the size. When detonation occurs before all the dry ice has evaporated, the remaining dry ice becomes fragments that can cause frost-bite when contacting skin tissue. It is inexpensive and easy to make powerful device.

Cluster bombs (CB)

The United States and Israel used U.S.-built cluster bombs in both Vietnam and Middle East respectively to suppress air defenses and destroy large-area targets. Since the 1960s, the U.S. has developed a wide variety of cluster bomb systems and warheads. To increase the rocket's accuracy when lofted or released from long range, the weapon can be fitted with a laser guidance seeker and a proximity fuse to initiate the release of the bomblets when the weapon nears the target. The U.S. Air Force has developed a series of laser-guided cluster bomb weapons. In addition to instantaneous-destruct antipersonnel or anti-armor

warheads, the cluster bomb's dispenser can release time-delay bomblets or special mines that can destroy trucks, armor, or personnel over a period of hours. The munitions dispenser can be fitted with either a laser guidance kit or television guidance seeker and fins for accurate long-range attacks.

Composition B

Designation for explosive material, also known as Hexolite or Hexotol, composed of a 60:40 mixture of RDX and TNT.

Composition C

Original British designation for plastic explosive; standardized by the U.S. with designations C-2, C-3, and C-4.

Deflagration

Rapid and powerful self-sustained burning of a propellant or explosive less than the speed of sound.

Det cord

Short for for detonating cord.

Detonating cord

A round, flexible cord generally containing a center core of an explosive such as RDX or PETN that is protected by a sheath of various textiles, waterproofing materials in the same manner as blasting caps. , or plastics. Detonating cord is used to detonate charges of high explosive in the same manner as blasting caps.

Detonation

A reaction within a solid or liquid explosive that uses the fuel and oxidizer in the compound to propagate a constant velocity reaction through the explosive charge, converting most of the explosive compound to hot gases.

Detonator

Sometimes used interchangeably with blasting cap. Fuze detonators or blasting caps, containing a primary explosive, are used to detonate main charges or secondary explosives in an explosive train. A detonator may be initiated either electrically or

nonelectrically. Another type of detonator is the exploding (or electronic) bridge wire.

Dynamite

Most commercial dynamites are made of liquid nitroglycerine, oxidizers, and binder material. All dynamites may be detonated using either electric or nonelectric blasting caps or detonating cord widely used for blasting operations throughout the world and frequently used by criminal . It is most bombers ammonia-gelatin dynamites. Also see straight, ammonia, gelatin and ammonia-gelatin dynamites.

Electric match

See squib.

Electroexplosive Device (EED)

An electrically initiated explosive device. It is susceptible to initiation from electromagnetic radiation.

EOD

See explosive ordnance disposal.

Explosion

A detonation resulting from a sudden release of energy. Explosives can be classified into three categories:

a. A mechanical explosion is illustrated by the failure of steam boiler or pressure cooker. As heat is applied to the water inside the pressure vessel, steam is generated and confined. If the container is not equipped with some type of safety valve, the mounting pressure will eventually reach a point at which it overcomes the structural or material resistance of the container, and an explosion will occur.

b. A chemical explosion is characterized by the rapid conversion of a solid or liquid explosive compound into hot gaseous compound having a much greater volume than the substances from which it is generated. The entire conversion process takes only a fraction of a second produces extremely high temperatures (several thousand degrees), and is accompanied by a shock wave and loud noise.

c. Nuclear explosion

Exploding (or electronic) bridge wire (EBW)

A detonator that contains no explosives. EBWs function by the rapid discharge of a high amperage charge causing the bridge wire to explode initiating the explosive train. EBWs are very safe to handle because they contain no explosives.

Explosive ordnance

All munitions containing explosives, nuclear fission, or fusion materials and biological and chemical agents. This ordnance includes bombs and warheads, guided and ballistic missiles; artillery, mortar rocket, and small arms ammunition. Also, ordnance includes all mines, torpedoes, and depth charges; pyrotechnics; clusters and dispensers; cartridges and propellant actuated devices; electroexplosive devices; clandestine and improvised explosive devices; and all similar or related items or components explosive in nature.

Explosive ordnance disposal (EOD)

The activity of neutralizing the hazards associated with ordnance and improvised explosive devices that present a threat to operations, installations, personnel, or material. EOD is carried by the U.S. military or other special units or personnel specially trained and equipped.

Explosive ordnance disposal procedures

Those particular courses or modes of action for access to, recovery, rendering safe, and final disposal of explosive ordnance or any hazardous material associated with explosive ordnance disposal:

a. Access Procedures. Those actions to locate exactly and to gain access to unexploded ordnance.

b. Recovery Procedures. Those actions to recover unexploded ordnance.

c. Render Safe Procedures. The portion of the explosive ordnance disposal procedures involving the application of special explosive ordnance disposal methods and tools to provide the interruption of functions or separation of essential components

of unexploded ordnance to prevent function as designed.

d. Final Disposal Procedures. The final disposal of explosive ordnance by explosive ord-nance disposal personnel, which may include demolition or burning in place, removal to a disposal area, or other appropriate means.

Explosive ordnance disposal unit

Military EOD personnel with special training and equipment who render explosive ordnance (such as bombs, mines, projectiles, and booby traps) safe, make intelligence reports on such ordnance, and supervise the safe removal thereof. EOD assistance outside DoD installations are normally the responsibility of civil authorities.

Explosive ordnance reconnaissance

Reconnaissance involving the investigation, detection, location, marking, initial identification, and reporting of suspected unexploded ordnance, by explosive ordnance reconnaissance agents, to determine further action.

Explosive train

A series of explosives arranged to produce a specific outcome, usually the most effective detonation or explosion of a particular explosive. For example, a three-stage explosive train consists of a detonator, booster and main charge.

Firing device

A device that causes the initiation of explosive charges either directly, or through its effect on a blasting cap, electric squib, or detonating cord. It may be electrical, mechanical, or electromechanical.

Flash bulbs

Although not explosive by nature, carefully prepared flash bulbs or light bulbs can be used as initiation devices when placed in contact with explosive materials that are sensitive to heat and flame. They can be initiated electrically to provide the necessary heat required to ignite black powder, smokeless powder, and other heat-sensitive explosive or incendiary mixtures.

F.P.S.

Short form for feet per second.

Fragmentation effects

If an explosive charge has a case, both fragmentation and blast effects will occur. Fragmentation can be the most destructive characteristic of a bomb. The concentrated power of a fragment can force penetration deeply into a target, tearing and shredding as it goes.

Fuel air explosives (FAE)

Fuel air explosives, a recent concept, dispense a cloud of fuel to form an explosive vapor. When the vapor density is distributed over the target area, time delay detonators are fired, creating a highly destructive shock wave. Fuel air explosives are three to five times more destructive than a similar weight of TNT. Late in the Vietnam War, the U.S. Navy and the Marine Corps employed CBU-55B fuel air explosive weapons in Vietnam for preparing helicopter landing zones and clearing mines.

Fuse

A continuous train of combustible substances enclosed in a standardized core for setting off explosives.

Fuse igniters

Used to apply sparks or flame to manufactured or improvised safety fuse.

Fuze

(Not be be confused with "fuse") A mechanical, electrical, or electro-mechanical device used to function an explosive device such as a bomb or projectile. In demolition work, a firing device may be termed a fuze.

Fuze train

One or more devices used to detonate the main charge. It consists of all parts of the explosive train up to but not including the main charge, plus any activating element such as a switch, timer, sensor, device etc. to initiate the explosive train.

Galvanometers

An electrical assembly for testing the electrical continuity of a firing circuit.

Gelatin dynamite

Gelatin dynamite contains a base of water resistant "gel" made by dissolving or colloiding nitrocotton with nitroglycerine. The gel varies from a thick viscous liquid to a tough rubbery substance. It is used extensively for blasting very hard tough rock or ore.

High explosive (HE)

An energetic material that detonates (instead of deflagrating or burning); the rate of advance of the reaction zone into the unreacted material exceeds the velocity of sound in the unreacted material.

HMX

Designation for a byproduct of RDX production, homocyclonite. This powerful high explosive is also known as octogen.

IED

Acronym for improvised explosive device See below.

IHE

Acronym for insensitive high explosive. See below.

Improvised explosive device (IED)

Any device that is fabricated in an improvised manner, incorporating explosives or destructive, lethal, noxious, pyrotechnic, or incendiary chemicals, designed to destroy, disfigure, distract, or harass.

Incendiary effect

The incendiary effect is usually seen as the bright flash or fireball at the instant of detonation. In general, a low explosive will produce a longer thermal effect than will a high explosive. High explosives produce much higher temperatures.

Insensitive high explosive (IHE) - Link to video

A high explosive that is specifically formulated to be less sensitive to shock and other stimuli that might be encountered in an accident; usually based on the compound TATB (triaminotrinitrobenzene); insensitive high explosives have lower energy densities than conventional high explosives, and thus more material is required to produce the same explosive energy.

Low explosive

Classification of explosives that deflagrate rather than detonate. Primarily used as propellants, low explosives may be initiated by a simple flame or acid/flame reaction, and do not require the shock of a blasting cap. Common examples include black powder and smokeless powder.

Match heads

A main charge consisting of ordinary match heads confined inside a steel pipe will produce an effective explosion. Bombs filled with match heads are extremely sensitive to heat, shock, and friction and should always be handled with care.

Misfire

The failure of a charge to explode in response to a proper initiation attempt. When the charge fires at some time later than intended, it may be referred to as a "hang fire."

Main charge

The ultimate object of detonation in an explosive train. Also referred to as bursting explosives, includes explosives such as Explosive D, amatol, TNT, tetryl, pentolite, picratol, tritonal, RDX compositions, Torpex, HBX, etc., (see table 4-3).

m/s

Short form for meters per second.

Nitroglycerine

The main explosive component of straight dynamite and is found in less concentrations in a number of other explosives. It is an

oily liquid about 1.6 times heavier than water and that will not mix with water. It may very in color from clear (pure) to amber (impure). In a pure state, it is very sensitive to heat, shock, and friction. Sensitivity is increased markedly by the application of heat.

PETN

Short form for pentaerythritol tetra-nitrate, a major component in U.S. C-4 plastic explosives.

Pipe bomb

A fragmentation device. Sections of pipe or pipe nipples are filled with explosive, or propellant (gun powder) and closed with end caps through which a fuze has been introduced. When the filler is ignited, the resultant explosion causes the pipe to fail and form fragments.

Plastic explosive

Plastic explosives are known by different names, including "plastique," "plastex," "plastico," and "composition." Plastic explosives consist of an explosive material, such as RDX or PETN (see table 4-3 for physical characteristics and uses), and a plasticizer component. The explosives are well suited to military applications as they are insensitive to rifle bullet impact and can be molded by hand for various applications. The are sensitive to initiation by a blasting cap and have great brisance, or shattering power. This is the explosive of choice for various international terrorist groups. Small quantities may be optimally placed to do maximum damage.

Percussion primer (impact)

Uses the shock of a firing pin or striker impacting to initiate the explosives contained in the primer.

Potassium/sodium chlorate

Potassium chlorate or sodium chlorate and sugar mixtures are widely used as incendiary and explosive materials. Though essentially incendiary compounds, these mixtures will explode when initiated in confinement.

Power

In relation to explosives, the term refers to relative end results. It takes into account such factors as brisance, detonation rate, cratering potential steel penetration capability, etc.

Primer

An explosive charge used in the intermediate (boost) process of an explosive train.

Primary explosive

Classification of explosives that are used as the first step (detonation) in an explosive chain. Primary explosives are initiated by shock, impact, heat, or heat-producing friction. Common examples include lead azide, lead styphnate, and mercury fulminate used in blasting caps.

RDT&E

Acronym for Research, Development, Test and Evaluation.

RDX

Original designation for "rapidly detonating explosive" or "research development explosive." Also used for the high explosive cyclonite.

Render safe procedure (RSP)

To remove the explosive threat through any of a number of procedures and techniques. RSP is to be accomplished only by qualified technician.

Safety fuse

Used for detonating explosives nonelectrically. Since its burning rate can easily be regulated in manufacture, black powder is widely used as the core burning powder in the safety fuse used commercially and by the military to provide a delay time prior to an explosion.

Secondary explosive

Classification of explosives that are used as a booster and/or

main charge after the first step in an explosive chain. Secondary explosives are relatively insensitive to shock, friction, flame, or heat compared to primary explosives. They may be initiated or detonated by a strong explosive wave. Common examples include:

(1) boosters: pentolite, TNT, RDX. PETN, tetryl, and tetryl;

(2) main charges: dynamites and ammonium nitrate; and

(3) blasting agents: nitrocarbonitrate. (see table 4-3)

Shaped charge

Shape charges are explosive devices that focus the explosive force in a specific direction, usually by forming a cavity in the charge, to create a directed pressure or projectile. Conical shape charges are used to penetrate armor or punch holes. Linear shape charges are used to cut a straight line.

Sheet explosive

Also known as Flex-X or Deta-sheet is a flexible rubber-like explosive that be easily cut with a knife, remains flexible through a wide temperature range, and is waterproof. Military sheet explosive has pressure-sensitive adhesive backing, making it possible to quickly apply the sheet to irregular or curved surfaces.

Shock tube

"Shock tube" and "signal tube" are generic names for a small diameter plastic laminate tube that has the inside of the tubing coated with a very thin reactive material that transmits in initiation signal or "shock" to an attached blasting cap.

Shrapnel

Any metallic case shards or included objects that are thrown from a charge upon detonation to enhance the fragmentation effects. Among the favorite objects used as shrapnel in terrorist bombs are nails and large fence staples. Pipe bombs are a common fragmentation device.

Smokeless powder

The world standard propelling powder for small arms, cannons and

in a slightly different form, some rockets. All low explosives currently used as propellants have a nitrocellulose base and are commonly referred to as smokeless powder.

Squib

An electric match. Used primarily for initiating low explosives where a burning action is desired.

Straight dynamite

Liquid nitroglycerine absorbed in a mixture of various carbon rich materials, such as wood pulp or ground meal. Sodium nitrate is added primarily to supply oxygen for complete combustion of the carbon1-rich materials, thereby increasing the strength of the explosive. This is the most hazardous of the dynamites to handle and store.

TATP

Short form for triacetone triperoxide, also known as tricycloacetone peroxide.

Tetrytol

Effective as a cutting or breaching charge, tetrytol may be used as an alternate to TNT in general demolition work.

TNT

Short form for trinitrotoluene, a powerful explosive. It is the most common military explosive and, alone or as part of a composite explosive, is widely used as a booster charge bursting charge, and demolition charge. It is used as a standard explosive against which other military high explosives are rated.

Two-part explosives

Consist of two inert components that are nonexplosive until mixed. After mixing, the solution becomes cap sensitive and is considered a high explosive. Unmixed components may be shipped by common carrier or by airfreight with no special handling required. Astro-Pak and Kinepak are the most common examples.

X-ray

Typically, a stream of relatively high-energy photons, used for their penetrating power in radiography, radiology, radiotherapy, and research. When used x-ray photography, provide a means for detecting structures that are shielded from normal view.

35_5.0 Tools for Destructive Entry of Safes and Vaults

In **Chapter 32**, methods of forcible entry to open locks were examined. Some of those tools and procedures can be used for and are equally applicable to safes and safe locks. Both common and custom implements are employed to effect a forced-entry. Generic and specialized equipment is required to drill, pry, punch, blow, rip, cut, chop, grind, break, pull, burn, melt, freeze, vaporize, alter, or destroy barrier materials. The following discussion provides information regarding the equipment used by the safe technician.

35_5.1 Generic Tools

The following inventory offers a guide as to the equipment that is required to properly and effectively penetrate a security container while causing the least amount of damage.

- **Allen wrenches for removing hinge bolts;**
- **Ballpeen hammer;**
- **Center punches;**
- **Change-keys for common safe locks;**
- **Dead blow hammer;**
- **Drill motor, high speed, 3500 RPM or faster;**
- **Drill motor, low speed, 550 - 1200 RPM;**
- **Drivers, socket ends;**
- **Hammer drill, variable speed;**
- **Hammer;**
- **Hand tools;**
- **Ice picks;**
- **Illuminator, battery powered, flexible and straight;**
- **Laptop computer for access to Internet databases;**
- **Mall, two pound;**
- **Manipulation aids;**
- **Pickup tool, magnetic, long telescoping model;**

- **Pin punches and removable pins (Lockmasters Ram sets, 3″ length);**
- **Pointed vice grips for gripping broken spindles;**
- **Punch rods, 8, 16, 24, 30″, stainless steel round stock;**
- **Punches, flat and chisel pointed, ¼″, 5/16″, 3/8″, used to break up hard plate. Several are generally required. Tool steel tip and mild steel handle are recommended;**
- **Reamer;**
- **Reference data for safes and locks;**
- **Rods, long, water hardened, all diameters;**
- **Safety glasses;**
- **Screwdrivers;**
- **Sledgehammer;**
- **Tape measure;**
- **Tool caddy;**
- **UV light source;**
- **Vice grips;**
- **Wire cutters;**
- **Wire;**
- **Wrenches.**

35_5.2 Specialized Entry Tools

- **ATG driver;**
- **Audio amplifier;**
- **Borescope, long fiber optic;**
- **Bosch drill, heavy duty;**
- **Broco thermic lance;**
- **Change-key set;**
- **Compressed air can, or turkey baste syringe;**
- **Dead-blow hammer;**
- **Dial puller;**
- **Drill bits, cobalt;**
- **Drill bits, core drilling;**
- **Drill bits, high-speed steel, 6″-24″ length, 1/8″, 3/16″-1/2**

diameter, for drilling mild steel (not stainless or hard plate);

- **Drill bits, masonry;**
- **Drill bits, metal-cutting carbide bits, ¼″, 4″-6″ in length;**
- **Drill motor: Bosch 1198 VSR ½″, Hilte, Milwaukee, or Makita. Drill chuck, 3/8″-1/2″, variable speed, 3000 RPM maximum required, allows application of torque with pressure, >4.5-7.0 amps;**
- **Drill point locators;**
- **Drill rig, Collins lever;**
- **Drill rig, magnetic, Lockmasters #457 or equivalent;**
- **Drill rig, snap-on type;**
- **Drill rig, Strong-Arm MiniRig;**
- **Drill rig, vacuum;**
- **Drill templates;**
- **Emergency dials, different diameters, or Prob-A-Scope;**
- **Emergency spindles;**
- **Flashlight, fiber optic;**
- **Flexible lights;**
- **Forceps kit;**
- **Grinder for sharpening punches;**
- **Grinding wheels;**
- **Hole saws, different diameters;**
- **Iron pick;**
- **ITL 1000 computerized solenoid;**
- **LaGard skip pick;**
- **Lock picks for pin tumbler and lever locks;**
- **Lubricant, Group 1 lock;**
- **Lubricants and grease;**
- **Nose puller;**
- **Ophthalmoscope;**
- **Optivisor;**
- **Otoscope;**
- **Read-Eze manipulation aid;**

- **Safe-deposit penetration kit;**
- **Safe-saver pins for hole repair;**
- **Safety goggles;**
- **Saws, reciprocating, Makita or equivalent;**
- **Saws-all cutter;**
- **Screwdriver, mini;**
- **Silica gel;**
- **Stethoscope;**
- **Torque measurement kit;**
- **Video camera, adapter, monitor;**
- **Welder, metal inert gas;**

Note: Suggestions from readers or manufacturers for the inclusion of new tools in subsequent editions would be welcome.

35_5.2.1 Optical Viewing Devices

There are two essential categories of tools used for professional safe penetration: **optical viewing devices** and **drills** (and related components). Our discussion of tools begins with brief comments regarding the borescope, because it is the primary instrument utilized to view locking components after penetration. See **Chapter 31** for a detailed discussion relating to optical viewing devices and their use for decoding locks. A borescope, otoscope, or ophthalmoscope is an optical device that is employed to view inaccessible areas within a combination lock or security container. They were developed for use in the medical field to inspect internal organs; they are ideally suited for safe and vault work. To "scope a lock," means that an internal component is viewed externally through an optical probe.

Each of these three devices can be used to perform specific types of observations, based upon the thickness of barrier material, diameter of the hole, and location of critical locking components. All of these implements are essential to allow the qualified safe technician to perform his task. There are many different designs for the borescope in terms of length, diameter, viewing angle, optical relay system, and image capture. Price will provide an index as to the clarity of the image and the degree of sophistication of image transmission and light-gathering efficiency.

Although there are many manufacturers, Olympus is probably the most well known and respected vendor of precision borescopes in

the world. They manufacture rigid, flexible, and fiber-optic-based devices. See **Chapter 31** for a detailed description of optical viewing devices.

A borescope may be handheld and self-contained, or it may rely upon an external light source with its own power supply. The handheld models will contain batteries and high- intensity illumination, generally within the handle. Usually, fiber strands carry light to the scope tip. A special internal lens may also be provided for different fields of view. A mirror tube may fit onto the shaft of the scope to allow for different viewing angles of up to 90°, for full 360° rotation. A second mirror can allow a "back angle view" to observe the entry point into the container.

35_5.2.1.1 Special Precautions

Before a borescope is inserted through a hole, insure that the area to be probed is free of debris. Dust on the surface of a mirror or lens will decrease light transmission and the quality of the image. Take great care with the surface of the lenses; they can be scratched or easily damaged. The author utilizes lens tissue and alcohol, or cleaner and pressurized dry air.

35_5.2.2 Drills, Bits, and Related Tools

35_5.2.2.1 Introduction

The subject of drilling, from the perspective of the chemistry and physics of metallurgy, was described in **Chapter 5**. Safes are opened with drills in the vast majority of forced penetrations. In most cases, the **lock** rather than the safe mechanism is actually drilled. Even more important, **accurate drilling** constitutes 90% of an effective opening technique.

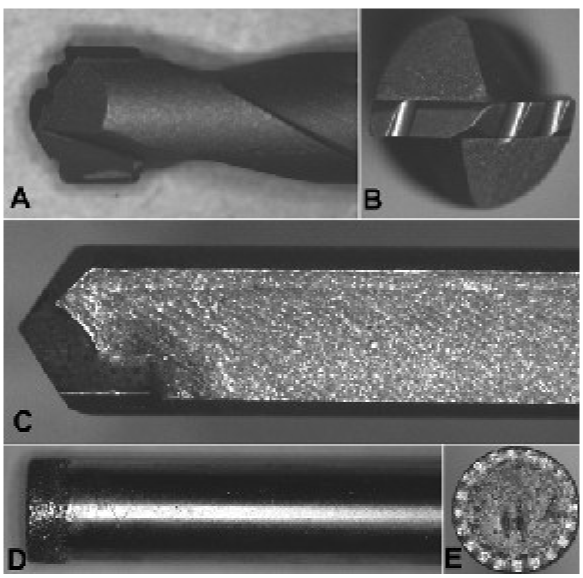
Virtually every safe that carries a **TL** rating can be opened in this manner. When a safe is drilled, locks are usually bypassed through a drill point under the dial ring. This allows for straight-in penetration unless there is glass. The reader is cautioned that drill point information published prior to the 1970s should not be relied upon as accurate.

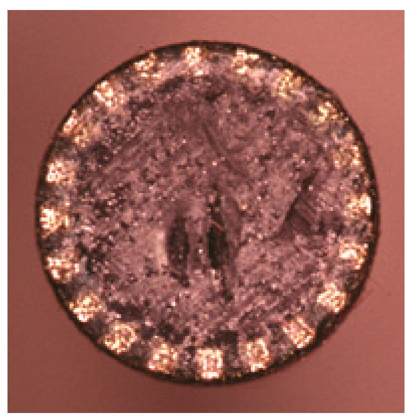
A drill bit constitutes more than just a hard and sharp cutting edge; it is a very complex cutting tool, as has been discussed in earlier chapters. Its components must be understood in order to

master the process of removing metal and the proper maintenance of the cutting edge. Many complex components must work in unison in order for the drill to efficiently remove material from a work surface.

35_5.2.2.2 Drill Bits: Classification and Materials

Many types of drill bits are available to the safe technician. They are required because of the various grades of barrier materials that must be penetrated. There are three primary categories of drill bits: **carbon, high-speed steel (HSS),** and **special alloy.** They are produced in six different materials: carbon steel, high-speed steel, cobalt, carbide, diamond core, and tungsten.





35_5.2.2.2.1 Carbon Steels

Carbon steel drills are used for penetrating mild steel and softer materials that have not been hardened. If a tougher bit is required, then more carbon and other alloys are added.

35_5.2.2.2.2 High-Speed Steels

High-speed steel drills (HSS) are produced in many grades of hardness; perhaps the most common is M2. These may also be referred to as 18-4-1 and 18-4-2 alloys, with the designation indicating the percentage of other metals within the steel.

Thus, the above example would refer to a metal with 18 percent tungsten, 4 percent chromium, and 1 or 2 percent vanadium. The alloy contained within these tools is altered for optimum hardness, shock resistance, heat conductance, resistance to annealing, and abrasion resistance, allowing them to tolerate higher speeds with more applied pressure. They are also more efficient at cutting metal as compared to standard carbon steel bits. An HSS bit can penetrate 1” of steel in about two minutes.

Masonry bits are used for penetrating concrete but can also be used for hard plate and composite materials. They have a large carbide chip insert that is soldered into place. Generally, the chip is not sharpened. **Cobalt drills** (M45 steel) are required for barrier material that creates high temperatures during cutting. The alloy, when added to HSS, maintains hardness and cutting surface during red-point drilling. These bits are tempered to an **austentite** condition for optimum hardness and toughness. They are quite hard and brittle and will often snap during drilling.

The cobalt drills will outperform HSS bits; they can cut more material at higher speeds. However, they are less resistant to destructive shock and stress, often caused by a constant change of drilling angle. The tip can be easily shattered if hard nugget or spots are encountered. These bits are used to penetrate stainless steel, armor plate, and manganese.

35_5.2.2.2.3 Special Alloys

Carbide Drills are even harder than HSS or cobalt and will withstand higher temperatures than the hard plate they are drilling. Hardness ratings for carbides range from 89.5-93.0 on the Rockwell “A” scale. Carbides produce chips during penetration that are very hot and blue-black in color. A great deal of squealing usually accompanies the drilling process.

Although there are hundreds of grades of carbide, only four are relevant in the context of drilling alloy hard plate. These can be classified as **tungsten carbide, crater resisting carbides, titanium carbides, and coated carbides**. A standard carbide bit is simply a drill with two chisel-edged planes to form an angle for cutting. The chisel edge is the least efficient because it does not cut but actually squeezes or extrudes the work material. This type of bit actually does more scraping than cutting.

Tungsten Carbide

Tungsten carbide drills are utilized when penetrating most barriers except diamond and ceramics. They are one of the hardest man-made materials, approaching that of a diamond. There are hundreds of degrees of hardness of T/C, achieved by the addition of different metals. They are usually composed of between 94 - 97% tungsten carbide, with cobalt the remaining material. The first carbide drills were made of a steel shaft, slotted on the tip, with a spade-shaped piece of carbide soldered to it. The cutting edge was sharp, and brought to a point.

They were originally developed at the beginning of the twentieth century (1896) by a French chemist. An incredibly tough drill was created when a mixture of iron, charcoal, and sugar were added to pure tungsten. This mixture was then crushed into a powder, together with cobalt. Actually, tungsten carbide was developed as a hardening agent. It was an outgrowth of the addition of carbon, chromium, and tungsten. Then, carbide chips were added to the drill point with cobalt for extreme hardness. Space-age metals, such as titanium, tantalum, and colombian have also been incorporated for enhanced characteristics.

Physically, carbide chips are brazed or soldered to a steel drill shank to create a very hard and brittle bit. Their design calls for a minimum relief angle and rake angle to maintain a cutting edge. The red-point drilling characteristics of tungsten carbide and tantalum carbide are excellent. When the proper pressure and speed are used, the bit turns into a homogenous structure that can create enough heat to melt the target material.

The life of a carbide drill bit cannot be accurately projected; many complex factors will determine how long the bit will perform. In one instance, several bits may be required to drill through one door. In another case, only one may be used. As noted in **Chapter 5**, the addition of certain elements enhances performance. The tungsten provides increased hardness and heat resistance, chromium offers shock resistance, and vanadium allows greater fatigue resistance and overall toughness. T/C is the most abrasion resistant of the cemented carbides.

Crater-Resisting Carbides

“Cratering” of hard metals is a characteristic that results from the interaction of the cutting edge of a drill bit with hard plate. A crater actually forms a short distance from the cutting edge and will continue to enlarge until the bit breaks through a portion of the surface. These drills contain titanium and

tantalum carbides added to tungsten. Their primary use is for machining alloy cast irons and other cratering-prone metals.

Titanium Carbides

Titanium carbide drills have small percentages of nickel and molybdenum. They perform well at higher speeds and temperatures but are brittle and will easily fracture from thermal and mechanical shocks. These bits have good cratering resistance.

Coated Carbides

Drills are coated to enhance resistance to thermal shock, although this characteristic is dependent upon the type of coating. Carbides can be treated with titanium oxide, titanium nitride, and aluminum oxide.

Cubic Boron Nitride

Diamond is the only material harder than cubic boron nitride. Drills with this composition, trade-named Borazon, are used to cut extremely hard and tough metals. A **Diamond core drill** resembles other core bits; they simply have diamond chips embedded around the circumference. Traditional core drills are a tool of heavy construction and are used to make holes up to 18” in concrete, brick, and other materials. These drills actually grind the material during the cutting process, rather than shearing as with other types of bits.

The diamond core drills are constructed as hollow tubes, coated and bonded with industrial diamonds. Their characteristics require that they be utilized with a fixed drill rig for stability and maintenance of constant pressure. Often used with hole saws, they can easily make a hole in most barrier materials. First, the HSS hole saw is employed to cut through the mild steel skin; the diamond core will then pierce the hard plate. They are not designed to work with softer materials, and only function efficiently with hard plate.

The diamond inserts have a very limited cutting life, generally from 1.5 - 2 inches of material. A blue wax material within the center of the drill provides lubrication, and melts as the barrier material is penetrated. It also will carry away chips from the work surface. Although they offer a very hard surface, carbide tipped drills can be sharpened using a green silicon carbide wheel with K120 grit. Professional safe and vault

technicians are familiar with the Diamatip core bit, manufactured by Magnum.

35_5.2.2.3 Tip Failure

There are two primary causes of tip failure. In the first instance, the drill body acts as a heat sink to carry high-temperatures away from the bonding agent. Failure occurs when the silver solder breaks down. If the drill is utilized for hot drilling, then pressure must be intermittently reduced to allow the tip to cool.

Many manufacturers include carbide chips and abrasive materials within their hard plate. These are bonded with bronze or nickel alloys and contained in rods or nuggets. Materials that contain such hard chips or nuggets, such as aloxite manufactured by Chubb, will shatter a tip during drilling. This is precisely what the manufacturer intended. As noted elsewhere in this text, a negative rake angle can improve performance when these materials are encountered, but the problem is not solved.

35_5.2.2.4 Drill Design

An understanding of the geometry of the cutting edge will allow an insight into how metal is removed during the drilling process. This in turn will provide guidance as to the best bit to use for a specific type of barrier material. Knowledge as to bit design will also permit them to be easily sharpened for optimum use. A more technical discussion is presented in **Chapter 5**.

35_5.2.2.4.1 Flutes

It appears that the Egyptians, around 4000 B.C., utilized the original straight-fluted drill for making holes. The first patent was issued to Stephen A. Morse in 1863 for a fluted bit. Flutes carry the cuttings from the work surface. Their design is quite complex and must encompass the correct web thickness to reduce cutting pressures. Additionally, chip splitters are incorporated into the cutting edge to increase the flow of cuttings through the flutes.

Generally, two flutes are designed to transport chips from the base of the hole (tip of the drill) and be ejected. The lands and the way they are spiraled determine the rotation of the drill (right or left). This will control how the chips are carried.

35_5.2.2.4.2 Rakes: Positive and Negative

The cutting edge of a drill is defined and referenced as to whether it is positive or negative. The "standard" bit has a positive rake, indicating that the cutting edge leads when making contact with the work surface. Its function is to slice material during rotation.

Positive-rake drills cannot be used with included hard plate, as the cutting edge will be destroyed almost instantly. Instead, a negative rake is recommended. These bits have their leading edge modified so that there is minimized contact with the irregular surface. Negative-rake angles make it possible for the cutting edge to ride above an irregular included surface. This reduces shock, minimizing fracture and shatter. Unfortunately, shocks encountered in drilling certain hard plate will eventually destroy the drill.

The rake angle is directly related to required pressure to effect cutting. An increase in angle of approximately 1° will increase pressure by one percent. The converse is true for positive rake drills.

35_5.2.2.5 Primary Components of the Drill Bit

The traditional fluted drill can be subdivided into two primary components: the body and shank. The body does the actual cutting and contains the flutes and relief areas. It is the complex portion of the drill. The shank allows the drill to be fastened to a drill motor, and is shaped in a straight or tapered design. Its diameter can be reduced for acceptance into a smaller drill chuck.

The **margin diameter** or **body diameter** creates a clearance for the drill; it is measured from edge to edge. The diameter of the drill is actually reduced behind the tip to create clearance so that the drill can cut. The design of the **helix angle** is based upon the material to be penetrated, the depth of the hole to be made, and the type of chips being produced. A low twist or low helix design is preferred for soft material such as brass, copper and plastic.

Steels that can be machined produce small, curly chips that may encounter difficulty in riding the flute. A "standard" helix angle is used for most drilling operations. As the helix angle

increases, more chips will be produced with softer materials. The helix in the carbide drill will have a greater angle in order to eject the fine metal chips produced by drilling hard plate. Drilling cast iron and hardened steel can produce flake or powder that can cause a packing problem at the tip of the bit.

35_5.2.2.5.1 Point Angles

The point angle is generally described as the included angle of the tip. The two standard point angles are 118° and 135°. A 118° point is for general-purpose cutting. An angle of 135° (that forms a flatter point) is used for alloy steel hard plate. A drill for manganese steel, for example, would have a point angle of 140° with a 6°-9° relief angle. This drill would require slow speed and high pressure.

The point angle and the length of the cutting-edge lip are inversely proportional. That is, as the point angle increases, the length of the lips decrease with a corresponding decrease in pressure required to cut the material. A 135° point angle makes it more difficult to begin penetration, and it generally requires a pilot hole.

The lands meet to form a **chisel edge** in the center of the drill point. Its function is to move material away from the center of the bit in order to allow transport by the flutes. The **web** (material at the center of the drill bit) provides structure and strength. Generally, the web increases in thickness toward the shank.

35_5.2.2.6 Sharpening of Drill Bits

Drill bits must be sharpened to increase their performance and prolong their useful life. Sharpening can also modify and control the operation of the bit, based upon the type of material being penetrated. The complex angles of the drill point all must work in unison for optimum cutting and removal of material. These angles are maintained by proper sharpening. Sharpening can be dangerous because microscopic fractures may exist throughout the bit and shank caused by previous stress. The result: the drill can separate or disintegrate at high speeds.

Accurate sharpening requires either a commercial machine or a bench grinder and drill gauge in order to properly accomplish the process. The gauge provides a scale to measure the lip length

and its angle (but not the relief angle). This is a simple tool, but it requires practice to be used properly. If a grinding wheel is employed, it must be dressed to maintain a flat surface. All sharpening is done on its face and not on the side. Caution should be exercised because improper grinding practice can cause the wheel to explode or shatter.

35_5.2.2.6.1 The Sharpening Process: Definitions and Rules

The process requires the alteration of three critical components: **point angle**, **relief angle**, and **lip length**. Using the two-flute drill as a model, the following rules apply for sharpening drill bits:

Chip breaker is a groove cut into the lip of a drill bit to prevent chips from clogging the flutes. They are used when drilling soft materials and steel. Grooves are generally offset between lips and are usually closer to one than the other. These tips are shaped likes spades and cause the removed material to be ejected sideways with more efficiency than a rounded HSS bit. It is, however, more difficult for the chips to move from the cutting area. In reality, a chip breaker is a divider, thus creating a multifaceted web that forms several chips. These are easier to disperse, requiring less pressure to cut the work surface. Although chip breakers can be effective, they weaken the tip and are often used in high-speed drilling with a coolant. They may reduce the ability to cut and can shorten drill life.

Lands, often called the "surface of the point" behind the lip, provide support while the lips are cutting and transport heat from the tip. However, too much relief will cause the tip to melt.

Lip Angles to the center of the bit must be identical. If not equal, the bit will cut chips with different material thickness. This will result in distortion of the tip and an oversize hole that is not linear. The hole will appear as a helix and will not allow the insertion of a straight shaft.

Lip Length must also be identical in order to create a round, true hole. If one of the lips is longer, then only it will cut. In such case, the drill will wobble in the hole.

Negative Relief Angle will increase the durability of the tip because the cutting edge is reduced. The technique is used with

a hammer drill to transmit impact to the material being penetrated. This tip design will not penetrate hard plate.

Point Angle is measured from the centerline of the drill body and will encompass the included angle of the tip.

Rake Angle of the cutting edge is controlled by the helix angle. Generally, the rake angle should not be changed. A **reduction** in the angle will prevent "grabbing" as the material is broken through, and will cut more efficiently. High pressures are withstood better while heat is transported away from the tip. Bits with a reduced rake angle are best for cutting soft materials such as copper, brass, plastics, laminates, and thin metals. However, less efficient chip transport will also occur. Instead, chips become tightly wound around the bit rather than being produced in ribbons.

Relief Angle must be sufficient behind the lip to allow the cutting portion of the drill to work properly. The land behind the lip must be angled to prevent contact with the bottom of the hole. The relief angle is usually between 8-12°. If 0° or less, the bit will not cut any metal. The relief angle controls the thickness of the chip that is produced during cutting. If too shallow, the drill will cut less metal while generating excessive heat at the tip. If the angle is too great, too much material will be attacked. Placing too much stress on the bit can cause it to shatter. As material is removed behind the lip to relieve the cutting edge, the corners of the bit can break.

Split-Point and Reduced-Point Bits will bore into materials easier and will be less likely to "walk." Modifying a drill in this fashion will relieve the heels of the drill point. A sharp-cornered grinding wheel is used to create a second set of cutting edges across the web of the body. The alternate sides of the chisel-point are ground away, thus creating a drill point within a larger drill point. This design is popular on long drills and is known as a "crankshaft" or "split-point grinding" drill point. The technique will almost eliminate the chisel-point and greatly reduce required pressure during drilling.

Web Thickness or P**oint Reduction** reduces the width of the chisel point. It is accomplished on the heel of the drill tip, not into the lips. Reduction of the width will minimize the feed pressure.

Web Thinning or thinning of the drill point can add cutting efficiency to a drill. This occurs because a more efficient

cutting area is placed into contact with the work surface. Cutting pressure is thereby reduced.

35_5.2.2.7 Maintenance of Drill Bits

The life of a drill bit depends upon its physical composition, the material being cut, the skill of the operator, and its maintenance. Efficiency and profitability can be enhanced by proper care. The drill bit that is correctly maintained and sharpened can cut materials faster with less operator fatigue and will produce a cleaner hole. A sharp drill will generate less heat.

What happens to a bit as it is used? Generally, most wear will occur at the corners of the lips. They will tend to break down and extend across the surface of the bit. Heat will increase as the drill fails, resulting in the inability of the cutting edge to remove any material. Proper maintenance of drills, including sharpening, can restore cutting edges. An equally important benefit is the minimization of the effects of the heat generated by the drill point upon the barrier material. If the drill is not operating properly, a “work-hardening” will result or the tip can melt or become annealed (soft).

35_5.2.3 Drill Rigs

Handheld drill motors are not acceptable where high tolerance in the location and angle of a hole is required. Precision drilling can only be accomplished with a drill rig. There is no best drill rig. The choice depends upon a number of factors, including time, weight, type of safe, and the work place. This section will examine professional hardware that is available for placing exact holes in a safe or vault.

Certain rigs will not work on particular safes. Thus, magnetic drill rigs may not adhere to stainless steel or non-magnetic surfaces, or to materials that are too rough, or not thick enough to hold the rig. Rigs are categorized based upon their method of attachment to the surface of the safe or vault. Drill rigs can thus be described as:

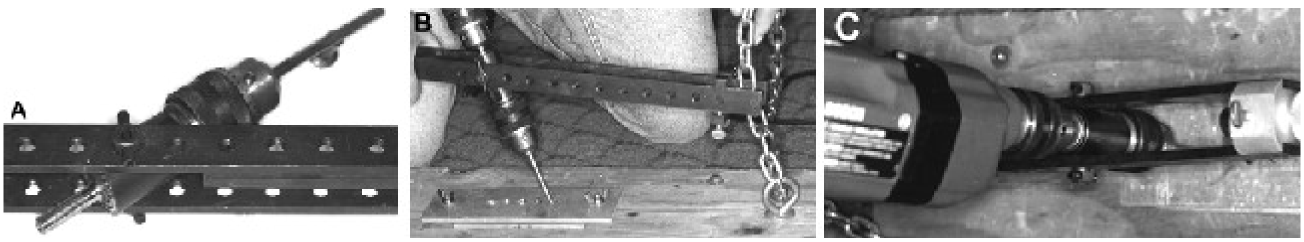
- **Pressure bar lever rig (not fixed);**
- **Simple fixed rig;**
- **Magnetic;**
- **Vacuum.**

35_5.2.3.1 Non-Fixed Drill Rigs

In situations where precise drilling is not required, a handheld drill rig can be utilized. The simplest form that is in use by many technicians is the Pressure bar lever rig described below.

35_5.2.3.1.1 Pressure Bar Lever Rig

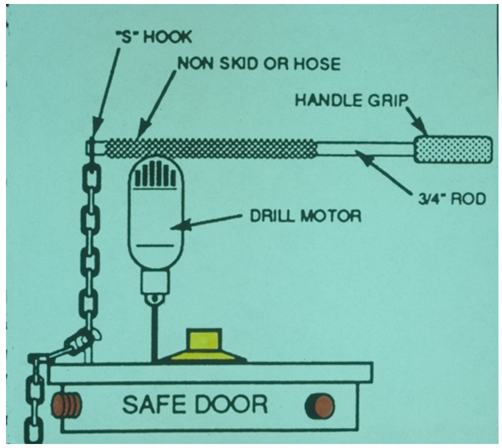
The pressure bar lever rig is probably the cheapest and most widely used tool. Although rudimentary in design, it will allow freehand angle drilling at the back, sides, and top of a container. These rigs are used for non-critical drill points.



Many practitioners will construct their own tools made of wood, metal, pipe, and chain. The design simply requires that the drill is fastened to a length of chain and a fulcrum point (handle) is established. This will provide the ability to tighten and lock the drill motor into a fixed position and apply pressure to it.

Some rigs are attached to the safe with pipe clamps, strap, and ratchet mechanism. Various drill motor holding designs are available for precise feeding. The rig allows the leveraging of applied pressure to the drill through the fulcrum point, up to a 20:1 ratio. The length of the handle and chain hookup bar can be adjusted, for maximum control.





35_5.2.3.2 Fixed Drill Rigs

Precision tolerance with respect to hole placement means depth and angle control, requiring that a fixed rig be employed. These devices are actually a portable drill press that can be mounted in any orientation to the surface of a door. There are a number of designs available that vary in complexity, capability, and price.

35_5.2.3.2.1 Simple Fixed Drill Rig

A simple fixed drill rig has as its primary component a platform for the drill motor that can be positioned on the face of the safe. Straps, clamps, or chains attach the drill to the rig; a ratchet, turnbuckle, or other device accomplishes tightening. The drill motor is moved with an arbor mechanism or lead screw that also allows control of over-drilling.

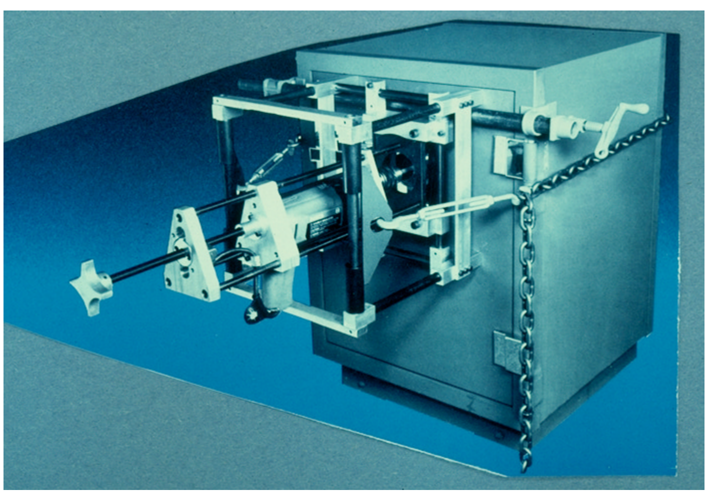
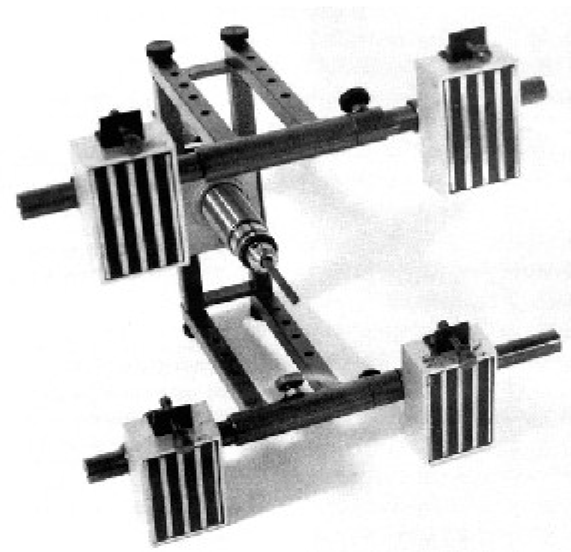


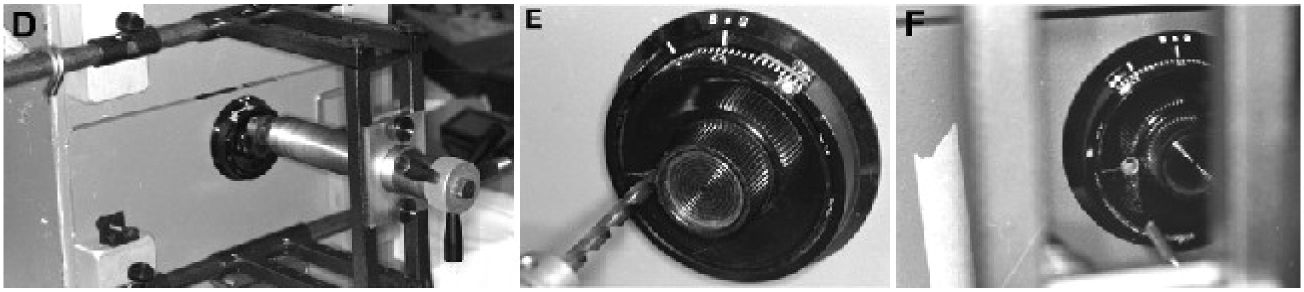
Figure LSS+3534 A fixed drill rig (ISP-87-3563).

35_5.2.3.2.2 Magnetic Drill Press



There are several such devices available to the professional safe technician. They all utilize a configuration of magnets to attach themselves to the surface material. Depending upon design, they will vary as to holding strength. Some of these tools have been produced in a very compact configuration because of the availability of rare earth magnets that measure a few inches in diameter and can deliver several thousand pounds of holding power.





35_5.2.3.2.3 Vacuum Drill Rig

The vacuum rig is a variation of the magnetic attachment. Suction, rather than magnetism, is utilized to hold the device to the surface of the container.

35_5.2.3.3 Drill Motor

Speed, pressure, and feed can be directly correlated to the drill motor design and related parameters. Many manufacturers, notably Bosch, Hilte, Milwaukee, and Makita produce motors suitable for safe and vault work. The greatest threat to a motor is heat. This can be caused by the use of an underrated armature or winding. An inadequate specification can be identified by low current consumption. Ventilation is critical, especially when extreme pressure is applied during the drilling process. If the motor becomes hot, it will sound differently while running. In such event, the drill should be run without any applied pressure until cooldown occurs.

Drill motors should have the following characteristics:

- **3/8″-½″ chuck;**
- **Variable speed;**
- **5000 RPM Maximum, although 3000 is generally sufficient;**
- **4.5-7 ampere current rating that controls the ability to apply torque;**
- **Should feel good when handheld;**
- **Assess how the motor is held;**
- **Assess how the motor feels when pressure is applied;**
- **Ventilation: how many air ports;**
- **Running temperature of the motor.**

35_6.0 The Penetration of Safes and Vaults by Drilling

35_6.1 Introduction

Drilling is a very complicated problem with many variables. The process is performed in order to neutralize a specific component within a lock or bolt mechanism. Successful drilling demands precise measurement, the proper equipment, and correct technique. The type of hard plate, drill speed and pressure requirements, and the calculation of the drill point are factors that can make the process of drilling quite difficult.

Drilling is accomplished in many ways and is dependent upon the lock, the design of the container, and the barrier material that is utilized by the manufacturer to protect the safe and its internal components. Most problems encountered in forced penetration can be traced to one of five errors:

- **Lack of accurate information about the container;**
- **Formulation of wrong entry approach or technique;**
- **Improper equipment;**
- **Improper drill motor speed;**
- **Improper pressure: too little or too much.**

This section offers detailed information about the complex factors that make up the technology of penetrating safes and vaults by drilling. We begin with an overview of the process, followed by information about the development of anti-drill barrier materials and methods of bypass. The location and computation of drill points are also explained. Finally, a comprehensive analysis of drill points in relation to critical locking components is presented, together with the supporting information required to successfully open a locked safe.

35_6.2 Drilling Safes: An Overview

The theoretical procedure for penetrating a safe is quite elementary. The actual drilling procedure, however, can become very difficult and time consuming. For the professional safe technician as well as the educated burglar, the preferred method of entry into a safe is by drilling, if manipulation fails. The reasons to drill, however, are often misunderstood. The reader

should also understand that an amateur might attempt drilling in order to create an opening into the container, regardless of size or resulting damage.

Then, there is drilling by a craftsman in order to accomplish a purpose that denotes knowledge of the safe, its lock, and contents. The evidence technician and case investigator should always be mindful of the difference.

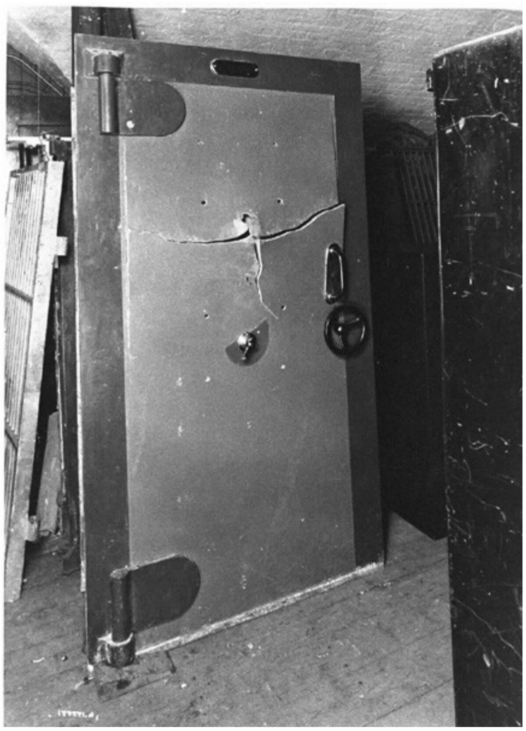




Figure LSS+3535 Shown (right) is a burglary where it is suspected that a drill rig caused the fracture of the outer skin of the door. In the photograph (right) a core drill was utilized.

In its simplest form, drilling is a straightforward procedure and will be summarized here. A detailed drilling sequence protocol is presented in Section **6.4**.

Generally, a high-speed steel bit (HSS) is used to drill **to the hard plate.** When no more cutting occurs, the technician changes to a tungsten carbide or similar bit specially designed for the purpose. If the carbide bit does not grab onto nuggets, steel balls, or other materials designed to block its path and cause fracture, then drilling continues through the hard plate. Another high-speed steel bit is used to finish the job, penetrating into the lock case.

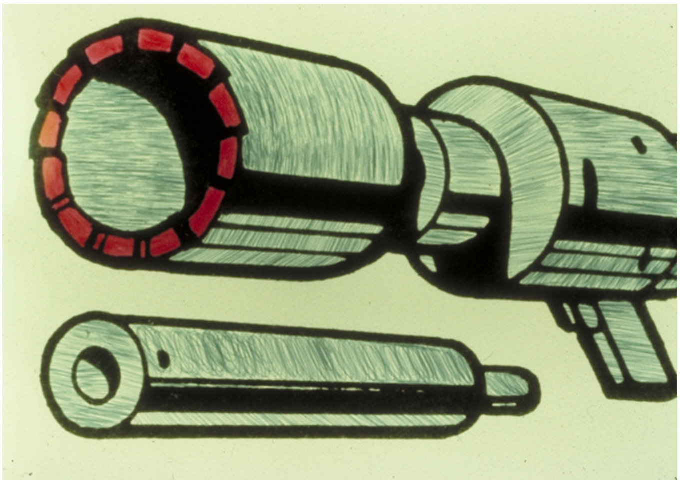




Figure LSS+3536 (ISP 77-3563 left, 78 right) Core drill can produce a large hole through which access can be gained to the bolt works or lock box. Courtesy of Illinois State Police, Bill Sherlock.

35_6.3 Drill points

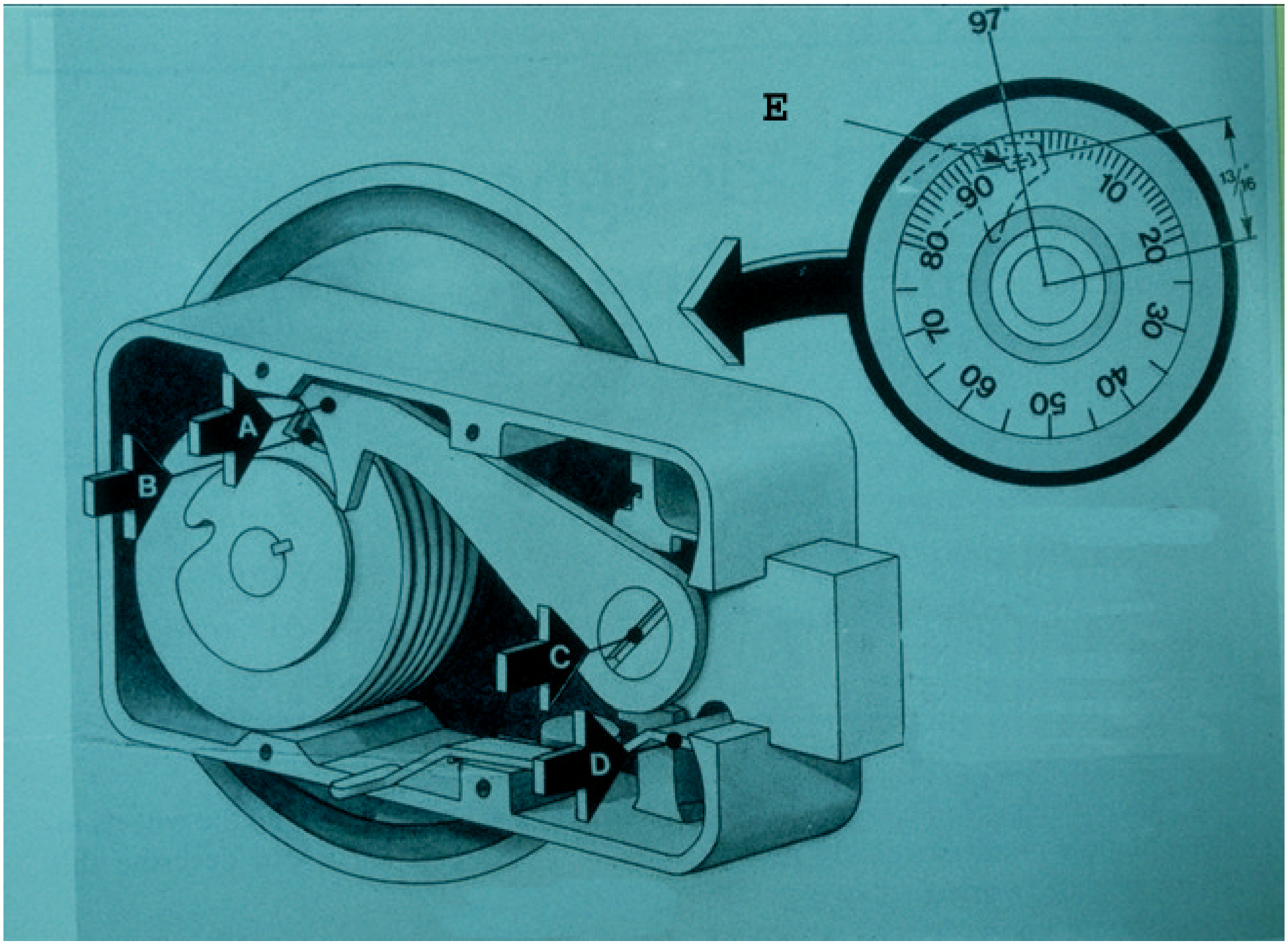


Figure LSS+3537 (ISP 102-3563) Critical drill points are shown. This is a rear view,
with the lock case removed, as if looking from inside the safe toward the dial.
(A) fence location; (B) gate location; (C) bolt screw location; (D) relocker location;
(E) fence drill point.

Although most professional safe and vault penetrations require that a hole first be made by drilling, the location and purpose will depend upon the method of bypass of the lock or boltwork. Because drilling is the preferred method of entry, the various techniques will be explored in detail. The precise location that is selected for penetration is called the **drill point.** It is calculated from measurements provided by references published by the lock manufacturer, Ed Willis, Mark Bates, Lockmasters, SAVTA, NSO, and other sources. Comprehensive information about most

safes and locks is also available at **security.org**.

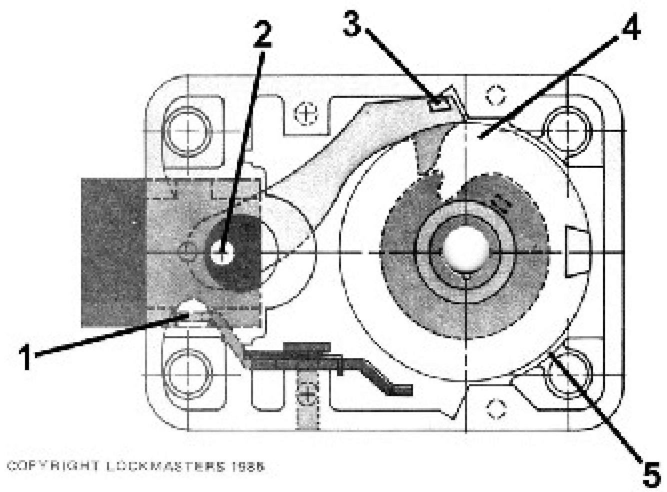
Based upon the targeted component, there are up to twenty possible locations that may be selected as a drill point. Proper technique will allow any of these to provide the means to open the lock or bypass the boltwork. In every safe or safe lock, the following drill points can be identified to provide access to critical components:

- **Bolt;**
- **Change-key hole;**
- **Creation of gates;**
- **Dial ring;**
- **Fence;**
- **Handle cam;**
- **Handle shaft;**
- **Lever screw;**
- **Locating relockers;**
- **Locking cam or lever;**
- **Manipulation of components;**
- **Mounting screws;**
- **Pilot hole through hard plate;**
- **Reading of gates;**
- **Relock devices that have become engaged;**
- **Relock trigger;**
- **Scope dial ring;**
- **Scope lock case;**
- **Spindle shaft;**
- **Square section of holes, creating;**
- **Viewing hole, front, top, sides, or back of safe, for introduction of borescope, to allow:**
    - **Reading of gates;**
    - **Locating relockers;**
  - **Manipulation of components;**
- **Wheel pack.**

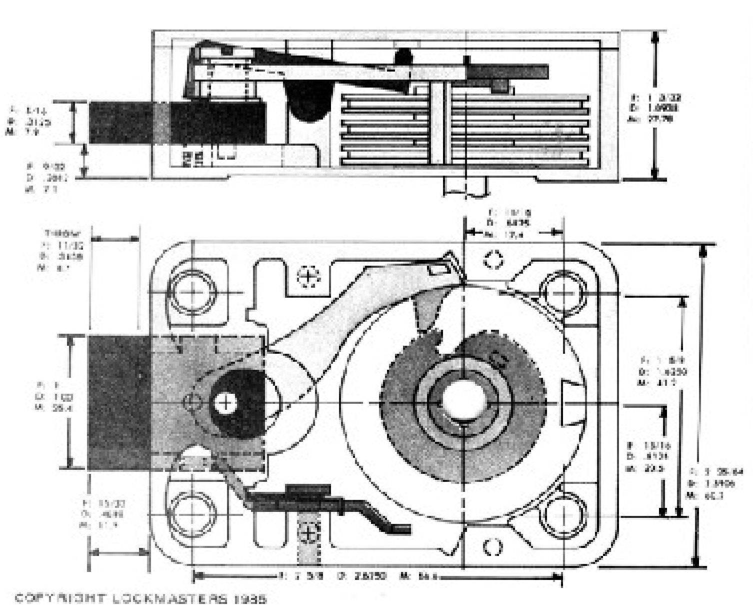
35_6.3.1 Drill Templates

There is no room for error when drilling open a safe. Most forced-entry difficulties can be traced to faulty technique on

the part of the technician in determining drill point location or in the actual use of the drill.

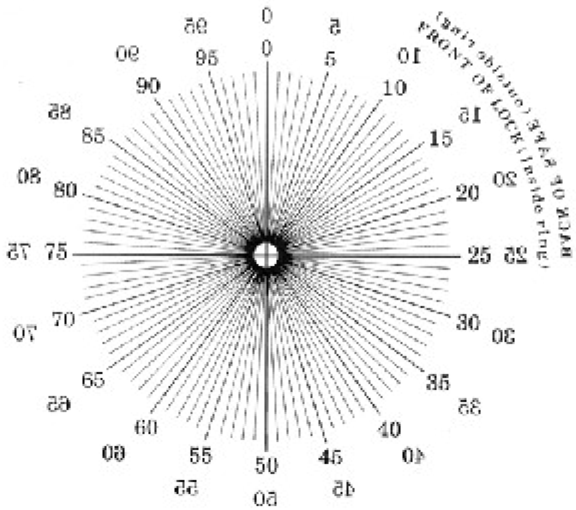


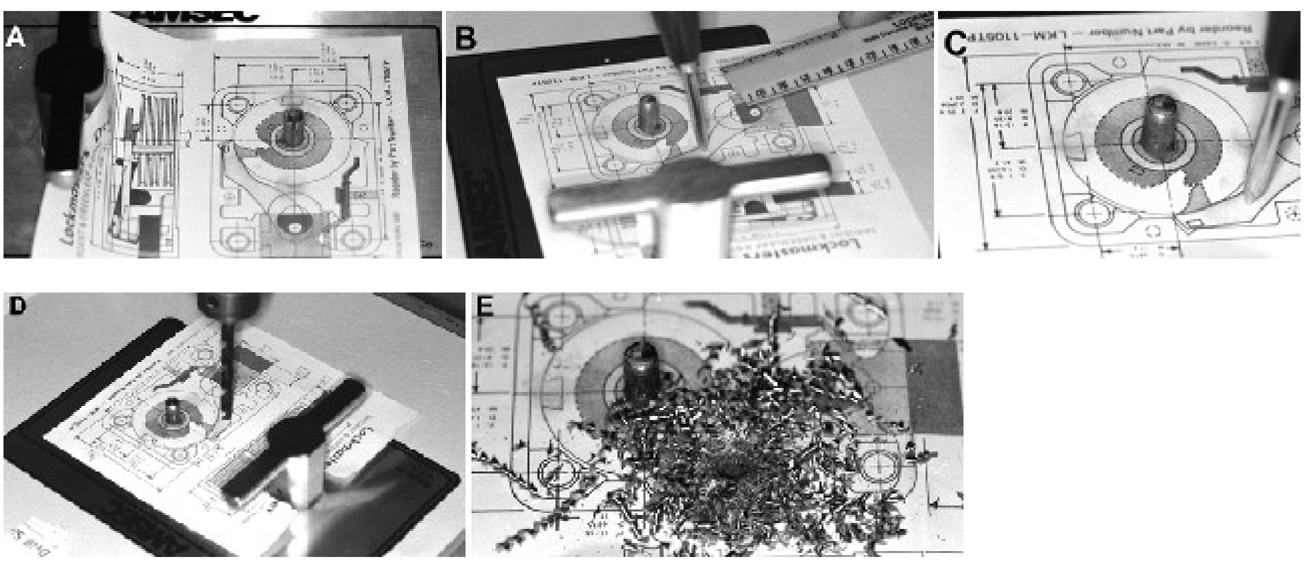
A hole drilled at the wrong angle, one placed in the wrong spot, or one that misses the intended target translates to wasted time, effort, potential damage to the lock, and frustration. Proper opening technique dictates that only one hole is made at the required position in order to offer a view or access to critical components.



Magnetic drill templates provide a precise method of determining drill points for all of the popular safe locks. Their use is

extremely popular and highly recommended. These templates provide the equivalent of an x-ray view of the critical locking components described earlier. Use of the correct template, once squared with the lock and oriented for proper handing, eliminates all measurement errors. The template is placed directly over the lock after the dial is removed or is utilized as a reference point for precise calculations. The exact drill point is located and center punched.



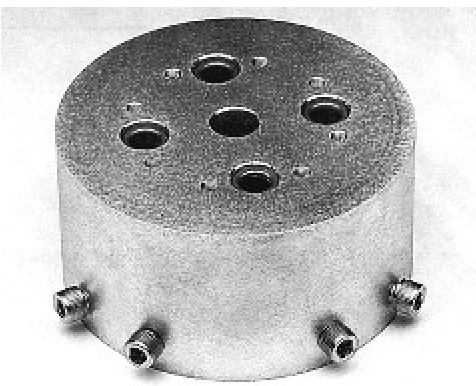


35_6.3.1.1   Predrilled Metal Templates

A guide plate is available that has predrilled holes for establishing exact drill points. If the proper handing and

manufacturer is known, it is virtually impossible to locate a hole in the wrong place. The angle, however, must still be precisely defined. If a drill rig is used with a guide plate, success is assured.

Once identified, the drill point location must be marked and punched to allow for precise penetration. Generally, this process occurs after the dial and dial ring have been removed. In practice, a template is located over the spindle, taking care that the handing orientation is correct. A center punch marks the location for the drill. If a template is not available, then measurements must be made from known coordinates. Their computation and location is discussed below, as well as in Chapter 34.



The drill point can be placed in many different spots, depending upon the ultimate goal. If, for example, the fence is to be scoped, then the drill must be positioned to allow the borescope to enter directly below the fence and at the edge of the wheel. This will allow observation of the end of the fence, as well as the gates.

35_6.3.2 Marking the Drill Point

Although precise measurements are essential for successful drilling, both vertical and horizontal movement of the spindle can cause problems. In such a case, the template should be moved up, down, left, and right to determine and mark the outer bounds of movement. An average between these dimensions should be selected as the optimum location to drill.

Sometimes the dial cannot be removed, but is reduced in size. In such case, a line should be extended from the dial center to the physical drop in point prior to the reduction in dial size. A

trammel may be utilized to allow measurement from a flat ruler or template to the irregular surface of the dial.

35_6.3.3 Computing Coordinates, Measurements and Dimensions

A method to precisely determine and communicate the location of drill points must be adopted for all drawings, diagrams, photographs, and reference materials if a safe or vault is to be properly penetrated. Of course, once the hole has been drilled, a **translation** must still be made between that point and the drop in, except in the case of the lever fence. Translation theory is discussed subsequently. There are two recognized formats for placing a drill point: **radial measurement** and **coordinates**.

35_6.3.3.1 Coordinates

The location of bolts and related mechanisms, relockers, and lock drill points can be determined using coordinates. The drill point reference is usually in relation to the vertical and horizontal axis center of the dial. It relates to whether left (LC), right (RC), above or below dial **center**. Sometimes, measurements are made from the edge of the door, based upon a specific safe or vault design. In an S&G 6730, the drill point for the fence would be expressed as 3/16” LC x 1 1/32” up. This translates to drilling a hole left of center of the dial, at 1 1/32” up from that point.

35_6.3.3.2 Radial Measurement

A radial measurement derives its reference from the center of the dial and relies upon the dial numbering to determine the location of the drill point. A line is extended from the dial center that shall be referred to as Point A, through the number on the dial Point B, referenced to the zero marker position. The location of the drill point is measured from A, **toward** B. For example, in an S&G lock, the precise drill point for the fence would be expressed as 97 x 1.” This means that the drill point is located 1” from dial center, along the angle created by running a line through 97.

The rules for radial measurement require that:

- **Measurement is always from dial center;**
- **The dial is referenced to the zero index marker;**

- **The marker will always be at the top of the lock;**
- **The handing of the lock is not considered.**

Measurements for drill points are generally based upon locks mounted RH, or right handed. A simple translation can account for locks that are positioned LH, VU, and VD. In order to determine the correct gate position, either 25 or 50 is added or subtracted from the radial location for LH, VU, and VD. From the RH orientation, add 25 for VU and LH, subtract the same for a VD.

Original Position Move	Translated Position	Lock	Compute
RH left	**VU**	**RH**	**+25**
RH right	**VD**	**RH**	**-25**
RH	**LH**	**LH**	**+50**

Note: The numbering on the dial is reversed for a LH type lock.

35_6.3.3.2.1 Computation of Radial Distance

Any variation in the angle at which the hole is drilled can cause distortion when viewing the gates. This can alter the accuracy by one or more numbers. The problem can be corrected by adding and subtracting one, two, or three numbers from the drill point number sequence.

35_6.3.4 Viewing and Translating the Combination Through the Drill Point

Once a hole is made in the correct position, a **translation** must occur between the location of the drill point and the actual drop in point (unless the drill point was for the fence). This translation must correlate the number of divisions of the wheels between the zero index marker and position of the borescope. Remember that the wheels must be rotated and their gates observed by the safe technician, based upon a view from a location other than the actual drop in point (the drilled hole).

All of the gates are first aligned to this "virtual" location to ascertain the **relative** position of each gate. Then, their position is computed so that the gates appear under the fence when the translation is factored into the equation. The ability to accurately translate the viewed gate data to actual drop in

point can be affected by the angle of the hole with reference to the wheel pack. Sometimes a "direct view" is possible; in other cases, the drill is fed at an angle. If not all of the wheels are visible, the hole must be enlarged, moved, or scoped.

If a direct view of all of the gates is possible, the procedure is straightforward. A line should be extended from the center of the drill point to the dial ring, in order to create an index marker. From this point, calculation of the gate position can be made, allowing a reading of dial numbers. Depending upon the design of the lock, the wheel closest to the hole will be the first or last to move. The farthest wheel from the drive cam will become the first number of the combination. In S&G locks that position the wheel post at the bottom of the lock case, the top wheel moves last.

35_6.3.4.1 Translation Theory

There are two fundamental principles that allow the translation of gate position from the drill point hole to the drop in point. Wheels are linked by flys and drive pins. They always retain their exact spatial relationship with respect to gate position. A combination that is run to a virtual index marker (positioned at the drill point hole) will result in all gates physically aligning to that point. The relationship between each gate and the virtual marker can be transferred to the real index marker. If the location of the physical drop is identified, then a correlation can be established between it and the drill point drop in point. The radial difference is added to each number of the drill point combination.

35_6.3.4.2 Translation Procedure

It is a relatively simple matter to translate the actual combination from the individual wheel position as each disc is observed with the borescope. An example, using an S&G 6730 three-wheel lock, will illustrate the procedure.

In order to extrapolate the number sequence of the combination, each of the wheels must be individually rotated as if the proper combination was being entered. A virtual index marker must be drawn vertically through the viewing hole. The center of each gate is aligned with this line. As each gate crosses the field of view, the number on the emergency dial is noted. When the "drill point combination" has been run so that all three wheels are aligned to an imaginary or virtual fence, the numbers are

translated to compensate for the difference between actual and virtual drop in point.

The hole must be in the proper location to provide a clear view of the edge of each wheel. Then the first, second, and third wheels are rotated, based upon the turning sequence of the lock. This is generally left-tight-left. Each of the gates is brought into view just as if there were an actual fence present. Once all of the gates are aligned to the virtual fence, **add** the proper number to equal the radial distance from the drill point to the drop in point. The product is the combination that will open the lock.

There may be a variance of up to five numbers. This will depend upon the precision of the computation of the radial distance from the actual drop in. Numbers are **added** to the combination to move the gates to the left; **subtracted** to the right. Test the combination on the drill point index marker first in order to be certain that each wheel aligns properly. It is always prudent to write down the translation numbers. If the lock won't open, oscillate the dial rapidly to shake or jar the fence into the gates.

35_6.3.4.3 Potential Problems in Translation

There are several factors than can affect the accuracy of translation. All can be determined through a process of trial and error.

35_6.3.4.3.1 Handing

The handing is significant when a lock is to be drilled. The position of the case must be known to determine the drop in point. If the door is open, the handing may be determined by examining the bolt and the direction it extends. A right-handed lock is one in which the bolt faces to the right, away from the hinged side. A LH lock will be the opposite. In VD and VU orientation, the bolts will face down or up. Generally, whichever direction the door opens or swings to will reflect the handing of the lock. Thus, if the door swings outward to the right, it has a right-handed lock.

35_6.3.4.3.1.1 Handing Error

A handing error can occur if the technician misinterpreted the lock or safe data. If a mistake is made in the determination of

handing, then the drill point will be incorrect for viewing wheels and their gates. If the gates can be observed, the problem can be corrected without drilling another hole.

35_6.3.4.3.2 Dial Removed Without a Reference Marker

If the dial has been removed without placing an index marker on the dial ring or safe body, then there is no direct way to correlate the position of the gates with respect to the drop in point. To remedy this problem, utilize a cutaway lock as a calibration model, or create a template and translate the information to another lock. A template is made by overlaying a piece of paper on the face of the door. Be certain that it is square, using the spindle as an anchor. Punch a hole through the paper at the drill point.

Remove the paper and draw a circle from the center of the spindle. If the drop in point is known and the handing of the lock is determined, then the radial difference between the two can be computed using another lock as a model. If the physical drop is not known, it can be extrapolated. This is accomplished by aligning the drive cam gate with the drill point hole, then rotating the emergency dial until the left and right contact points are determined.

The contact points can be felt as the lever rides on the drive cam. The left contact is most significant and provides the location where the fence can drop into the gates. Simply adjust the drill point combination by adding the difference. Obviously, there may be a tolerance error because the drop in area will not be precise with respect to the lever fence.

In all S&G, Federal, LaGard, and Diebold locks, the most common drop is 97. The Yale OC5 is 80 and Mosler 302 is 91. The physical drop for these locks will always appear between 80-97. In many of the Asian locks and some produced by Sentry, the bolt retracts directly into the gates. In such cases, the physical drop is 75. In the older Yale OB locks, the physical drop is 50-52.

If there is no indication as to where the physical drop might appear, it should be assumed that it will fall between 50-97. Start with 97, then 91, 80, 75, 60, and 50. Add a window of ±5 to allow for variances. Remember that the physical drop is the actual location where the fence drops into the gates, and not a

dial reading or dial number. The **drop in area** or **dial indicator** is the left and right contact points and provides the range wherein the drop in point can lie.

35_6.4 Detailed Drilling Sequence Overview

Drilling is the preferred method of forced-entry. As described elsewhere, a safe is penetrated by drilling, resulting from many factors. The technique will vary, depending upon whether the safe is rated for fire or burglary. This is because barrier materials are constructed and designed differently, based upon the security of the container.

Regardless of the design of the safe, however, the basic drilling procedure is uniform. It is premised upon creating an opening in a strategic location through which access to a critical locking component can be achieved. The goal is to disable, bypass, remove, view, or neutralize that part which is preventing bolt retraction. Usually only one hole is drilled and entry is effected; then the hole is repaired. Of course, if the placement of the hole is incorrect, then additional intrusions will be required. In 1987, Philips received a patent for a method to drill a safe under the dial ring that would permit precise measurement and viewing of the gate positions (**4662201(405)**).

35_6.4.1 Safe Construction and Drilling

The construction of the safe will define drilling procedure. Most safes contain three primary layers of protective metal: the outer mild steel skin, hard plate barrier material to protect the lock, and a final mild steel layer to which the lock is affixed. In most cases, three bits are utilized for penetration. The mild steel outer barrier is drilled with a high-speed steel bit to the **edge** of the hard plate. These HSS drills should never be used for stainless or hard plate. Titanium carbide tipped or diamond drills are usually employed for cutting through the armor plate. On the backside of the hard plate, an HSS bit is again used to enter the lock case.

35_6.4.2 Drilling Sequence

The drilling sequence for the lever fence in a **Group 2** lock with a regular dial (a Group 1 lock uses a similar technique) is illustrative of the required steps in the process. In order to penetrate a container to neutralize the fence, the technician

must:

- **Inspect the safe;**
- **Set the dial to zero;**
- **Mark the zero point on the dial, for reference. This is accomplished by drilling through the dial with a 1/8″ bit so that the tip will mark the door corresponding to the zero point;**
- **Drill a 3/16″ hole in the center of the dial knob until the spindle is reached;**
- **Tap the hole with a ¼ x 20 tap into the spindle;**
- **Thread a ¼ x 20 screw until the dial separates from the spindle. A puller can also be used if the dial is made of zamak;**
- **Remove the dial and dial ring or reduce the diameter of the dial;**
- **Overlay a drill template and square it or make precise measurements from coordinates;**
- **Center punch the drill point;**
- **Position the drill rig and determine the depth of penetration for each type of barrier material;**
- **Using a high-speed drill, penetrate the first mild steel barrier, generally 3/16″-1/4″, until reaching the hard plate;**
- **Verify that the drill bit is entering the container at precisely a perpendicular or proper angle (if not at 90º);**
- **Enlarge the hole for clearance of a tungsten carbide bit;**
- **View the barrier material to assess its makeup. For example, determine if the surface is rough or discolored, indicating an alloy hard plate;**
- **Using a tapered drift punch, break up or create small carbide chips, disturbing an otherwise smooth surface;**
- **When using carbide bits, alternately punch and drill at a speed of 1200 - 2200 RPM, with applied pressure;**
- **Periodically check the bit to insure that it is still cutting. This is accomplished by examining the material being ejected from the hole. It should**

be very fine metal powder;

- **Once the hard plate has been completely penetrated, use a high-speed drill to enter the lock case. Use extreme caution once zamak or similar soft material is encountered. Ejection of white metal chips is evidence of this. Once the case has been penetrated, stop drilling and replace the bit with a sharp one;**
- **Slowly penetrate the lock case, then blow out the hole to remove all chips;**
- **Use an emergency dial connected to the spindle to control the wheel pack;**
- **Scope or feel the wheel pack and drive cam and rotate until the lever drops;**
- **Open the lock.**

35_6.4.3 Drilled Hole Size

Once the decision has been made to open a safe by drilling, consideration must be given to the diameter of the hole. Although a larger hole can afford more room to manipulate a borescope and other tools, it is also more difficult and time consuming to complete. The size of the hole will in part be based upon the tool used to create the opening: drill, hole saw, torch, thermic lance, or other technique. This in turn will be dependent upon the type of container, the lockout problem, the amount of accurate data available regarding the container, and whether the hole is to be repaired.

The rule of practice has always been a ¼” opening. However, such a hole has several disadvantages:

- **A small hole requires precision in locating the drill point;**
- **There is no tolerance for error, especially through a thick door, if the drill point has been calculated in error. This is even truer where drilling is at an angle or the drill has drifted;**
- **The tunneling effect when using an ophthalmoscope or otoscope is severe; it is compounded with a small opening. Without a borescope inserted into the body of the container, the view resembles that of looking through a drinking straw;**
- **A small-diameter drill bit has a weak shaft and will**

break or bend easier when under the pressure required to penetrate hard plate;
- **Enlarging a hole can be time consuming, difficult, and costly.**

Although a greater hole size can take significantly longer to achieve, there are several advantages to a 3/8″ or larger opening, including:

- **Measurement errors can be overcome and the target area still observed or manipulated;**
- **Errors in angled drilling may be remedied;**
- **Bits will not be so likely to break under pressure;**
- **Room to manipulate internal components, especially relockers and bolts, can mean the difference between a successful opening and failure.**

A preliminary determination should be made as to the tools that will be required to pass through the hole in order to open the safe. If a hole is made solely for scoping the wheel pack or other components and the borescope allows for an angled view, then the size of the hole becomes far less critical. The diameter can be just slightly greater than that of the scope. If, on the other hand, relockers, bolts, levers, or other components must be physically manipulated, then a larger tool and leverage may be required.

35_6.5 Hard Plate Barrier Material

35_6.5.1 Introduction

Hard plate is a specially formulated metal that is used to protect the lock, boltwork, and relockers from drilling. The material can be extremely hard, often having a Rockwell C rating approaching 90 or above. Hard plate can also be a combination of hard and soft metals. This discussion will address anti-drilling features incorporated into most types of barrier material, as well as drilling technique that must be utilized with these metals. See **Chapter 5** for a detailed analysis of the metallurgy involved in the formulation of tempered hard plate.

Hard plate is known by many names, depending upon the manufacturer: Relsom (Mosler), Maxaloy, Kimloy, aloxite (Chubb). The composition can be case-hardened, laminates, or plastic

polymers, and incorporate other materials for secondary protection. There is a class of hard plate known as "superalloys," based upon their exotic mixture of additives. These are employed in very high-security containers. Interestingly, the metals are not as hard as hardened steel but have optimized high-strength with deformation characteristics. This will allow them to deform plastically when pressure is applied during cutting.

The characteristic of **plastic deformation** explains a condition that is encountered by safe technicians when drilling these materials. The condition is identified by the appearance of a small, bright conical indentation within the hole being drilled. The crater is caused by the application of pressure from a hard drill bit that actually rearranges the work surface. A small amount of metal is actually removed during drilling; its position is simply altered.

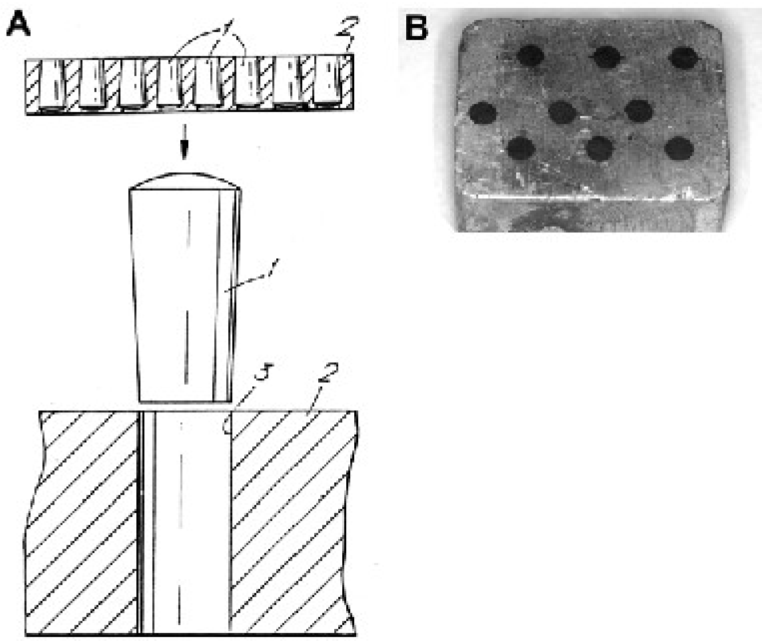
All hard plate is designed to accomplish one primary task: prevent penetration or cause significant delays in the process. Differences in each product, or even each within a batch from the same manufacturer, may present varying levels of difficulty in drilling. This can be based upon the ratios of chrome, tungsten, carbon, nickel, and other elements. Characteristics of hard metals are dependent upon complex and sophisticated metallurgy that may take years to develop. Regardless of origin, the material will provide significant resistance to drilling, abrasion, concussion, and heat. Special tools and procedures are required to penetrate it.

Hard plate is generally placed between the lock and the front of the door, mounted either vertically or at an angle of up to 15°. The barrier, usually ¼"-3/8" in thickness, will protect critical components from attack. Fire safes generally have a barrier of no more than 1/8" because the goal is to protect against fire and not burglary.

35_6.5.2 Overview: Metallurgy of Hard Plate

The principles of metallurgy that form the basis for the development of hard plate is discussed in detail in **Chapter 5** but will be summarized here. Metals are hardened in many different ways. Each technique utilizes different processes involving the absorption of carbon (case-hardening), as well as heat treating and quenching. The method of hardening will in part dictate the procedure for drilling. Case-hardening, for example, will only

affect the skin of the material, but not the center. See **Chapter 3** of Price for a historical reference regarding the use of case-hardening in safes.



Usually, cold rolled plate steel is placed within a furnace in an atmosphere of oxygen or nitrogen for a precisely controlled period. Carbon, ammonia, and other elements and compounds may be added. The material is cooled or quenched to complete the hardening process. The hardness of the steel is primarily dependent upon its chemical composition (iron and carbon). Alloy steel will contain other materials such as nickel, molybdenum, and chromium. These metals will add special characteristics, detailed in **Chapter 5**, and will be classified according to a numbering system developed by the Society of Automotive Engineers (SAE). This protocol, using a four-digit number, will define the type of metal and carbon content.

Hard Plate Alloy is a unique blend of metals used for high-security containers. It should not be confused with alloys that are mixed with hard plate to enhance the strength or hardness characteristics of the metal.

"**Included Hard Plate**" contains a layer of ceramic, bronze, epoxy, or other metals. Within this layer are included a matrix of small chips or pieces of cobalt, cemented tungsten, tantalum, titanium carbon grains, carbide, aloxite, nickel, or other materials.

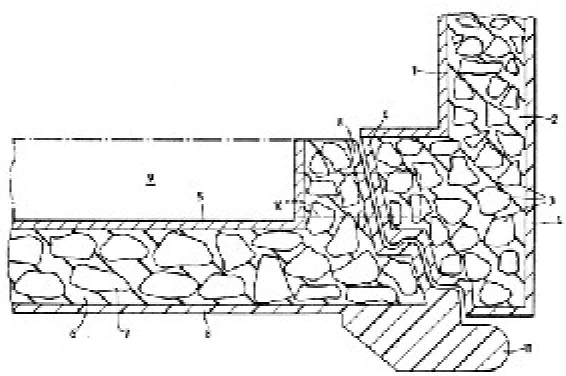
Their consistency and density forms a coarse and jagged skin that presents an irregular surface to a drill bit.

Laminates may form a sandwich of hard plate with soft steel, copper, and other metals. Each layer will provide unique protection against a form of attack.

Spattered hard plate is steel coated with tungsten carbide or T/C, brazed or welded to the surface.

Ceramics comprise another group of barrier materials. Characteristics of ceramics provide drill resistance and heat deflection.

Composite materials will contain high tensile-strength concrete and steel. The more sophisticated of these will be mixed with hardened pins, ball bearings, ceramic balls, chips, deformed steel rod, and other materials.



35_6.5.3 Anti-Drilling Techniques and Materials

Many improvements in barrier materials have occurred during the past two centuries to frustrate drilling. Originally, the concept was to protect the door with laminations composed of iron, laced with studs. Then, steel was employed with hardened discs that were free to rotate. Case-hardened plate was also placed behind the keyhole for added protection. Chubb has continued to lead the industry in methods to make barrier materials more resistant to attack. See for example their process for producing an anti-drill barrier structure for safe or strong room doors or walls (GB **2153406A(406)**) granted in 1985. Other relevant patents include (GB **2197362A(407)**) issued to Chubb in 1988

Today, a variety of materials and techniques are available to make penetration by drilling and other forms of attack extremely difficult. Barriers utilize metals having high Rockwell C ratings. Layers of aluminum, mild steel, high-density concrete, and manganese provide additional resistance. Randomly embedded ceramic or metal nuggets, anti-drill closely spaced arrays of carbide pins, balls, rods, discs, or loose or pressed ball bearings also make drilling difficult. Bearings that are free floating will generally be suspended in oil.

Metal chips can also be welded to the surface of hard plate to make drilling extremely difficult. Mosler, which produces a barrier material, utilizes this technique. Sophisticated heat sinks using beryllium and copper plates, or metals with similar characterizes, are employed to draw high temperatures away from an area that has been attacked by a torch or red-hot drill point. Various mechanical obstructions can also impede drilling. For example, the **Deflector** is incorporated within high-security Chubb safes to deter drilling. This is actually a piece of angled steel that is placed in strategic locations to prevent a drill bit from penetrating critical locking components.

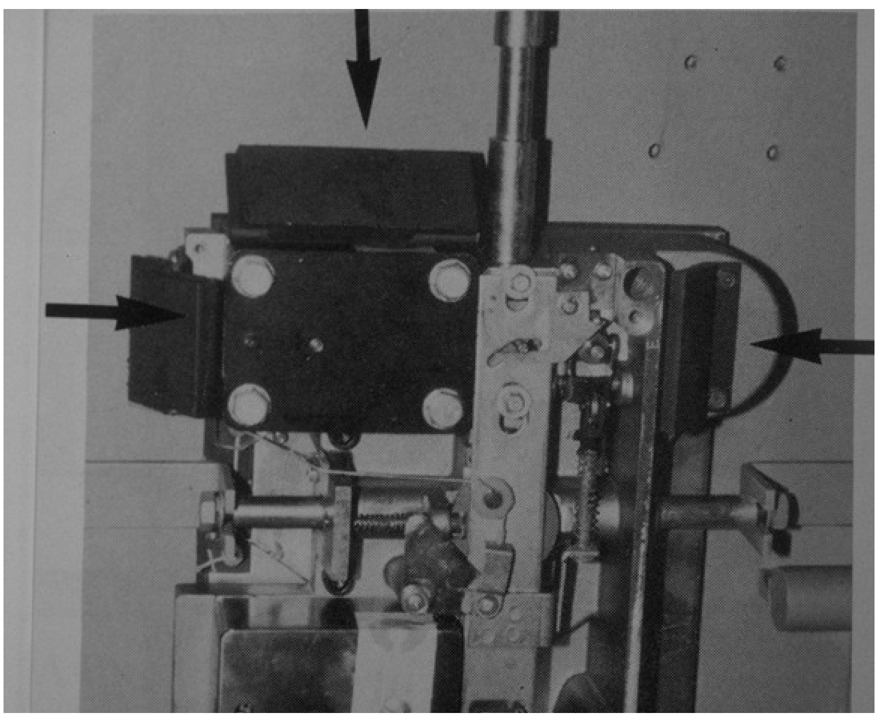


Figure LSS+3538 (ISP 23-2963) Deflector plates made of angle iron are added to deter drilling.

35_6.5.4 Penetrating Hard Plate by Drilling

Depending upon the material, there are several basic approaches to the penetration of hard plate. However, all principles of drilling are based upon **speed, pressure, and stability**. Their proper combination will cause the drill to become hot enough to melt or anneal the barrier, allowing removal of material from the hole. Drilling technique is also based upon the type of drill employed. Cutting techniques for each bit is discussed subsequently. A description of the different types of bits was covered earlier in this chapter.

35_6.5.4.1 Speed

Speed is dependent upon the material and is identified as low (0-600 RPM), moderate (600 - 1500), and high (2000 - 5000). Drilling speed is of prime importance in the penetration of hard plate. It controls the way in which the bit attacks the metal, how much metal is removed, and the life of the drill bit. The differences in hard plate and drill tips will determine speed.

There is a divergence of opinion as to the most effective way to penetrate hard plate. One theory holds that extreme speed and pressure is the optimum technique. The other theory requires that controlled pressure with low speed will yield the best results. Both methods work. Personal choice dictates the approach that is taken.

35_6.5.4.1.1 High RPM Drilling

High-speed drilling requires that the drill motor is operating at 4000 - 5000 RPM and that it is accompanied with high pressure placed on the bit. When the two functions are combined, friction and heat are the products. The heat, in turn, will anneal or soften the work surface so that the red-hot tip will be more efficient at cutting.

Once drilling has commenced, it should be continued until the hard plate has been completely penetrated. If drilling is interrupted, then the material can become heat treated and hardened. A balance must be reached because the carbide tip can become brittle and shatter or may soften and lose its ability to cut.

35_6.5.4.1.1.1 General Guidelines for

High-Speed Drilling with Carbide-Tipped Bits

The following general rules apply to high-speed drilling:

- **Only use a carbide bit to penetrate treated metals;**
- **Be certain that the bit is not dull in order to optimize cutting and reduce the generation of heat;**
- **Use a high-quality bit with brazed, rather than soldered tips. The plating finish will be gold in color;**
- **Insure that the bit has a positive rake for tempered steel and a negative rake for alloy hard plate;**
- **Create friction and heat through the application of the proper amount of pressure;**
- **Stop drilling when the hard plate has been drilled through;**
- **Do not use a carbide bit to penetrate the lock case;**
- **Be certain that there is a controlled pressure feed to avoid damage to critical components;**
- **Only penetrate alloy hard plate using high speeds.**

35_6.5.4.1.2 Low RPM Drilling

Low-speed drilling generally falls into the range of 500-2000 RPM. A drill motor with high torque is required to compensate for the decrease in speed due to the applied pressure. Usually a four-ampere or higher motor is necessary with fixed speed, or a gear drive change for speed ranges.

Speed is a function of pressure; to optimize both can be somewhat tricky. Perhaps the best indication is the continuous ejection of metal filings from the hole. Tempered steel drilling requires sufficient pressure to cause the bit to cut metal. Bits can utilize soldered rather than brazed tips, because the generated heat is diminished. Although the drill bit will have a greater tendency to catch and break, less expensive bits can be used successfully.

35_6.5.4.1.2.1 General Guidelines for Low-Speed Drilling with Carbide-Tipped Bits

- **Drill motors must be relatively stable to eliminate wobble and drill misalignment;**
- **Inexpensive drill bits can be used;**
- **Utilize high pressure on the bit;**
- **Utilize a drill rig if possible, rather than a handheld motor;**
- **Optimum speed and pressure will result in a continuous curl of metal being ejected from the hole;**
- **Do not penetrate soft metals with carbide bits;**
- **Do not penetrate alloy hard plate at low speeds;**
- **Most barrier materials can be drilled at 1000-1500 RPM, with a properly sharpened bit;**
- **If attempting to drill through the Chubb aloxite barrier material, low RPM and high pressure is recommended.**

35_6.5.4.1.2.2 General Guidelines for Drilling with HSS Bits

If a high-speed steel bit is to be used for penetrating alloy hard plate, the following guidelines apply:

- **Prevent excessive heat that can cause work-hardening of the material. This can be accomplished by controlling drill motor speed and the drill rate. Generally, an accepted rate is 40 - 50 surface feet/minute (SFM). The formula to compute speed is based upon the drill bit diameter. Thus: RPM = 3.8 (SFM/DRILL DIAMETER IN INCHES);**
- **Use caution to avoid fracture or breaking of the bit;**
- **Sharpen the drill bit with an included tip angle from 135º-140º and a clearance angle of 6º-8º;**
- **Do not allow the drill bit to run in the hole without the application of pressure;**
- **Cobalt drills can be run approximately twenty percent faster;**
- **Carbon steel drills should be operated at forty to fifty percent slower rate;**
- **Use cutting fluid, if possible.**

35_6.5.4.2 Pressure

Pressure is a critical component of the drilling process. It controls how a drill bit cuts and the temperature that is created during penetration. Improper pressure will cause bits to fail and break, thereby sealing the hole. Fracture can also occur as the bit breaks through the hard plate.

Sufficient pressure is required to begin the cutting process on the outer surface of the hard plate. Usually, the more pressure, the better, although this is not always the case. However, the larger the bit, the more pressure that is required. The best rule in determining the proper amount of pressure: listen to the drill motor. Pressure is a function of speed. Tungsten, cobalt, and carbide-tipped bits require high pressure, together with speeds between 2000-5000 RPM. Drilling angles are usually set at about 15°, depending upon the thickness of the material.

35_6.5.4.3 Drill Motor Stability

The stability of the drill motor is extremely important for many reasons:

- **Prevent failure of drill shank and tips;**
- **Allow application of proper pressure while drilling;**
- **Allow for the proper generation of heat caused from the interaction of the drill tip to the work surface;**
- **Reduce the danger of injury to the operator.**

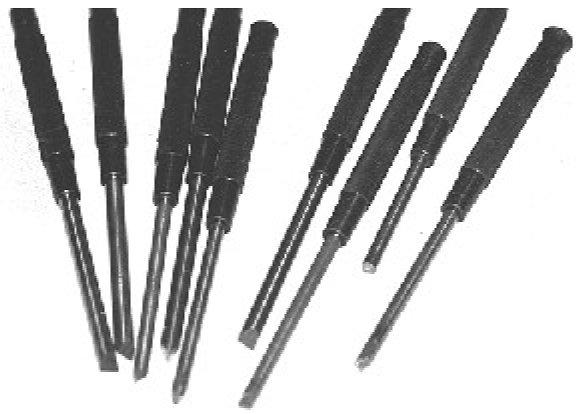
35_6.5.4.4 Drilling Technique for Hard Plate

Hard plate requires special drilling technique due to the toughness of the material. Two primary rules apply: **the drill bit must be harder than the hard plate, or the hard plate must be altered to allow cutting by the drill.** Pilot holes should not be made in hard plate, especially if using a handheld drill. The irregular surface and small bit diameter will cause the shaft to flex and break. Generally, red-point drilling (that anneals the material) is required. A punch is also employed prior to the use of the drill, in order to shatter the carbide and ceramic bits that are bonded to the surface of the hard plate.

Once drilling begins, there will come a time when progress is

slowed. At this point, a punch is again employed to shatter the hard chips. This may require several blows. Drilling is resumed. The process of alternating between drilling and punching takes advantage of the brittleness of the barrier material to fracture it, allowing the bit to penetrate.

Standard punches can be utilized if there is a means for sharpening them during the drilling process. Pieces of drill rod, flame-tempered until straw in color, can be immersed in oil to make a hard punch. A hammer drill, with an impact bit or star drill, will also work.



Steel ball bearings may be embedded in the hard plate. These can be loose, either suspended in oil or pressed. In such a case, they must be hit with the punch to stabilize them, then drilled.

35_6.5.4.4.1 Drilling Alloy Hard Plate

Drilling in wood, mild steel, and tool steel has little resemblance to penetrating hard plate. Drilling of alloy hard plate requires special procedures because of the usually rough surface of the material. The following guidelines apply:

- **Be certain that the drill bit is harder than the material to be penetrated;**
- **Prepare the surface prior to drilling. This requires that any rough texture is smooth or flat and any irregularities such as chips are removed. Failure to do so will destroy the cutting edge of the drill bit;**
- **Chips are brittle and can be hammered and punched until they are broken and can be removed. Use a**

flat-end drift punch and a two or three-pound hammer, followed by a center punch;
- **Both positive and negative rake bits can be used, although negative is recommended;**
- **Alternate between punching and drilling;**
- **Do not use a slow drilling speed. This will avoid catching the tip on the work surface;**
- **Do not use high speed unless quality bits are employed. Otherwise, a mid-range speed of about 2000 RPM is optimum;**
- **Controlled high-pressure is required. This can only be provided by a lever or fixed rig;**
- **Keep the drilling sequences of short duration, generally no longer than thirty seconds;**
- **Continually check the cutting tip and depth progress;**
- **If a very fine metal dust is produced, the pressure must be increased or a new bit installed;**
- **Few chips will be created during drilling; this is normal.**

35_6.5.4.4.2 Included Hard Plate

A "punch and drill" protocol is required for these types of materials, using motor speeds of between 1000-1500 RPM. Masonry or a die-marker type bit should be used initially to make an indent in the surface. Then, a punch is placed in the hole and struck with a sledgehammer in an attempt to fracture the surface. Drilling is resumed. The process is repeated until the hard plate is penetrated.

35_6.5.4.4.3 Splattered or Welded Hard Plate

A combination of techniques previously described may be used with this material at a drill speed of 1500-2000 RPM, and moderate pressure. Red-point drilling is not required.

35_6.5.4.4.4 Composite Materials

A fixed drill rig is required for penetrating these materials. Utilize HSS, masonry bits, cobalt, TIN coated bits, hammer drills, or a thermic lance. Composites can be exceedingly difficult to drill and usually have secondary layers of barrier

materials for added security.

35_6.5.4.5 Red-Point Drilling

Red-point drilling is a process that anneals the work surface to make it less resistant to penetration. The procedure generally requires high drill-motor speeds, coupled with moderate pressure using a carbide bit. The result is a rapid generation of heat, causing the tip and work surface to become red-hot.

35_7.0 Detailed Drill Point Information

35_7.1 Introduction

Holes allow observation or manipulation of critical components. The lock or safe body is penetrated to accomplish a specific goal, based upon the design of the container, barrier material, its condition, previous entry attempts, security rating, and type of lock. The following discussion describes all of the traditional drill points (whether inside or outside the dial ring), as well as special application notes where relevant.

35_7.2 Specific Drill Point Identification: Inside or Outside the Dial Ring

The following discussion provides detailed information regarding all drill points used for the penetration of safes. Drilling can be defined within two distinct categories: **inside**, or **outside** the dial ring. Drill points outside the dial ring can be further subdivided: drilling **within the door area**, and **all other places** within the container. The decision as to where to drill is based upon many factors, including:

- **The container;**
- **The lock;**
- **Reasons for penetration;**
- **Personal preference and experience;**
- **Cost and benefit of each method or technique;**
- **Opening strategy.**

Drilling within the dial ring is required in order to obtain a view of critical locking components or to neutralize them. Each

of the recognized techniques is described below. Drilling outside the dial ring is generally performed to manipulate, view, or bypass the bolt works or relockers.

Generally, a hole is made under the dial ring if the dial cannot be removed, the lock cannot be identified, or the physical drop cannot be determined. Once a hole is placed in the correct location, the gate positions are read and translated to the physical drop. If the drop in point is also unknown, a correlation is computed between the hole and cam gate. Our discussion will identify all drill points that are available for successfully penetrating a security container, without differentiating whether they are inside or outside of the dial ring.

35_7.2.1 Bolt

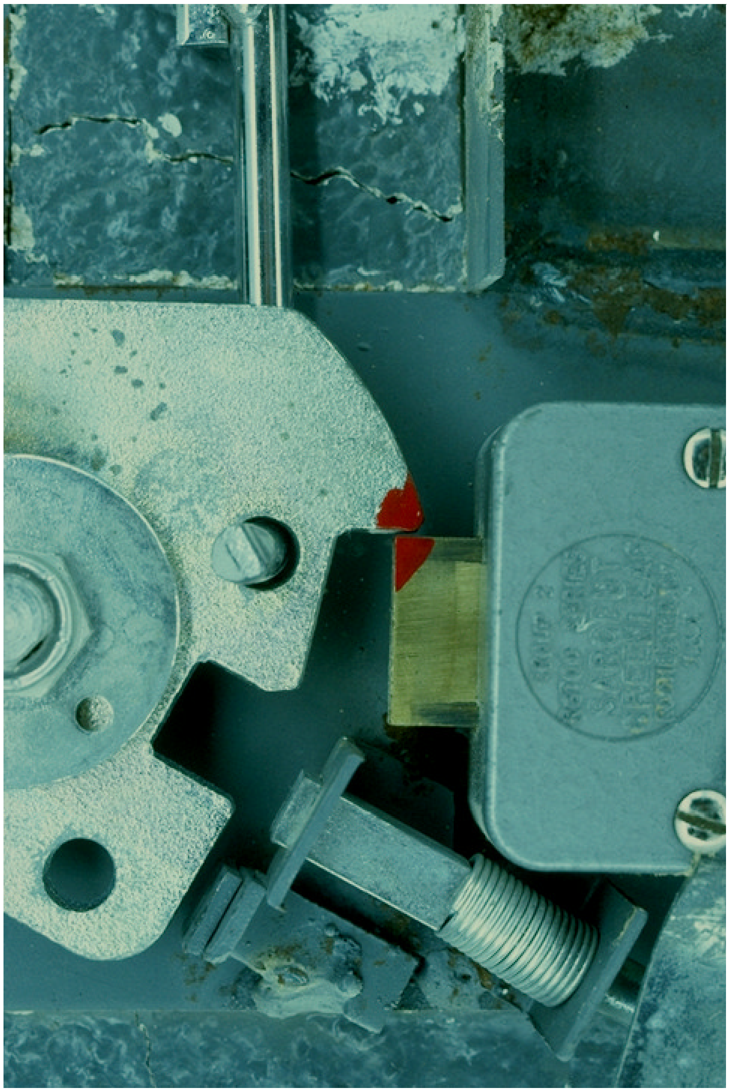


Figure LSS+3539 (ISP 104-3563) The bolt is punched out of the way (shown in red) in order for the handle cam to be rotated.

A hole may be made to the side of the bolt in order to accomplish three tasks:

- **Manipulate or punch the locking bolt out of the way;**
- **Permit the locking cam to be rotated or moved;**
- **Force the bolt, through the application of**

pressure.

35_7.2.1.1 Pressure Applied to Bolt works

Penetration through the side of the safe is standard procedure when there is a mechanical linking problem that prevents the handle or other mechanism from actuating the bolt. In some inexpensive safes with a direct-entry fence, the connecting piece fails, causing the handle to spin freely. The same opening procedure can also be applied to a fired relocker. The container is side-drilled on a line equal to the centerline of the dial and handle, and toward the rear, a couple of inches. A ¼″ hole is made, and a punch or long rod is used to push the bolt to the unlocked position.

If a punch fails to move the bolt bar into the door, a larger hole should be made and then tapped. Use a grade 5 bolt, forcing it forward as with a dent-puller. This method can also be employed to dislodge the lock and relockers. When this technique is employed, care should be exercised not to apply pressure to the bolts near the top or bottom of the bolt bar, as bending may result. Target the bolts closest to the lock.

If the location of the bolt cannot be determined, check the jamb for paint chips or markings. Bolt width for most standard combination locks, including S&G, Mosler, and LaGard, is precisely 1″; the door bolts are generally ¾″ to 1″ in diameter. Although most high-security containers include protection to neutralize side pressure applied to the bolt, the procedure can be used to bypass glass plate, relockers, and hard plate barrier materials. In some instances, a small safe can be moved or vibrated so that gravity can remedy the problem of a broken link. This is not, however, a reliable method in all cases.





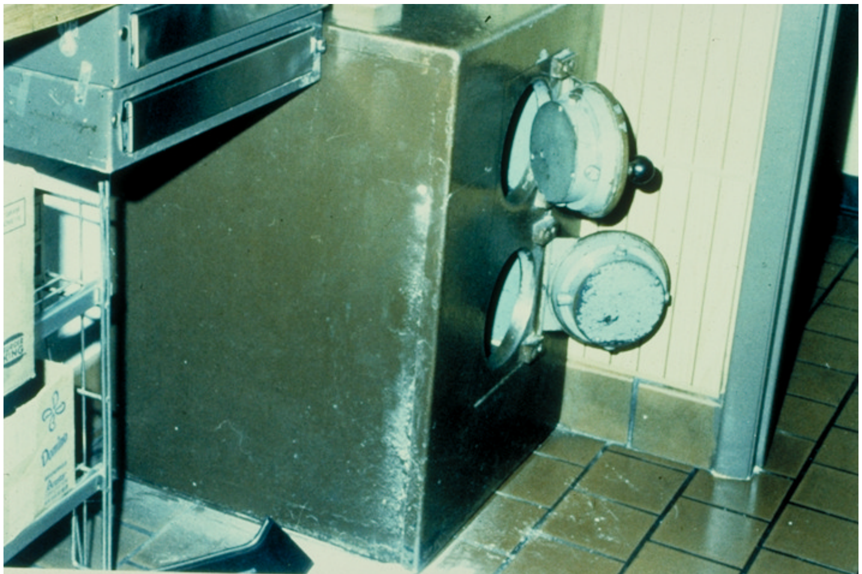


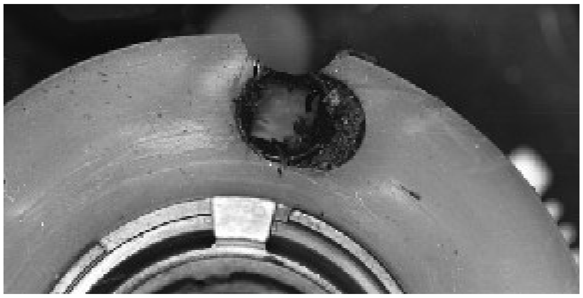


Figure LSS+3540 (top left, ISP 2-2963; right 3-2963; bottom left 5-2963; right 6-2963) In 2,3 above, burglars drilled into the side of the safe to punch and drive the bolt out of the way. The same procedure was utilized in 5,6. Courtesy of Illinois State Police, Bill Sherlock.

35_7.2.2 Creation of Gates

An infrequently used procedure allows for the creation of a completely new set of gates in the wheel pack. This is

accomplished by drilling a hole through the edge of all wheels to allow retraction of the fence.



35_7.2.3 Change-Key Hole

Use of the change-key hole for reading wheels, by Harry Sher

All modern programmable mechanical locks have an opening directly into the wheel pack through the back of the lock case. This aperture provides a view of the gates of each wheel, eliminating the need to make a hole through hard plate barrier material and obviating the hazard of triggering a glass relocker. This method of entry eliminates penetration of the door, and the attendant need to replace the lock. Some safe technicians will drill directly through the **front** of the lock, at the precise position opposite to the change hole.

The change-key opening can also be probed using a borescope in order to view and decode the wheel pack. A drill point must be located that will allow the borescope to view the back of the lock case through the keyhole. Depending upon the angle of entry, a 90° viewing angle for the borescope may be required. A hole can also be drilled through any side of the container in line with the change-key entry point in order to accomplish the same result. This procedure can eliminate the requirement of drilling through hard plate.

Prior to drilling for a view of the wheel pack from the side of the safe, the following information must be determined:

- **Door thickness to the back of the lock case. There is often a metal strip called a "door stop," to prevent the door from swinging inward too far. A thin ruler or sheet of plastic can be slid into the crevice between the door frame and door in order to**

determine its thickness.

A precise method for determining door thickness requires that the dial be pulled from the spindle. Be certain that the drive cam is against the lock case cover, by pushing the spindle inward. A thin wire is inserted next to the spindle until stopped by the drive cam post. Add ¾" to the length of the wire in order to compute the dimension between the door face to the back of the lock case for an S&G. It is often wise to add another 1/8" to account for the thickness of the case covers and spindles that may have been cut slightly longer than required.

- **Handing of the lock. The shape of the change-key hole appears like an arrow, and will point in the direction of the locking bolt. In this manner, the handing of the lock can be determined;**
- **Internal layout of the boltwork;**
- **Location and design of relockers;**
- **Interior design of the safe;**
- **Critical components or obstructions;**
- **Position and mounting of the safe;**
- **Location of the hinges.**

The procedure to determine the combination from the change-key hole requires:

- **Alignment of the square holes in the wheels so that they are in line with the change-key hole to provide the combination to the change index, then correlate the reading;**

- **Alignment of the gates at the change-key hole, beginning with the wheel closest to the probe.**

A video camera head attached to the borescope allows this procedure to be performed without difficulty. Otherwise, the scope must be placed within arm's reach of the dial, so that the wheels can be rotated while observing them.

35_7.2.3.1 Obstacles and Difficulties

Hard plate between .375"-.5" will often be placed at the back of the door to which the lock is affixed. There may also be a plate that covers the lock or there may be an air gap of up to ½". If

the drill point is not positioned correctly, the scope may be outside of this plate and adjacent to the lock. This will make viewing almost impossible. Poor lighting or the angle of view can cause translation errors, too. This can result in greater difficulty in alignment of the gates.

Locks with the drive cam next to the rear cover can pose added difficulty. In such cases, once the first wheel has been decoded, the discs behind it are obstructed from view. The cam must then be read at the change index line. This wheel will constitute the **third number** of the sequence. The second and third wheels are actually read through the gates and require special positioning of each disc during the decoding process.

The process requires an understanding of the relative position of the **gate**, **change hole**, **balance hole**, and **rivet** on the wheel. The gate and change-key hole are always fifty numbers apart. The rivet in the center of the wheel is equidistant between the two (twenty-five numbers from either). The balance hole is approximately ten numbers from the gate. Knowing the reference markers can make the process of decoding these locks straightforward.

Although necessitating replacement of the lock case, some safe technicians will drill the lock from the front at the opposite side of the change-key hole. This will provide a direct view, allowing wheel alignment in the normal sequence. A modified change-key is then inserted through the door and into the lock. The wheels are unlocked and set to a single number for opening. High-security Group 1 or 1R locks can contain non-metallic wheels made of synthetic materials. White plastic or other polymers can present a problem in viewing due to the lack of contrast.

35_7.2.3.2 Alignment of Gates v. Change Hole

Both the square change hole and gates can be aligned to derive the combination at the index line. If the square hole is chosen, simply decode the combination. Then factor in the radial distance between the changing index and the zero-index marker to determine the correct number sequence. The wheel gates and the change hole are 180° apart (fifty numbers). If the change hole were positioned at 10 on the index line, for example, then the true combination would be 60 at the zero marker.

35_7.2.4 Drilling Within the Dial Ring

A full-sized dial ring will cover all of the drill points within a lock case that are traditionally utilized for scoping or neutralization of components. In older safes, an exploratory hole can be made through the ring to determine the position of the physical drop. It is necessary to drill through the dial ring when working on old locks with brass and steel dials, because they cannot be removed. In certain cases, the only facts that may be known about a safe are:

- **The absence or presence of a change-index marker on the dial ring;**
- **Whether there are numbers between 0 and 20;**
- **Whether the dial can be removed;**
- **Whether there are any welds on the container.**

A small hole for a probe will reveal the location of the gates, and the type of lock.

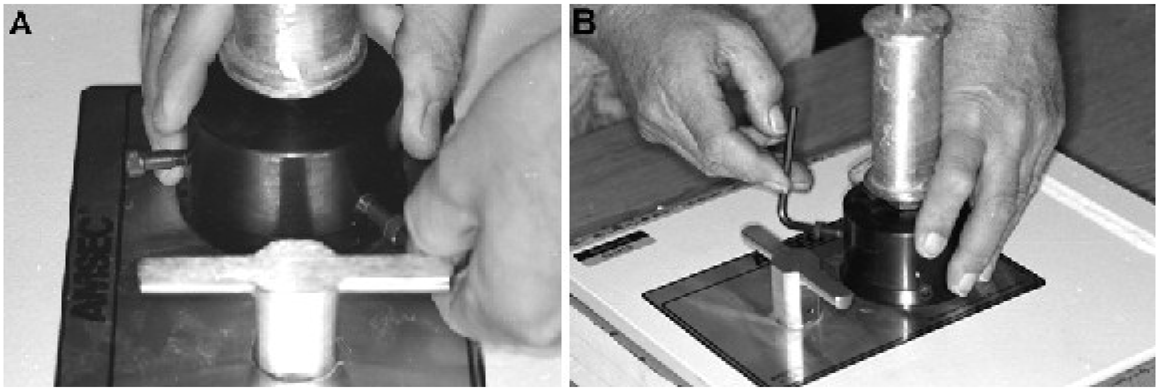
35_7.2.4.1 Overview of Drilling Procedure

Two critical drill points can provide information sufficient to open the lock. In the S&G, these are at 14 and 36. Generally, holes are angled to the left and downward toward the center of the dial. The optimum exit point will fall below the mounting screw, yet at the edge of the wheel pack.

Care should be taken to execute a proper angle of entry. This will avoid missing the lock entirely, or obtaining a view of the wheels that yield no information. If the angle is incorrect, redrill through the same hole. The actual angle will be dependent upon two factors: door thickness, and the position of the lock.

35_7.2.4.1.1 Dial Removal

The above-described procedure usually requires that the dial be removed or modified to allow clearance for the drill. There are four primary means for accomplishing the task. Certain dials cannot or should not be forcibly removed from their connecting shafts because they are threaded and pinned to the spindle. If pulling is attempted, the dial, drive cam, and internal components of the lock will be destroyed.



35_7.2.4.1.1.1 Excessive Force

Do not use excessive force. If the dial cannot be pulled easily, utilize other means of removal. Do not pull if the following conditions exist:

- **The dial is made of brass, bronze, steel, or resists pulling efforts;**
- **The dial is not made of zamak;**
- **Dial is on a TL rated container;**
- **A Manipulation-proof lock such as S&G 8400 or 8500 series, where the butterfly and inner spindle must be used for opening;**
- **Dial that is threaded or pinned to the spindle.**

Failure to adhere to these guidelines can result in:

- **Damage to the spindle;**
- **Damage to the lock;**
- **Damage to lock case;**
- **Spindle breakage below the surface of the door;**
- **Loss of contact between the drive cam and the last wheel.**

35_7.2.4.1.1.2 Pulling the Dial

Most dials can be removed with a pulling tool described in **Chapter 32.** Dial or dent pullers utilize a sliding weight to exert a counterforce that is sufficient to separate the dial from the spindle shaft. Generally, the process used by the

manufacturer for affixing the dial involves pressing of the straight knurled end of the shaft into the soft metal (usually zamak) dial.

35_7.2.4.1.1.3 Center Tapping

Dials can also be removed by tapping a hole in the center, just to the end of the spindle. A ¼ x 20 bolt is then utilized to forcefully withdraw the dial by screwing it in and tightening it against the spindle. This method reduces the possibility of warping the lock case.

35_7.2.4.1.1.4 Prying Loose or Breaking

Use one or two screwdrivers, sharp wedge, or a chisel placed under the dial to slowly pry the entire assembly upward. The dial should be rotated to insure that a constant and equal force is applied. A sharp chisel and hammer can also be employed to crack the dial and break it apart, or vice grips can be used to rock the dial loose.

35_7.2.4.1.1.5 Reducing the Dial Size

If the dial cannot be physically removed, then its diameter must be reduced using a 1½" hole saw. This method will provide drill point access behind the numbered portion, by separating it from the nose of the dial. The procedure also makes repair of the door easier, without the necessity of welding, grinding, or repainting. Prior to performing this procedure, the following steps must be accomplished:

- **Note the left and right contacts points;**
- **Mark the zero point of the dial on the center of the nose and on the face of the door;**
- **Rotate the dial four times right to pickup all drive pins, thus preventing them from slipping when the dial is removed;**
- **Prevent the dial from moving by wedging a small screwdriver underneath the lip;**
- **Certain drill rigs require a reduced nose diameter, to approximately 1 1/8", in order to accommodate the template. A die-grinder can be used for this purpose.**

A standard hole saw without the pilot bit is utilized with a

variable-speed drill. Care should be exercised that the drive cam is not suddenly rotated, thereby damaging drive pins and flys. Saw evenly around the dial.

Note that zamak is an alloy of relatively soft metal. Generated heat will have a tendency to cause the material to become spongy and clog the teeth of the saw. This results in binding and grabbing of the dial. Cutting should be accomplished in short bursts to minimize the potential for damage to the lock and insure the safety of the operator.

35_7.2.4.1.1.6 Emergency Dial

An emergency dial may be required for use with a burglarized safe where the spindle has been broken and the dial and dial ring have been removed. If the spindle can be turned and the lock has not been damaged, an emergency repair dial can be utilized to rotate the wheels. The safe technician should carry dials with different shaft diameters for this purpose.

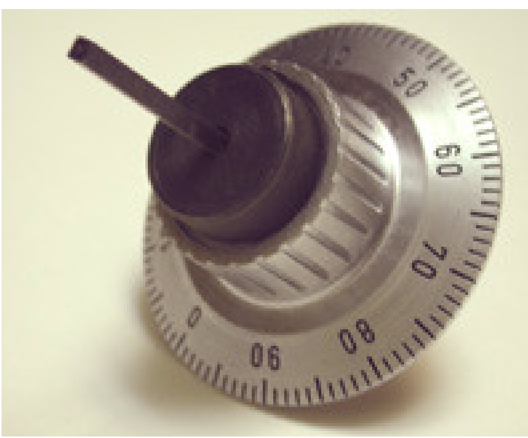




Figure LSS+3504 Emergency dials

The emergency dial has three components: the main body (knob and pointer ring), a moveable number ring, and a square rod with a pointed end. Generally, the number ring is secured on the pointer ring with a setscrew. The rod is removable from the knob and its length is adjusted with a setscrew. A round nut with a soft wire pointer, tapped to accept a specific spindle thread, can also be used as a dial. In such case, a number template must be utilized to simulate a normal dial.

In order to use the emergency dial properly, the contact points must be known. Once the dial is attached, it is turned to the right to feel the contact area. Once determined, the knob is

placed at the precise location of the right contact, and the number ring rotated and locked to that position. A note of caution: if the dial must be hammered onto the spindle, the spindle should be isolated with a wedge or vice grips prior to exerting force. This will prevent driving the spindle into the lock case, which can result in knocking off the back cover and triggering a relocker.

35_7.2.4.2 Scope the Wheels

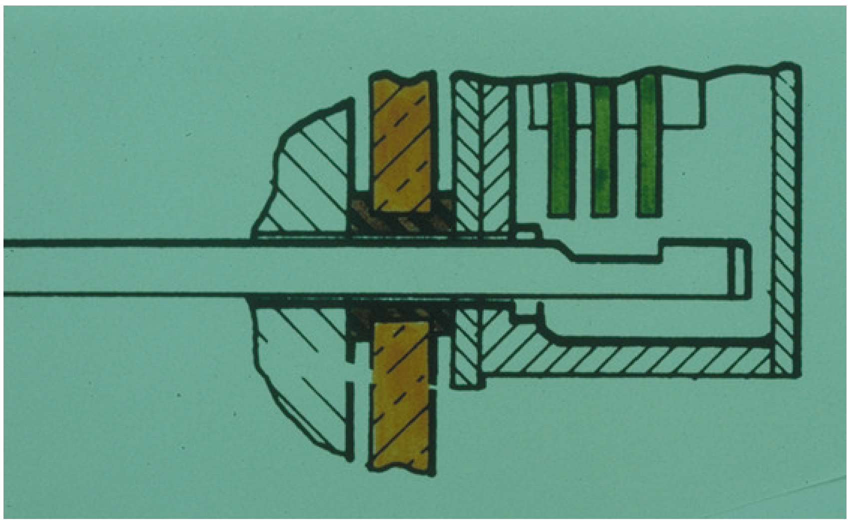


Figure LSS+3541 (ISP 17-2963) A scope is inserted to obtain a view of the wheel pack.

A hole can be made almost anywhere under the dial ring for scoping the wheels. The view will provide the location of the gates, so long as the hole is near the edge of the discs. The preferred location on an S&G lock is at 14 or 36, with a slight angle toward the center.

35_7.2.4.2.1 Feeling Wheels and Gates

When a borescope or other optical device is not available, a feeler probe may be used to obtain a tactile response. This allows the technician to determine gate position and to physically move wheels. A probe is inserted into the hole and pressed against each wheel, in the same fashion as if an optical device were being used. To determine the position of each gate, the wheel farthest from the drive cam must be probed first. As each disc is rotated, the device is pushed forward to read the

next gate, until the wheel pack has been completely decoded.

35_7.2.4.3 The Fence

There are two procedures pertaining to the fence: **scoping** and **drilling.** The first involves observing it and the position of the gates. The other procedure allows it to be removed by drilling, thereby freeing the lever to drop into the drive cam.

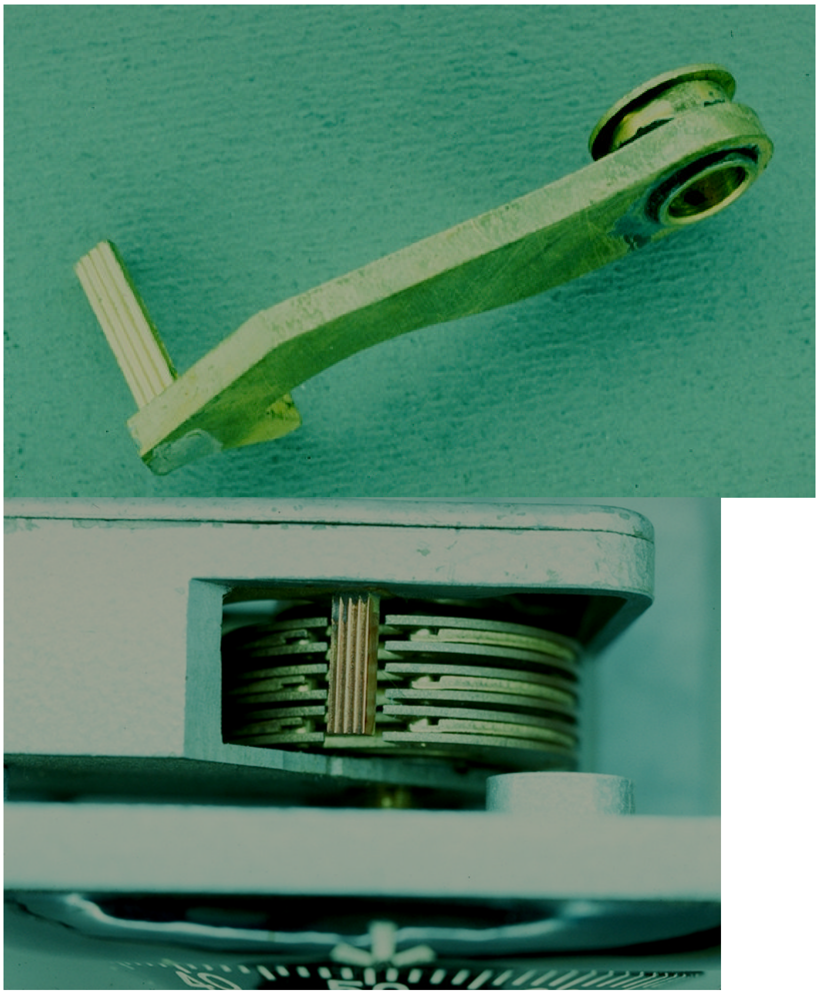
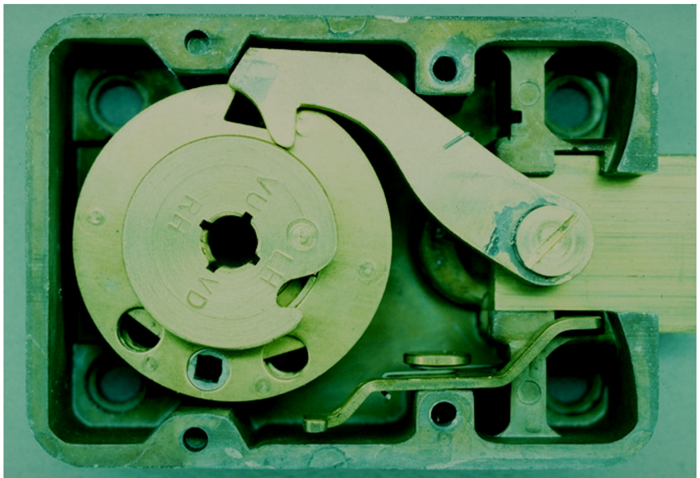
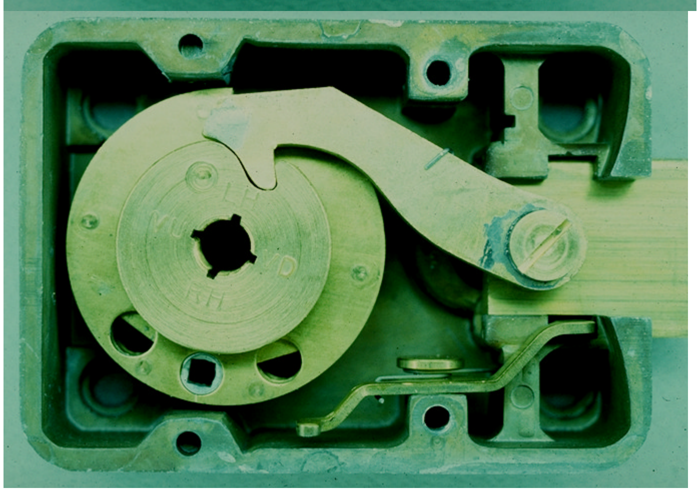
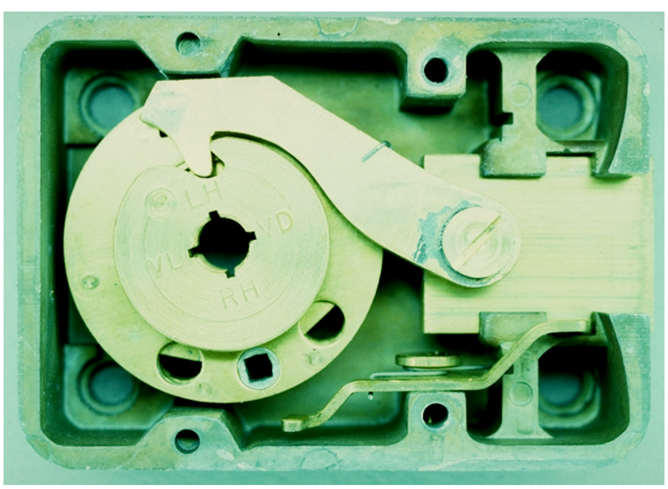


Figure LSS+3542 The fence is a prime target for drilling, either the soldered link or the actual
fence material. (Photo ID ISP 82-3563 left, and 83-3563 right).

35_7.2.4.3.1 Scoping the Fence







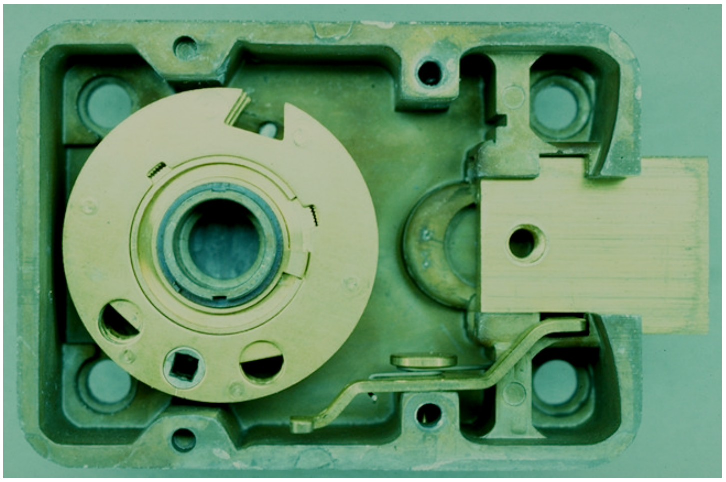


Figure LSS+3543 This series of photographs shows the progression of movement of the fence
into the gate of the wheel pack, and a lock case with the lever fence removed. (Photo ID
top left ISP 84-3563, top right 85-3563, bottom left 86-3563, and bottom right, 81-3563).
Courtesy of Illinois State Police, Bill Sherlock.

The drilling procedure to view the fence and align the gates is probably the most common method to penetrate a safe.

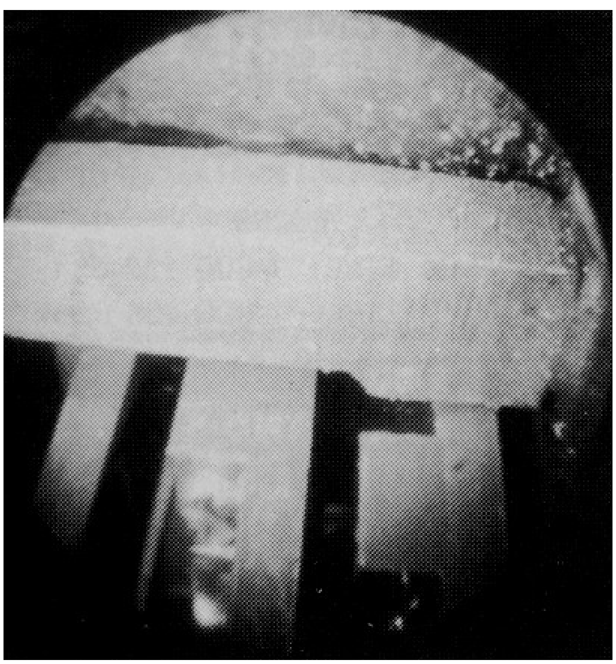
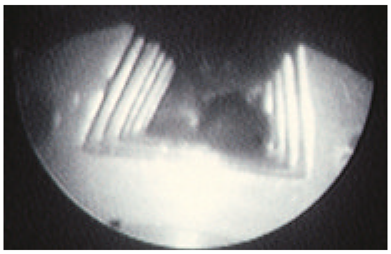


Figure LSS+3544 (ISP 22-2963) A 90 degree

angle view with a borescope using a mirror on a Mosler MR 302.

A hole is placed in such a position as to allow the technician to insert a borescope in order to view and align the gates under the lever fence. The penetration occurs directly underneath the fence. Certain manufacturers, such as Mosler and Federal, make this impossible because the fence is oriented toward the rear of the lock.



35_7.2.4.3.1.1 Procedure

A 1/8” pilot hole is made to the hard plate after the drill point location is determined. Be certain that the drill is exactly perpendicular with the door, because the precision of this entry will control the accuracy of the final hole. A clearance hole is created that is somewhat larger in diameter in order to permit the carbide bit to penetrate the barrier plate. The tolerance of this hole should be at least 1/16” so as to prevent the bit from being caught by the softer metal of the door.

Upon reaching the hard plate, the carbide bit is inserted and the barrier material completely penetrated. An HSS bit is used to penetrate to the lock case. Drilling between the hard plate and the lock case should be done with great care. Frequent inspections are made for signs of zamak chips. Upon reaching the lock case, a very sharp drill should be used. This will prevent the formation of ridges or bubbles on the inside wall that can rub against the bottom wheel. As the lock case is penetrated, the bit will vibrate, indicating a different type of metal. Once a clean hole is created, brass should be visible.

Great caution should be exercised when drilling into the lock case. If too much pressure is applied, the bit may thread itself through the zamak barrier and damage the wheels. Turning the drill bit by hand is often the practice in an effort to insure that the wheels are not disturbed.

Once drilling is completed, a view of the first wheel and lever fence is possible. If an S&G is the target, then the wheel that is first viewed will be the first digit of the combination. The wheels are rotated in the proper sequence as each is aligned below the fence. When the drive cam is under the fence, the lock can be opened after all wheels have been properly positioned.

35_7.2.4.3.2 Removing the Fence by Drilling

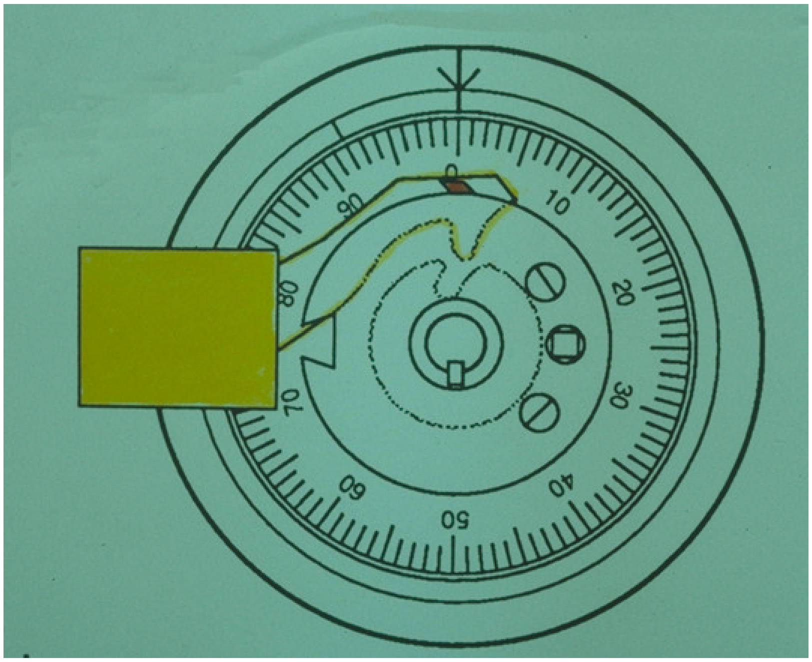
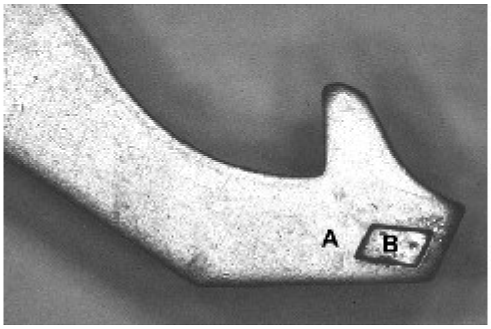
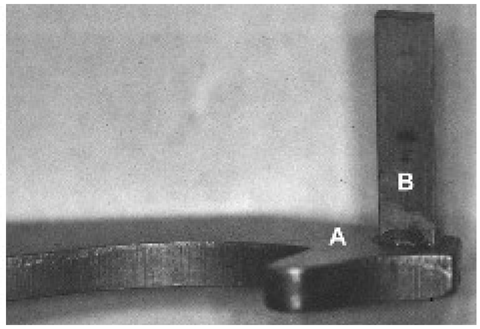


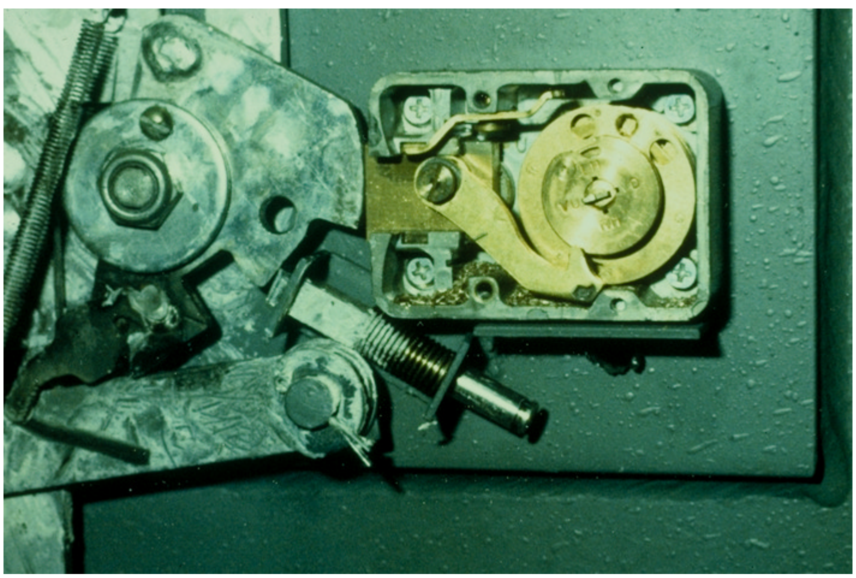
Figure LSS+3545 (ISP 103-3563) Locating the fence for drilling.

The fence is normally soldered to the lever assembly. It can be completely severed and removed by drilling. This is one of the most popular and reliable methods for neutralizing a mechanical combination lock, regardless of the manufacturer. The technique eliminates the obstruction that prevents the lever from being retracted into the drive cam. The dial must be removed or reduced in size to gain access to the drill point.





If done correctly, there will be no obstruction to block the lever from entering the drive cam gate, thereby allowing actuation of the bolt. Once drilled, the fence will usually become dislodged and fall away from the wheel pack. Some technicians drill **to the fence**, then attempt to dislodge it by punching. This practice is not recommended because connecting components can be damaged or broken, especially with a direct-entry fence.



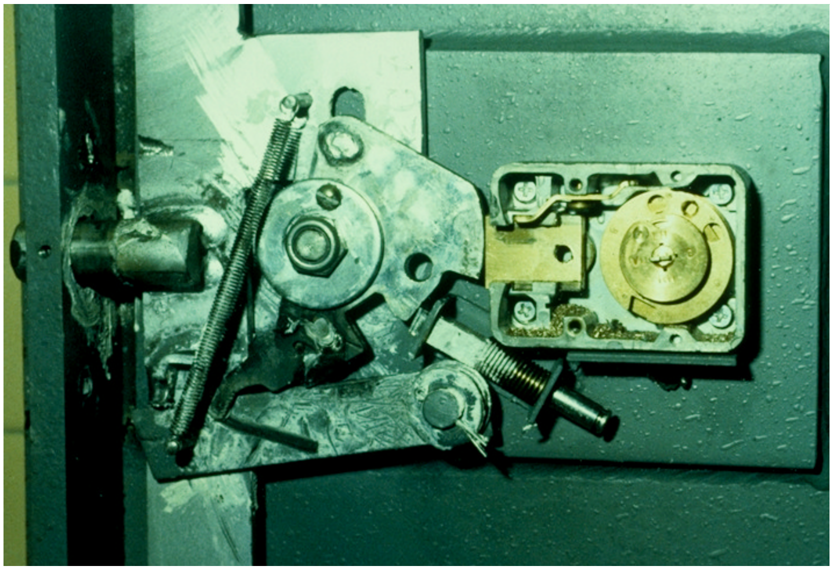


Figure LSS+3546 These photographs show a lever fence that has been drilled, and then removed. Photo ID ISP 97-3563 (left) and 98-3563 (right).

Removing the fence by drilling is utilized in a vast majority of forced openings and is particularly applicable:

- **When the combination is unknown or does not work;**
- **To bypass a mechanical failure;**
- **When the lever is bound;**
- **When drive pins or flys are broken or inoperative;**
- **When the wheels are seized or immovable and must be manipulated with a probe in order to align their gates.**

35_7.2.4.3.2.1 Drilling Procedure

The procedure requires precision accuracy in formulating the drill point ±.0625" from the center of the fence. The hole must be exactly perpendicular to the door and have no entry angle whatsoever. If done correctly, the penetration will allow removal of the fence, viewing of the wheel pack, and manipulation of each disc to alignment.

Using a fixed drill rig with a sharp HSS bit, very slowly drill the fence without causing distortion or twist. Remember that the fence is usually slightly more than ½" in length, so penetration

should be controlled to prevent drilling through the lever. If the end of the lever becomes severed, it may be impossible to retract the bolt. Once the fence has been removed, the drive cam can be rotated so that the nose enters it. A long screwdriver or ice pick may be required to accomplish this task.

35_7.2.4.3.2.1.1 Direct-Entry Fence

This type of mechanism is the easiest to neutralize because the fence is actually part of the bolt works. The method is the same for locks with different direct-entry fence designs.

35_7.2.4.4 Handle Cam

In most safes, the handle controls the boltwork, through a round cam. It is rotated once the correct combination is dialed, allowing the lock bolt to be retracted. The punching technique allows the cam to be bent or pushed inward far enough to clear the bolt of any obstruction.

The technique is often used with burglarized safes as a last resort. This is because it will require repairs to the door, can loosen the mounting plate under the lock, and can disconnect linkage. The procedure will usually have no effect on relockers. Caution must be exercised when working with older safes, because they may be outfitted with tear gas loads behind the bolt linkage and lock case. The chemical is stored in glass vials that are set to break upon impact.

35_7.2.4.5 Handle Shaft

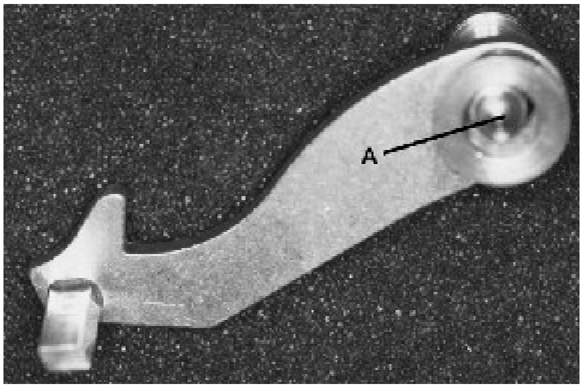
In certain cases, the handle shaft (arbor) can be utilized to push back the cam. This technique is a variation of punching the handle cam. It requires that the bolt handle be severed. Then the shaft is forced into the door to bypass the bolt. In practice, the arbor is drilled completely through the spindle shaft in order to shear the mechanism and the threads of the nut. This will provide access to the cam, which can then be depressed to allow the bolt to pass.

35_7.2.4.6 Lever Screw

3563-99

One of the surest methods to open a container is to drill for the lever screw. This technique will bypass problems associated with

lever or wheel pack malfunctions. It can be used successfully on all S&G, Diebold, Federal, and LaGard locks. The procedure will not work on the Mosler 302. A **diagram** illustrates the proper drill point to remove the lever screw.



It will be recalled that the fence is attached to a pivoting lever that is directly linked to the bolt. If the head of the lever screw is removed, the lever and fence can be shifted out of the way and the bolt manually retracted. A ¼" or 3/8" hole is made at the precise drill point location of the center of the screw; then, an ice pick or similar tool is used to move the bolt.

Once the screw has been removed, the bolt is easily shifted. Remember that a detent spring and ball may be used to retain the bolt in a locked or unlocked position. Thus, added pressure may be required for movement of the assembly. The failure of the remaining screw shaft and head to completely separate from the bolt can be a complicating factor. Thus, all parts of the screw must be removed in order to free the lock bolt. One solution is to grind the drill tip to a flat surface, resembling an end-mill.

35_7.2.4.6.1 Drill Point Location and Procedure

Generally, the bolt center and dial centerlines are linear. Thus, the drill point for the lever screw will be located at 0, 25, 50, or 75, depending upon handing and mounting. This in turn determines the location of the bolt in reference to the dial.

Mounting	Radial Position of Lever Screw
RH	75
LH	25
VU	0
VD	50

We shall use a Right Handed S&G 6730 to illustrate the procedure. The lever screw is 1 11/16" from dial center. Once the lock is penetrated and the backside of the bolt can be observed, a ¼" HSS bit is used to remove the brass lever screw. The drill becomes a grinder to disintegrate the body of the screw, with the goal of eliminating the linkage between the bolt and lever. Once the screw has been neutralized, an ice pick, screwdriver, or probe is utilized to move the bolt to the open position.

35_7.2.4.7 Locking Cam or Lever

If it is impossible to drill for the lever screw, the alternative is the locking cam or lever. This will remove the obstruction that prevents the bolt from retracting, and may result in a piece of the lever being destroyed during the process.

35_7.2.4.8 Lock Case Mounting Screws

Lock case mounting screws are generally not protected by hard plate. Thus, they can provide a drill point for the introduction of a probe to view critical components. There are usually predrilled holes in the barrier material to accommodate mounting screws. Containers are usually constructed by welding a mild steel mounting plate to the barrier material that is affixed directly to the inside surface of the door. Holes are drilled and tapped through the hard plate and into the door. Using the relatively soft screws as a channel through the hard plate can reduce the difficulty of gaining a probe point.

In the S&G 6730, the mounting screws are located 1 3/32" from the center of the dial. Two screws can be drilled. These are located at 10 (upper screw) and 39 (lower screw). The two locations, however, will not provide a direct observation of the wheel pack. As with the lever screw, these drill points require precision in defining their location.

35_7.2.4.8.1 Difficulties and Hazards

There are problems in selecting this drill point. Thus:

- **Screw centers are difficult to drill and maintain using a ¼" bit. A template is recommended;**
- **The screw-head can become a nuisance once the threads are removed. The head can fall into the**

lock body or wheel pack, especially in standing safes where the upper mounting screw has been drilled. The head can also become lodged in one or more of the gates, or against the wall of the lock case. In such case, a magnet can be used to move the head out of the way;

- A direct view of the wheels is not available;
- A scope is required;
- A fixed drill rig is required.

35_7.2.4.9 Relockers



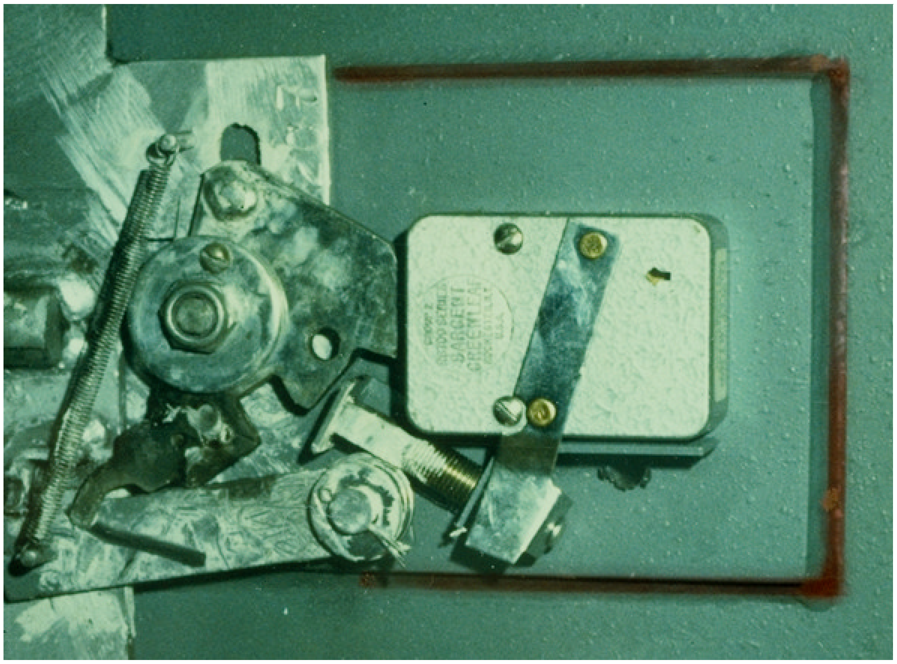


Figure LSS+3547 (left, ISP 95-3563, right ISP 96-3563). Drilled relockers and zoom view.

Relockers may be found in both the safe lock and container body. Their function is to provide a secondary block to the operation of the boltwork, once they are triggered. Certain types of relockers were described in **Chapter 33** and **34.** This section will contain a more detailed discussion as relates to neutralization and bypass. Depending upon their mechanical design and physical placement, they can be defeated by drilling, followed by manipulation and application of directed force such as punching.

Some relockers will cross-lock, meaning that the relocker is deadlocked after being fired. In such cases, pulling on the connecting cable will have no effect. This type of design is routinely employed in high-security safes. A relocker is said to be "active" when the locking mechanism is in a retracted state and until the connecting cord or cable is broken. Once this event occurs, the bolt releases.

Whenever a safe or vault is serviced, extreme caution should be exercised to insure that relockers are not engaged. If, for example, the lock case cover is loose after maintenance, a very difficult lockout problem is created if the door is closed. Whenever a lock is serviced for any reason, two critical rules

apply:

- **Insure that the lock case cover is secured tightly to the container;**
- **Always test the lock and boltwork system with the door open.**

35_7.2.4.9.1 External Relockers

These devices are spring- or gravity-activated projections that are incorporated within safe and vault doors to block the operation of primary bolts. Heat, temperature, vibration, shock, penetration in specific areas, or alteration of the door or lock triggers them.

35_7.2.4.9.1.1 Thermal or Fusible Links

A heat-sensitive link can be triggered by a rise in ambient temperature, caused by a torch, lance, or similar device. Generally, fusible links are constructed of two pieces of metal that are soldered together and spring biased. Once the threshold temperature is reached, a spring-loaded bolt will be released to block primary locking mechanisms.

35_7.2.4.9.1.2 Glass Plate Relockers

A pane of specially designed glass is located to protect critical components in the door. Drilling, shock, or vibration will shatter the glass and release tensioned lines that are attached to spring-loaded projections.

35_7.2.4.9.1.3 Lock Case Relockers

Relock triggers can be incorporated within the lock or external to it. Internal triggers are described elsewhere in this section.

35_7.2.4.9.1.4 External to the Lock Case

These devices are mounted outside of the lock case and are triggered by the alteration, removal, or destruction of the cover. They are specifically designed to guard against many forms of attack, including punching. Punching the spindle is perhaps the most common method to attack safes. In older containers and those having lower security ratings, the entire

lock, including the wheel pack, was knocked out of the way using this practice. The lever would be physically manipulated to the unlocked position. Manufacturers, in an effort to secure the container against the practice, have incorporated many design features within the lock and container. These include:

- **Place the drive cam in a position so that driving the spindle forward will not remove the wheel pack or allow the lever to fall;**
- **Place relockers in the lock case that are actuated by the removal of the lock;**
- **Integrate relockers into the handle by the use of shear pins and shafts that will break from excessive force or torque;**
- **Install relockers within the door that are triggered by any change in the lock case position or shape.**

35_7.2.4.9.2 Internal Relock Trigger

The relock trigger prevents the bolt from retracting when the thermal plug has melted or the lock case cover has been altered, distorted, destroyed, or is loose. As noted in **Chapter 34**, the relocker can also become active when the dial is knocked off and the spindle punched. It can also trigger from vibration. This can result from slamming the door or as the lock cover screws back themselves out over time.

The purpose of selecting this drill point is to disengage the relocker, **not to destroy it**. Thus, a hole is made in order to remove the obstruction that keeps the bolt from retracting. If the relock trigger has fired, the combination will run but the dial cannot be fully turned to retract the bolt.

35_7.2.4.9.2.1 Procedure to Disengage Relocker

There are many different designs for relock triggers, although they all perform essentially the same function. When the cover is firmly seated to the lock case, the trigger pin is depressed. Removal or movement of the cover will cause the spring-biased pin to pop up. This will engage a corresponding recess in the bolt, deadlocking it in the locked position.

We shall use the S&G 6730 for the purpose of illustration. In the 6730, the trigger is located at the lower right side of the

lock case (at about 60), 1 1/8” from dial center. To minimize the chance of severing the trigger arm, drill 1¼” from dial center, although this position will not afford a direct view of the arm. The goal for this drill point is to be in a position to move the relock lever toward the front of the container. This is accomplished using a wire snare while tension is applied to the dial in order to retract the bolt.

35_7.2.4.9.2.2 Relock Trigger Designs

Depending upon the manufacturer, relock triggers will have different mechanical designs. They are all engineered to block or stop the bolt from being retracted if there is an attempt to compromise the lock case. Based upon the configuration, the drill point should allow disengagement by either pushing or pulling the locking device from the bolt. Thus:

- **Mosler uses a brass pin, biased by a spring steel tab, measuring ¼” wide that is mounted on the back of the lock case;**
- **Yale employs a brass tab;**
- **LaGard provides a formed wire spring that is retained by a notched boss on the interior of the case cover. If the cover is removed or broken, the spring releases;**
- **S&G has a pivoting lever;**
- **S&G MP locks use a compound relocker, activated by the removal of the driver. This can be caused by the spindle being punched, or release of the cover. The result will be raising the trigger and releasing a locking pin into the bolt.**

35_7.2.4.9.3 Drill for a Relocker: Required Information

Information regarding the drilling of relock triggers is presented elsewhere in this section. In every case, drilling to neutralize a fired relocker requires detailed information regarding:

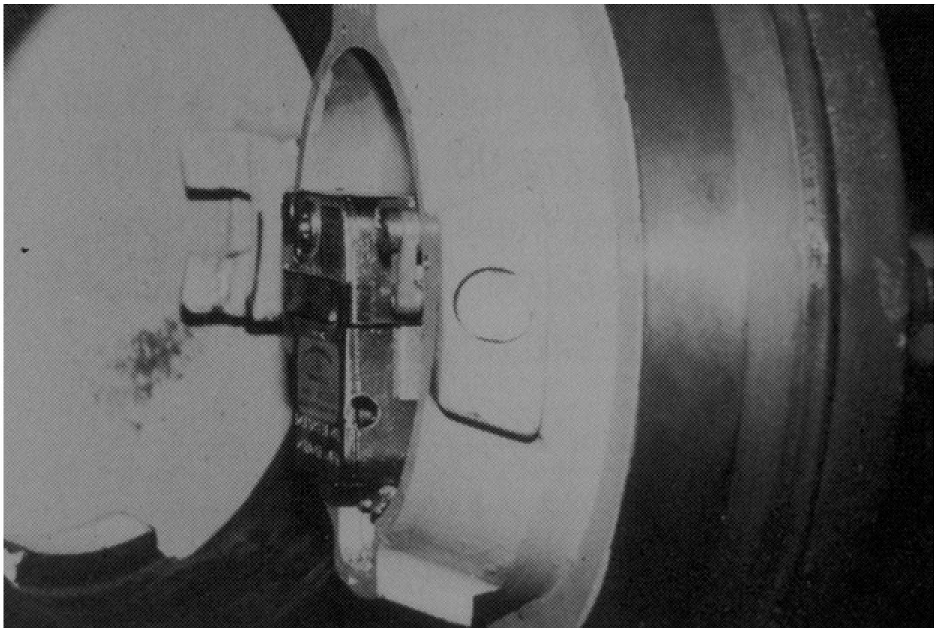
- **The type of relocker (internal or external);**
- **Mechanical configuration;**
- **Round or square projection;**

- **How the relocker is triggered;**
- **What is engaged, locked, blocked, or cross-locked by each relocker;**
- **How many relockers have been triggered;**
- **The location of each triggered relocker;**
- **Precise drill points for each relocker;**
- **Can deadlocking result from a fired relocker. For example, in the triggered and extended position, the projection may no longer be in alignment with the body of the relocker. This situation makes it extremely difficult to retract the secondary locking bolt;**
- **Every component that is affected by the triggered relocker;**
- **Additional complications that may be caused by attempts to neutralize each relocker. For example, a relocker that blocks the rotation of the handle cam has been fired. Forcing the handle, the shear screw, pin, or rivet will delink the handle cam from the shear plate, thus preventing the bolts from being actuated;**
- **What options exists for bypassing or neutralizing the relocker. Often, the only option is to drill a hole at the location of the relocker and then use a punch to destroy the bolt carrier to displace the relocker from the bolt.**

35_7.2.4.10 Spindle Shaft

The spindle shaft may be drilled in order to gain access to the handle cam. The bolt can be actuated once the cam is depressed and moved out of the way.

35_7.2.4.11 Viewing Hole: Front, Top, Sides, or Back of Safe



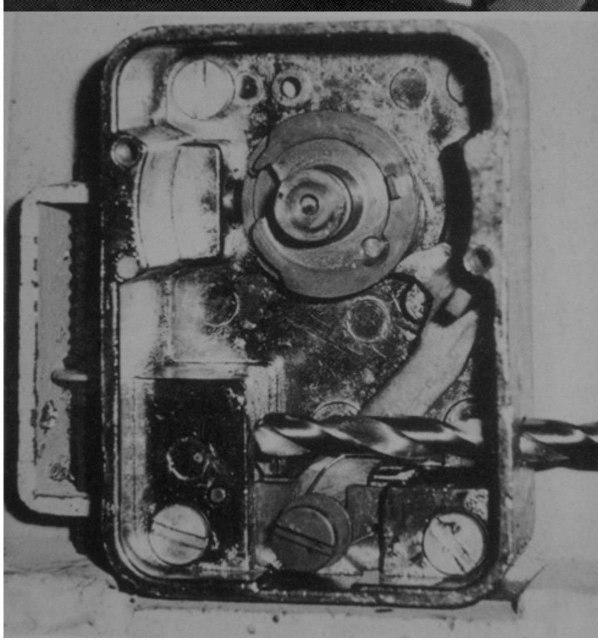


Figure LSS+3548 (Left, ISP 20-2963; right, 21-2963) Mosler MR-302 point of penetration.

Many doors are hardened or contain barrier material that cannot be easily penetrated. In such cases, a drill point can be selected to provide a view from the front, top, sides, or back of the safe. Each drill point will provide an observation of critical locking components. With respect to the front of the

door, the drill point will be inside or outside of the dial ring.

35_7.2.4.11.1 Lock Case

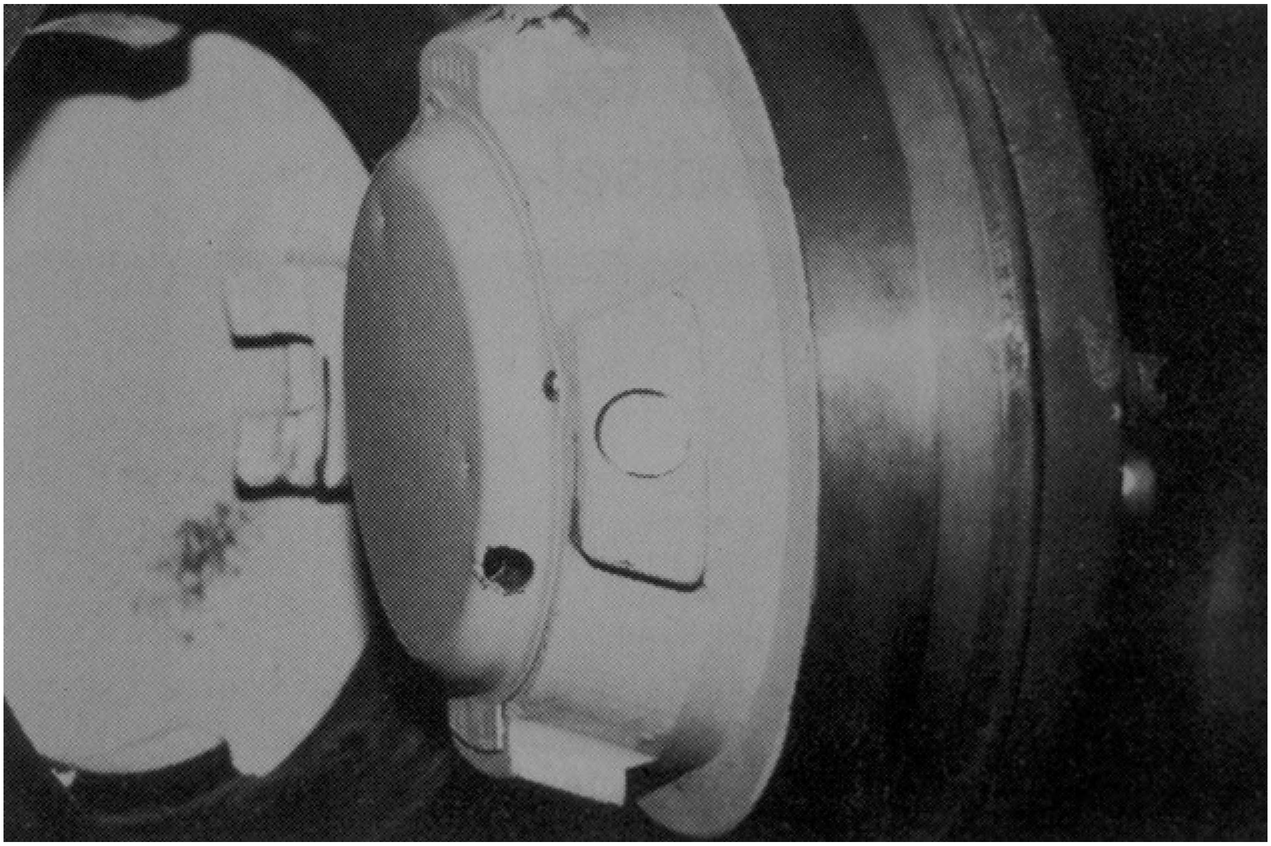


Figure LSS+3549 (ISP 19-2963) Hole drilled through cover plate.

A hole may be made through the front of the door or the side, top, bottom, or back of the container to scope the lock case in order to observe the fence and gates. The position of the hole will depend upon whether a borescope is available or a direct sighting must be made. If a borescope is not available, a hole must be placed at the edge of the wheel pack. In this instance, a view can be obtained around the radius (half the diameter) of the wheel.

Drilling for a **direct view** will allow observation of the fence and gate together. In such a case, no translation is required to correlate gate position with drop in. A drill rig must be used for this procedure in order to insure a precision tolerance of ±.125”-.375”. In older safes, the ability to view can be more difficult. This results from the use of gray wheels and a

polycarbonate fence. In locks such as the Mosler 120 and 302, or S&G 6709, the view of the fence is obstructed. In these mechanisms, the wheel post is on the case cover and the lever is mounted on the bottom of the case.

The direct view procedure will allow the combination to be determined by rotating each gate to alignment in the order that the number sequence is normally entered. That is, each wheel is rotated in the L-R-L or R-L-R order while viewing the gates. Each is aligned under the fence until the wheel pack is properly positioned in order to allow the lever to fall into the drive cam. The S&G 6730 is probably the most widely used lock for security containers. It will be used as a reference here. Critical information to obtain a direct view includes:

- **The wheel diameter (1.75″ for S&G);**
- **Location of the edge of the wheel pack from dial center (.875″ from dial center);**
- **Location of the fence (97 radiant on the dial);**
- **Drill point (97 x .875).**

The drilling procedure was described in detail earlier in this chapter. This technique can also be used to physically move each wheel into the proper position when drive pins or flys are broken.

35_7.2.4.11.2 Side Drilling the Lock Case

Side drilling of the safe will bypass glass relockers, except in some high-security containers, such as made by Chubb.



Figure LSS+3550 (ISP 18-2963) Side drilling and scoping the lock case.

35_7.2.4.11.3 Angle Drilling into the Lock Case





Figure LSS+3551 (ISP 8-2963 left; 10-2963 right). Example of floor safe that has been angle drilled to view wheel pack. Courtesy of Illinois State Police, Bill Sherlock.

Angle drilling can prevent damage to the locking mechanism. In addition, some locks cannot be directly drilled at a perpendicular angle to the door because the dial cannot be removed. Such is the case with the Yale OC5 friction fence lock, for example. To drill properly, first the door thickness is determined. Then, the drill point is set so that the top of the lock case is penetrated at an angle without touching the wheel pack. If done correctly, the edge of the wheel pack and driver will be observable.

35_7.2.4.12 Drilling Through the Top and Back of the Container

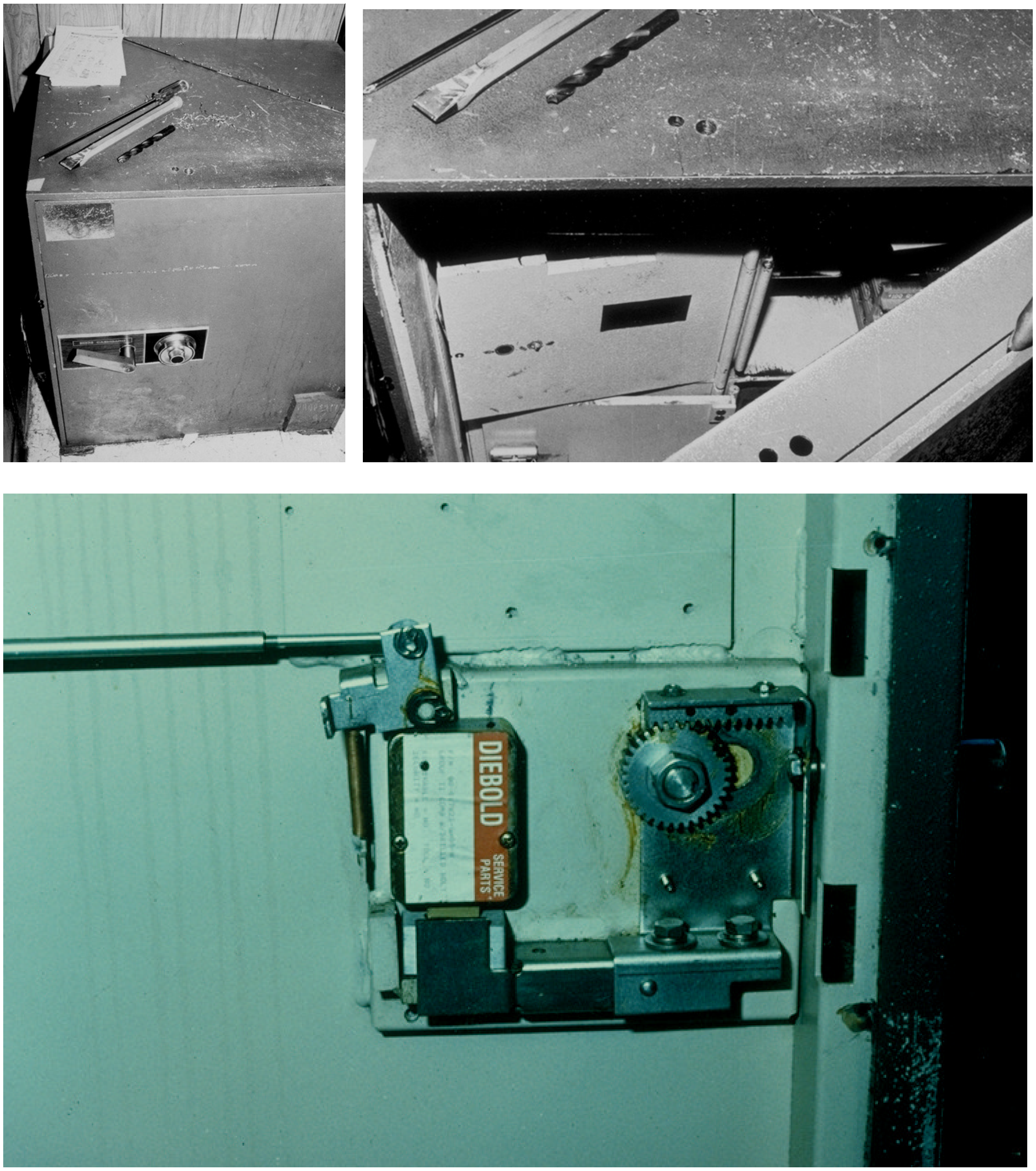


Figure LSS+3552 (Top left ISP 14-2963; right 15-2963; bottom, 16-2963). Burglary of a drug store chain, drilled from the top of safe to lock box to view the wheel pack. Courtesy of Illinois State Police, Bill Sherlock.

Drilling may be accomplished through the top and back of the container in order to penetrate the lock case. The procedure for each of these locations is essentially identical. The drill

point is determined from the dimensions of the lock and the location of the dial. It is placed to avoid contact with the internal components, yet provide an unobstructed view of the wheels. One or more holes may be placed in the back of the safe in order to read the lock or disassemble it.

35_7.2.4.12.1 Disassembly of the Lock

Several holes may be made in the rear of the container to allow disassembly of the lock. Generally of very limited utility, this procedure requires that a view hole, light hole, and manipulation hole be made to allow direct access to the back of the lock. Obviously, no obstructions can be present for this technique to work. Once access to the lock case has been provided, a long screwdriver is used to remove the cover. The combination is then dialed and the relock trigger depressed, to allow the bolt to retract.

35_7.2.4.12.2 Change-Key Hole

A hole in the back or side of the container can afford a direct view of the change-key hole, using a borescope. Through this limited opening, the wheel pack can be observed. The complexity of the procedure will depend upon whether the lock is front or rear drive. Remember, the image in the borescope may be reversed, adding another level of difficulty to the operation.

35_7.2.4.13 Square Section of Holes

Several holes in a square pattern can be made by drilling or by using a torch. Once the pattern has been completed, a sledgehammer is used to punch the remaining metal inward. The area should be large enough to allow for the insertion of a hand or mechanical device to remove contents.

35_7.2.4.14 Wheel Pack

Drill a precise hole to allow alignment of the gates under the fence. In some locks, notably Mosler and Federal, this is not possible because they face toward the cover. The evidence technician should note this fact. If a Mosler or Federal were drilled improperly, it would indicate a lack of knowledge on the part of the burglar.

35_7.2.4.15 Wiring Holes

Often, there are one-inch wiring inlets at the rear of a container for alarm circuit access. Generally, these holes will not provide a direct view of the bolt mechanism or lock, but may be worth considering if there are no other options.

35_8.0 Forced-Entry: Required Information and Data

Containers and their locks are predominantly mechanical and thus, subject to failure. Each safe may have special design issues that must be understood prior to drilling. Accurate information in advance of a forced-entry can determine whether the effort will be straightforward or complicated, difficult, and time consuming.

The analysis of a security container and its lock prior to attempting an entry occurs in two distinct stages. First, all of the known information regarding the safe or vault is gathered from the owner, user, or industry reference sources. This type of data will give the technician a clue as to how to proceed; he will know the required tools and the difficulty of entry.

If the lock or boltwork is inoperative, causing a lockout condition, then diagnostic analysis must be attempted in order to focus upon the proper target of attack. In such a case, all possible information must be gathered regarding operational difficulty or malfunctions prior to the lockout.

The conscientious safe technician will, whenever possible, keep detailed notes regarding the containers that he routinely services. This information should be kept in a secure location and coded with respect to a particular safe. Information that can and should be gathered **prior** to a lockout condition should be based upon drawings, photographs, diagrams, blueprints, or notes. The information should include:

- **Location of relockers;**
- **Data regarding the safe, boltwork, and lock;**
- **Photograph of the boltwork mechanism on the door;**
- **Location of bolts;**
- **Door measurements;**

- **Lock specifications;**
- **Drill points and hole placement.**

35_8.1 Photographs

Photographs, in order to be accurate, must include a method to determine scale. Two rulers, one vertical and one horizontal, should be placed next to critical components when taking photos. This will allow a 1:1 correlation for measurement and distance calculations. Remember that the lock case and bolt size can be used in old photographs to determine other dimensions within the picture. The length and width of the door may be similarly utilized as a reference. Photographs should be produced using either a macro or 52 mm lens with the film plane parallel to the object being recorded.

Before attempting the forced-entry of any lock or container, the technician must obtain as much information as possible about the target. Drilling or other forms of destructive entry requires a great deal more prior knowledge than if the lock is to be manipulated. Proper and accurate planning of the attack is crucial. This “reconnaissance” is essential, for many reasons:

- **Increase the likelihood of success;**
- **Reduce the time required for entry;**
- **Eliminate or reduce the potential for multiple-entry attempts due to errors in procedure;**
- **Minimize required repairs after entry has been effected;**
- **Minimize the damage done to the container;**
- **Reduce the likelihood of firing relockers or other protective devices that will create lockout conditions, and which may be extremely difficult to resolve;**
- **Minimize the dangers inherent in any forced-entry;**
- **Minimize the effects of penetration upon the security rating of the container;**
- **Reduce subsequent risk of penetration of the same container;**
- **Reduce the cost of repair or replacement of components;**
- **Reduce the sophistication or number of tools required to effect an opening.**

35_8.2 Information Regarding the Lock and Container

It is highly recommended that the technician take the necessary time to gather all available information before making the decision as to how entry is to be made. Sitting in front of the safe for a period of time and weighing courses of action can reap large dividends in terms of simplified openings. As noted elsewhere in this chapter, relocking devices can pose the greatest threat to a successful opening. If the proper information is not gathered or available prior to making the decision as to how a container will be bypassed, then it is likely that relock devices will be triggered. Once activated, the container may be extremely difficult to open. **The best way to deal with relockers is not to set them off.** Data regarding the following factors can be critical in making the decision to drill a container:

- **Barrier material and Rockwell rating;**
- **Best location to penetrate the lock case for an unrestricted view of the wheel pack without causing damage to the mechanism;**
- **Body thickness;**
- **Bolt diameter;**
- **Boltwork direction;**
- **Boltwork mechanical design;**
- **Boltwork location;**
- **Check for a stuck fly;**
- **Check the dial for excessive in-and-out play;**
- **Check the dial ring for tightness;**
- **Check the door for play;**
- **Combination or key lock;**
- **Comparison with similar containers and methods of construction;**
- **Contact point location;**
- **Container size;**
- **Cross-locking on relockers;**
- **Determine the drop in point;**
- **Identification of lock by design of dial and dial ring;**

- **Dial location;**
- **Diameter of the wheels;**
- **Direction of bolt extension from lock case. A right handed lock means that the bolt will extend from the left side of the lock as viewed from the dial, outside of the container;**
- **Direction of handle rotation to retract;**
- **Distance between opening handle and dial;**
- **Door size;**
- **Door cover plates;**
- **Drive cam diameter;**
- **Electronic locks often have bypass codes in case of lockout;**
- **Experience with particular container;**
- **Handle design;**
- **Hinge design: bypass capability;**
- **Is it possible to enter the container;**
- **Is the lock in working order;**
- **Is the safe insulated;**
- **Key lock, number of levers;**
- **Key lock, special tools for bypass available;**
- **Lever system in lock: universal, geared, gravity drop, biased, or straight tail piece;**
- **Lock identification, as outlined in Chapter 33;**
- **Manipulation of lock: is it possible;**
- **Manufacturer and model of safe and lock;**
- **Measurement: door face to bolt center;**
- **Measurement: door thickness;**
- **Measurement: door thickness to combination lock;**
- **Mounting of the lock;**
- **Movement of safe: is it on casters or wheels;**
- **Opening handle shape and position;**
- **Optimum place to enter the lock case;**
- **Original color of container;**
- **Rating for fire or burglary. Burglary protection will use more difficult barrier material to penetrate;**
- **Relock devices;**
- **Reverse the rotation, oscillating the dial at drop**

in;
- **Run the combination, oscillating the dial at the drop in;**
- **Thermal links;**
- **Thickness of each barrier level;**
- **Tools required;**
- **Tools which are unavailable;**
- **UL or other rating;**
- **Use of glass plates;**
- **Verify that all wheels are being picked up simultaneously;**
- **Verify that the spindle is intact and communicating motion to the wheels;**
- **Weight of container;**
- **What is the security classification of the lock: Group 1, 2, or unlisted;**
- **Wheel material: metal or plastic;**
- **When was the safe and lock last serviced;**
- **When was the spindle last lubricated.**

35_8.3 Preliminary Information about a Malfunction or Lockout

A lockout will most likely occur because the lock or mechanical components of the container were not serviced properly. Even a small amount of dirt or debris in the bolt receptacle or a coin or paper fragment in the door can cause the problem. The customer should not be relied upon to provide or volunteer the cause of the difficulty. If the safe must be opened as the result of a malfunction, a determination as to the nature of the problem should be attempted. There are at least fifty causes of lockout. In less than ten percent of those, drilling or other forms of forced-entry are actually required.

The following information about the target safe should be gathered and an analysis of both the lock and container should be undertaken prior to developing a plan of entry. Proper diagnoses of one or more of the following symptoms can often negate the requirement for drilling or other means of forced-entry:

- **#3 wheel is drifting to a higher or lower number;**
- **Bent lever;**

- **Bolt retraction not possible: relock trigger engaged;**
- **Drive pin broken;**
- **Broken fly;**
- **Cam is bound by corrosion;**
- **Cam gate slide is inoperative in an MP lock;**
- **Combination check;**
- **Dial binding, wobble, or hard to turn: spindle or drive cam problem;**
- **Dial has fallen or been knocked off, spindle intact;**
- **Dial is free spinning: broken drive pins, flys, or loss of contact between drive pin and fly;**
- **Dial is turned sharply: feel drive pins pickup flys and verify all are active and working;**
- **Dial knocked off, spindle punched;**
- **Dial off center: does it bind;**
- **Dial or spindle slippage;**
- **Dial ring loose;**
- **Dial ring marking centered;**
- **Dial stuck: was excessive force used, resulting in broken drive pin;**
- **Dial turns hard, usually due to water damage;**
- **Dial turns smoothly;**
- **Dirty and/or worn flys;**
- **Drive pin slippage;**
- **Drop in area: rap dial with soft-face mallet to compute and determine how far off from standard reference. May have been twisted with pliers by the user;**
- **End play on dial, driver not picking up wheels;**
- **End pressure on boltwork, causing lever to hang;**
- **Fly is stuck, can cause error of up to ten numbers in combination;**
- **Handle swings freely, shear pin broken;**
- **Lever spring is broken or fallen off;**
- **Levers bound by pressure from lock bolt;**
- **Levers bound or jammed;**
- **Lock case screw has fallen out, jamming lock;**
- **Locking cam is bound;**

- **Mounting screws loose;**
- **Obtain written combination from owner or user and have it entered in an attempt to open the lock;**
- **Operational difficulties in entering combination prior to lockout;**
- **Parts seized by dirt or moisture;**
- **Relocker set off, usually by back cover falling or being knocked loose;**
- **Relockers engaged, resulting from burglary attempt or dial handle broken;**
- **Spline key has fallen out, dial unscrews from center;**
- **Spline key is loose;**
- **Spline key is missing;**
- **Stuck fly;**
- **Unlocked wheel;**
- **Verify that correct combination is entered properly;**
- **Verify that the dial and dial ring have not been shifted from impact or loose spline key;**
- **Wear of components;**
- **Wheel mesh slippage, locked into new combination (not unlocked wheel);**
- **Wheel mesh unlocked (generally closest wheel to drive cam);**
- **Wheel pack binding: often #1 wheel. Mounting screws may have worked loose and engaged wheel pack.**

35_8.4 Diagnostics of the Lock and Container

There are as many variations in factors leading to a lockout as there are different brands of safes and locks. The following preliminary evaluation of symptoms, once identified, is generally the starting point in the drilling assessment process. The result should focus upon the proper course of action to open the container. Drilling should only be chosen as a last resort, based upon careful analysis of all known data regarding a lockout.

Analysis of all problems relating to the combination lock will begin with the dial. If it can be turned, then the problem will relate to those parts that control alignment of the gates. If the dial cannot be turned, then those components that control

rotation should be examined. The following analysis provides a summary of issues. It should serve as a guide, pointing the reader to more detailed maintenance reference manuals.

35_8.4.1 The Dial Turns, Yet the Lock Will Not Open with Correct Combination

Proper entry of the combination will not open the lock. The cam is at the drop in point, but the fence will not fall into position. The dial is oscillated ±5 numbers with no effect. It is believed that the spindle is intact, the contact points can be determined, and the wheels are being picked up during rotation.

Probable Solutions

There are several possible causes:

- **Correct combination not entered;**
- **Damage to drive pins or flys;**
- **Stuck fly;**
- **Unlocked wheel;**
- **Wheel slippage;**
- **Loose spline key.**

35_8.4.2 Correct Combination not Actually Entered

The correct numbers may not have been entered or remembered by the person attempting to open the safe. There are many possibilities relating to the entry of an improper sequence of numbers. A wheel may also have become disengaged or slipped, causing the problem. The following data should be verified regarding the entry of the correct combination:

- **The written combination should be provided to the safe technician;**
- **Determine if the person attempting to open the safe is the individual who normally does so and that he understands the correct opening procedure;**
- **Observe the entry of the combination. Are the correct numbers and sequence being used. Is the index marker being utilized correctly;**
- **Have maintenance problems been potentially created by the method of combination entry. For example,**

are rapid jerks or changes of direction employed when rotating the dial. This can cause drive pins and flys to break;

- **Is the dial seated tightly. Is it damaged. Could its marker position have been altered through impact with doors, furniture, or other objects;**
- **Can the dial ring be easily rotated;**
- **Can each wheel be felt as it is picked up. Can each drive pin and fly be felt as they interact;**
- **Is it believed that the spindle has been twisted from excessive torque. If so, the combination will be increased, equivalent to the rotation. One method to determine possible twist is to compare the actual location of the physical drop with factory specifications.**

35_8.4.3 Unlocked Wheel

It is possible that a wheel in a changeable lock has become disengaged or released, as if to be programmed. This malfunction is difficult to detect, because the wheel pack will act normally. A wheel that has become unlocked can randomly move from one position to another, thus erratically changing the spline-gate position.

Usually, it is the wheel closest to the drive cam that is causing the problem. This is because it receives the most wear and abuse. The problem is more pronounced with metal wheels and will rarely be seen with plastic discs. The change in gate position can be detected through manipulation. In practice, each wheel is isolated and run to the drop in point. Once the wheel is identified, it can be rotated to lower and higher numbers until an opening occurs.

35_8.4.4 Slipped Wheel

A wheel that has slipped is not the same as one that has become unlocked. Slippage can occur, mainly in the number three wheel, as the result of excessive torque. The best example was in early models of the LaGard 1980 series. It resulted from an undersized drive cam that was caught by a lever. It would not properly clear the gate after some wear had occurred. Upon locking the safe, the drive cam met the fly of the wheel. It would not move, however, because the fence restricted the gate. The result was that the teeth of the wheel were trapped, causing a change in the

wheel-gate relationship and thus, the combination. In all such cases, the combination must be translated to account for the difference between gate positions.

35_8.4.5 Slippage of Drive Pin or Fly

While turning the dial, binding will occur at one location. The problem can result from:

- **Binding wheel;**
- **Binding wheel pack;**
- **Drive cam wear or excessive tolerance that provides a gap between the wheel pack. Attempt to pull on the dial while the combination is entered in an effort to overcome the problem. It may also be possible to "walk" the fly around the wheel. This is done by continuing to back step from where the fly looses contact, then moving the wheel forward. The combination can also be run in reverse.**

35_8.4.5.1 Stuck Fly

A stuck fly is one of the most common causes for a lockout. Rotating the dial four times left or right, then reversing the direction while continuing to turn, can isolate a wheel. Each wheel will be picked up at the same position where the direction of rotation initially changed. A stuck fly can be released by sharp turning of the dial, oscillation and tapping, or running the combination in reverse direction.

This condition can also cause the combination to change if the fly is stuck or released. A stuck fly will never change the combination more than ten numbers. Remember, however, that one stuck fly can affect the entire combination sequence.

35_8.4.6 Loose Spline Key

The spline key provides the critical reference link for the dial marker, spindle, and drive cam. If it is loose or worn, the combination can change. Generally, the loose key can be felt during dial oscillation. Usually, the combination can be determined by adding ½ number for left rotation and subtracting ½ number for right turning.

35_8.4.7 Dial cannot be Turned

There are many reasons that a dial either cannot be turned or difficulty is encountered during a revolution. Ultimately, the problem will relate to the concentricity of the dial, dial ring, spindle, drive cam, or individual wheels. A lever that is frozen or sluggish may also result in problems. The following information must be obtained in order to determine the problem:

- **Does the dial turn with difficulty in both directions. If so, there is a concentricity error in the dial, spindle, or drive cam. Sometimes, these errors can be remedied by tapping the dial with a mallet to correct for any bends. If the problem remains unsolved, the drive cam is bound within the wheel post. The brass spindle may have been twisted from excessive applied pressure;**
- **Has the dial become harder to turn, or does it stick at a certain position. Added torque may have been applied by the customer, causing a drive pin to be broken;**
- **Is it possible that one of the wheels or the wheel pack is binding. Care should be exercised if it is believed that this condition exists, because added torque can shear a spline key or break drive pins and flys. Generally, the first wheel (bottom) of the pack is most likely to bind. Often, bound wheels can be forced through the application of sharp bursts of energy. Running the combination in the reverse direction may solve the problem;**
- **Do the wheels turn in one direction, but not the other. If so, there may be a loose mounting screw that is causing the binding. Shock, vibration, or the use of gravity (turning the safe upside down) may solve the problem;**
- **Does the dial bind when turned, indicating that it is not "true" with the dial ring;**
- **Does the lever move freely. Moving slowly past the drop in area will reveal if the lever has any restriction of movement. Either there is end pressure on the bolt, or the lever is blocked from movement. This can be caused from an obstruction, such as a loose mounting screw. Shock or vibration around the lock can often clear the problem.**

35_9.0 Safe Opening Protocol: A Case Study

The following example provides an insight into the protocol that may be followed to open a TL-15 rated safe. The procedure will obviously vary depending upon many factors, including:

- **Known data about the safe;**
- **Information as to the probable cause of the lockout;**
- **Damage to the container from a burglary attempt;**
- **Damage to critical locking components through improper service, misuse, abuse, wear, or failure;**
- **External factors such as coins and paper jammed in the door that are compounding the lockout;**
- **Fired relockers;**
- **Boltwork linkage failure.**

A more comprehensive list of possible failures was presented earlier in the chapter.

35_9.1 Background Information

The known or inferred facts for our example include:

- **The lock was functional until the lockout;**
- **This is a TL-30 burglar safe;**
- **The safe has no observable physical damage, in that the handle, hinges, and dial are working properly and intact;**
- **The wheel pack seems to be rotating freely, and the drive pins and flys are working properly;**
- **There is a dial indication of the lever drop;**
- **The lock was manufactured by S&G;**
- **We can measure the thickness of the door;**
- **We know where all of the drill points are located, because we have identified the lock;**
- **We can make an educated guess as to the handing of the lock;**
- **We know the correlation for the translation of gate position, based upon handing;**
- **We know that the dial can be pulled because it is**

made of zamak;
- **We believe, from all indications, that the combination has been lost and that is why the lock will not open.**

We do not know:

- **The location or number of relockers;**
- **The number and location of locking bolts, or the mechanical linkage for the bolt system, and bolt retraction.**

35_9.2 Opening the Safe

The following steps are followed to open this safe:

- **Remove the dial with a dent-puller or a screw drilled through the center. Caution should be exercised because we know this safe carries a TL rating, and thus, the dial is pinned to the spindle. A better decision may be to utilize a hole saw to reduce the dial size;**
- **Select and mark the drill point, using coordinate measurements or a template. In this case, we will drill for the fence;**
- **Attach a fixed drill rig;**
- **Begin drilling a pilot hole, first using an HSS bit until hard plate is reached. Be certain that the drilling angle is perpendicular to the door;**
- **Enlarge the pilot hole to create a clearance hole that will allow the carbide bit to rotate freely. This is required so that the bit does not grab softer metal while spinning;**
- **Determine when hard plate is encountered by sensing when metal cutting has stopped and the drill motor speed increases;**
- **Identify the type of hard plate and whether the material is smooth or included. Did the drill jump just before reaching the barrier. If so, there is a rough surface that is indicative of alloy hard plate. A borescope or otoscope may be used to verify this information;**

- **Use a punch to fracture the carbide chips in order to create a means for the drill bit to grab the material;**
- **Set the drill motor for a speed of 1000 - 2000 RPM;**
- **Select the appropriate drill bit (carbide tipped for this safe);**
- **Alternate between punching and drilling;**
- **Conduct short drilling cycles of about thirty seconds, then inspect the drill bit for dulling. Replace the bit if necessary, and repeat the fracturing of included material on the hard plate surface. The hole should be cleaned often;**
- **Once the hard plate has been completely penetrated, switch back to a sharp HSS bit to go through the mounting plate and lock case;**
- **View the edge of the gates of the wheels and align for opening;**
- **Translate the wheel position to the drop in point;**
- **Reenter the translated combination and open the safe.**

35_10.0 Forensic Evidence of Destructive Entry

35_10.1 Introduction

The investigation of illegal entry of safes, vaults, and safe-deposit boxes has been a primary focus in this text. Forensic evidence relating to the forced-entry of **locks** is discussed in **Chapters 23-27.** This section will provide general information regarding destructive forced-entry techniques as relates to physical evidence. It is not meant to be an exhaustive treatise, however, as the topic is well known. Forensic evidence is most often based upon tool mark identification.

A safe or vault that has been the subject of unauthorized entry can yield many clues to determine the modus operandi (MO) and identity of the perpetrator. In this section, the presence of evidence for both covert and forced-entry is discussed. Burglary methods, techniques to hide evidence of drilling, and information that can be derived from a crime scene are presented.

There are three primary classifications of safe burglars: opportunity, amateur without any specific knowledge, and expert. It is incumbent upon the crime scene investigator, whether forensic or criminal, to attempt a determination as to the motive and competence of the perpetrator.

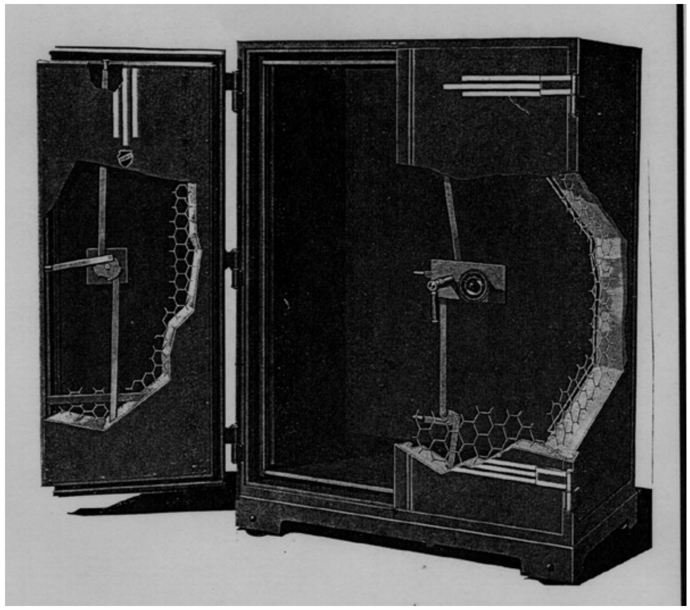
Safe Burglary by Opportunity: The offender usually commits a burglary and finds a safe on the premises. Tools used for entry are also utilized in an attempt to open the safe. Generally, hinges, the dial, or handle are the subjects of attack. The burglary is rarely successful.

Safe Burglary without Expert Knowledge of the Safe: In this instance, the offender knows there is a safe on the premises prior to entry, but he has no knowledge of the make or model, nor of specific entry techniques. He attacks the safe in several different areas with tools that are usually not sufficient to allow bypass. The office area is often looted because of the failure to obtain the contents of the safe.

Professional Safe Burglar: This individual has detailed information about the safe; its location, design, make, model, and security rating. He carries with him the appropriate tools, and leaves the tools at the scene so that he cannot be traced to them through tool marks or trace materials. The professional does not loot the office; he is there to open the safe take its contents, and make a successful exit.

As has been noted throughout this book, there are two primary safe classifications: fire and burglary. Within those groups, there are several subgroups, primarily within the burglary classification. These include money safes, encased/clad money safe, and floor safe. Within the fire rating are included **record safes**, **combination safes**, and **composite safe (Chubb Planet)**. The combination safe is generally constructed with a fire-resistant exterior, with a burglary-resistant interior container.





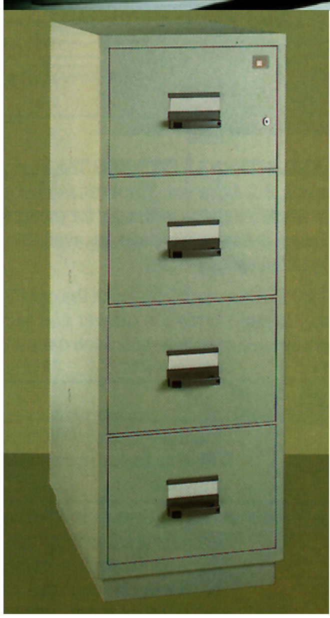


**Figure LSS+3505 Examples of fire and record safes. Shown (left) is the Chubb Planet composite
container that is burglary and fire resistant and described elsewhere in this text. A record
safe is constructed primarily to resist fire and provides only minimal burglary protection.**





**Figure LSS+3506 Example of a high-security money safe produced by Chubb. Money safes
are designed to protect valuables and cash from theft. Their design usually requires
thick steel doors and walls. Intricate locking mechanisms including relockers are
the practice.**



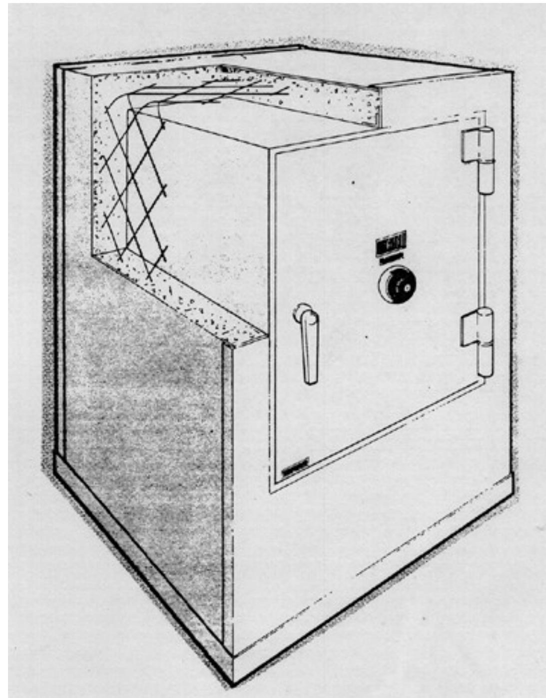


Figure LSS+3507 The cash container and encased/clad money safe. A money safe encased in concrete, then clad in steel or a money safe encased in concrete provides greater difficulty to burglars in removing the physical container from the premises. Encasing in concrete can also raise the safe to a more convenient working level.

35_10.2 Investigative Checklist

There can be many reasons for a forensic investigation of a safe or vault. In one instance, a routine security inspection is performed to insure the integrity of locks and containers. At the opposite extreme, a crime scene may have been declared with the goal of identifying a perpetrator. In the first case, there is no indication that a break-in has occurred until an inspection yields such evidence. At the crime scene, the method of entry may be obvious; only the burglar is unknown.

So, where does the investigation begin? The answer to that question involves many factors. They include:

- **Evidence at the scene;**
- **Prior knowledge of the investigator regarding a suspect's techniques of entry;**

- **Similar crimes;**
- **Target of the burglary;**
- **Complexity of the crime;**
- **Methods of entry and the types of evidence created, including tool marks;**
- **Time required and allowed for entry;**
- **Location;**
- **Access;**
- **Type of lock and enclosure;**
- **Barrier materials;**
- **Competence of the perpetrator;**
- **Sophistication of the tools employed;**
- **Potential that the burglary was simulated.**

Each of these factors will in part dictate the kinds of evidence that is created or left at the crime scene. The following checklist provides a master index of facts or evidence that can be deduced, inferred, or proven. No such list can ever be complete due to the unique nature of each occurrence. However, the material will suggest avenues of inquiry and documentation that can form the basis of any investigation.

35_10.2.1 Preliminary Questions

- **What is the appearance of the safe;**
- **Was the safe opened by forcible attack;**
- **Is the handle firmly attached;**
- **Does the dial rotate;**
- **Is there a dial;**
- **What did the burglar have to determine, in order to successfully open the safe;**
- **Are there any similar crimes or open cases;**
- **Was the lock left on the factory combination;**
- **Is the MO recognized;**
- **How was entry effected;**
- **Can covert entry be confirmed;**
- **Was there an attempt to hide the fact or method of entry;**
- **Has the method of entry been disguised to cover different or more sophisticated techniques, other**

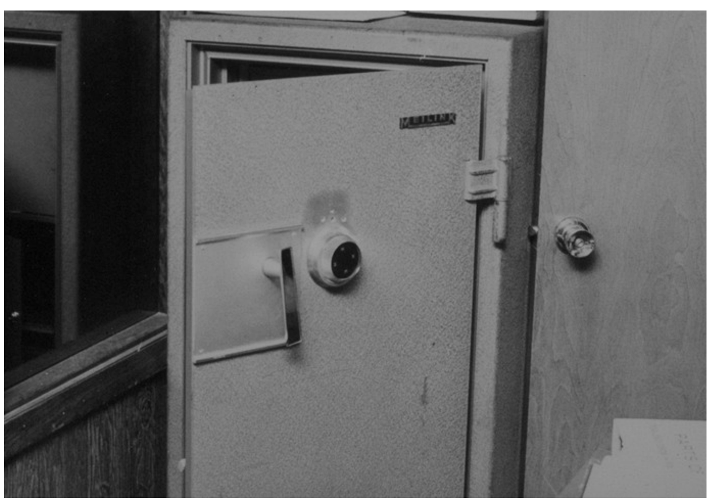
crimes, or the identity of the perpetrator;

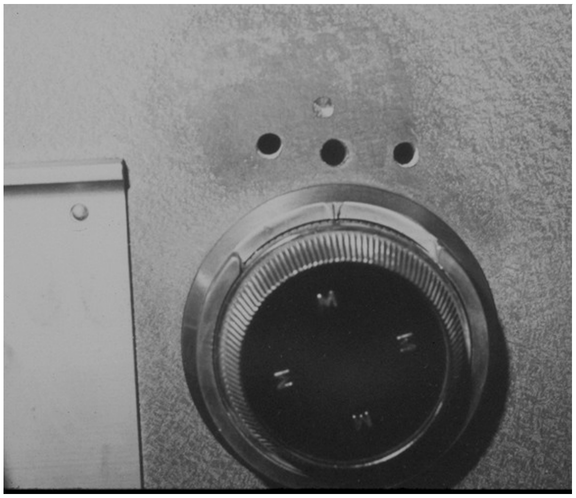
- **Have repairs been made to cover the fact of entry. If so, what is the skill level of the repair;**
- **Has prior work been done on the container that made it more susceptible to a subsequent forced-entry. Could the perpetrator have had prior knowledge of that repair;**
- **If prior repairs had been made that contributed to the present burglary, were those repairs accomplished according to specifications. GSA, for example, has stringent requirements whenever a container has been drilled and repaired. There is no such UL specification for repairs;**
- **Was the burglar interrupted, leaving tools at the scene or explosives not detonated;**
- **If explosives were utilized, have charges been left primed but not detonated, indicating interruption;**
- **Does it appear that explosives were set off improperly, indicating rough handling;**
- **Is there residue from explosives that could be detonated upon contact from crime scene technicians;**
- **Has the safe been moved, especially if on wheels;**
- **Are there wheel tracks on the floor;**
- **Does the size of a drilled hole equal that which would be required. The size can provide an idea as to the competence of the burglar;**
- **Does it appear that the job was abandoned when it should have been completed, indicating psychological pressure to escape by an amateur or lack of knowledge;**
- **Should the safe have been easy to open but was not, indicating lack of knowledge;**
- **Was there an attempt to remove a brass or steel dial on an old lock, indicating lack of expertise;**
- **If an older safe was opened, could vibration have been utilized to rotate the wheels to gate alignment. The type of lock must be checked;**
- **Are combination locks correctly installed;**
- **Are hinges correctly installed;**
- **Is there an oil-like deposit on everything in the area of the burglary indicating the use of a thermic**

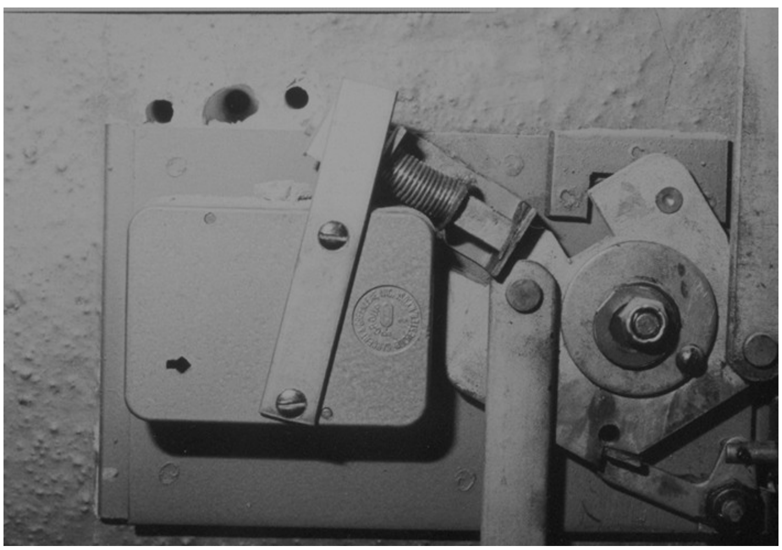
lance;

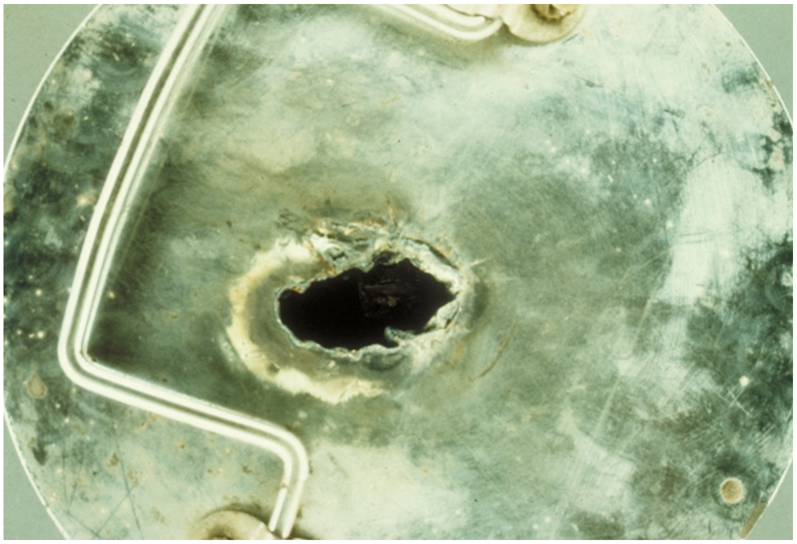
- **Is there evidence of drilling, especially through or under the dial ring. Disassembly of the lock may be required because of replacement or repainting;**
- **Are there lever marks on the face of the door;**
- **How much did the safe or door weigh, indicating how many burglars may have been involved;**
- **Was the door removed or altered to cover use of correct combination, or manipulation;**
- **Has the safe been recently serviced. Were drawings made by the service technician to provide precise drill points;**
- **Has a new cover plate been installed, indicating that one has been replaced after drilling;**
- **Take the door and lock apart to inspect for marks;**
- **Has the safe been recently moved;**
- **Are electric locks utilized on secure doors. If the power is interrupted, what is the result;**
- **Are high-security padlocks in use, such as the S&G 8088 or 8077. These have been designed to government specifications to provide an indication of entry. They are constructed with a shiny chrome-plated shell with shrouded dials.**



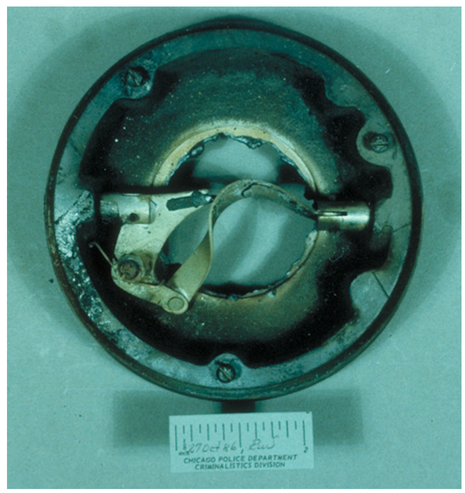


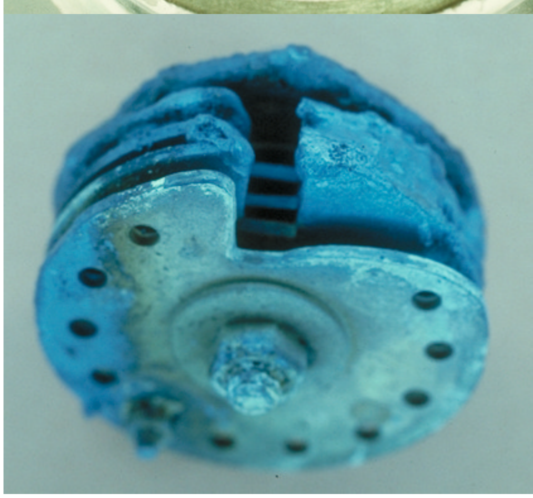









CHICAGO POLICE DEPARTMENT
CRIMINALISTICS DIVISION



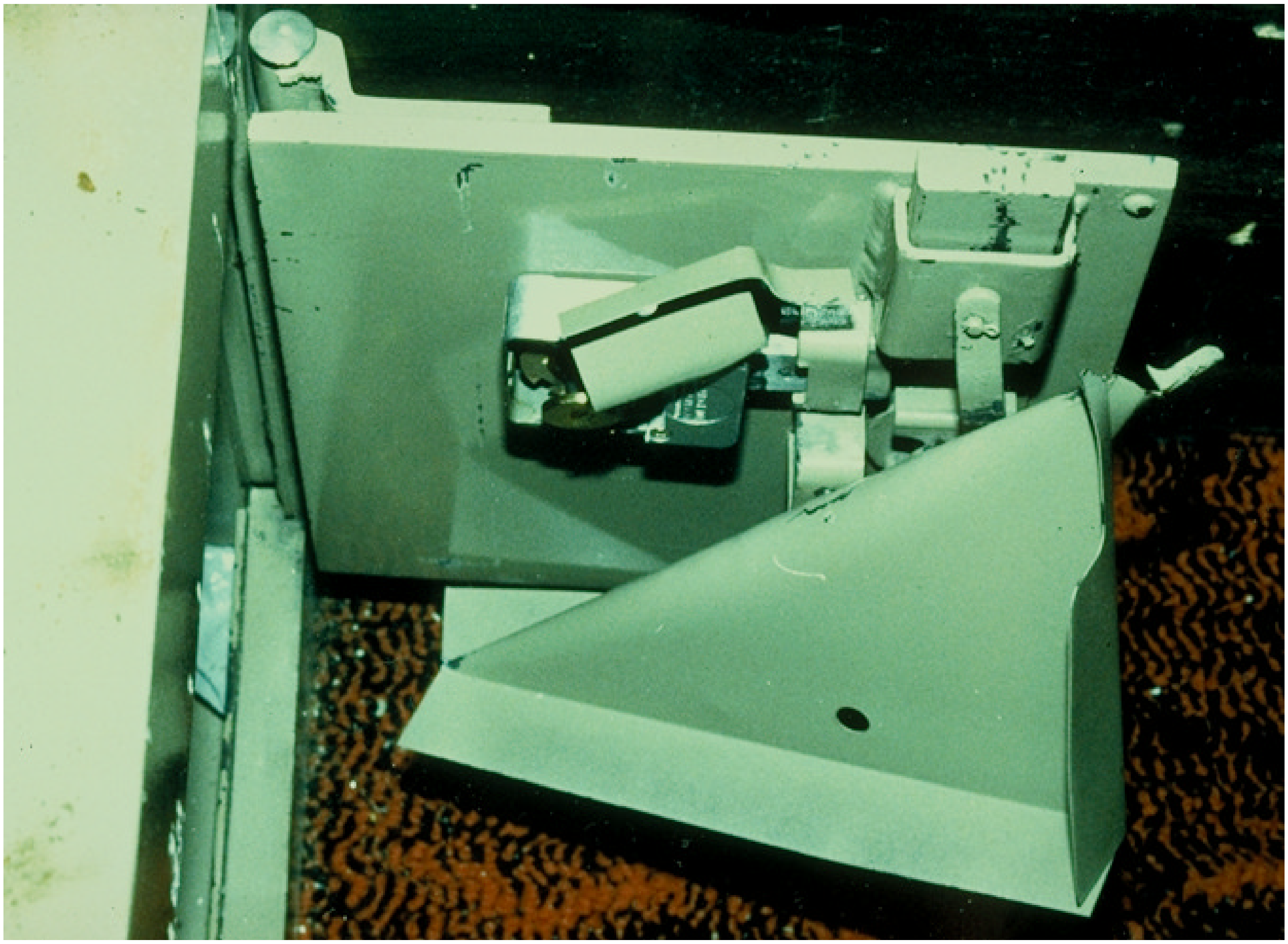


Figure LSS+3553 (PHOTO ID: Top left ISP 33-2963, center 34, right 35; second row left 36, right 37; third row left 38, center 39, right 40; bottom 41). Is there something that does not appear correct in the way the safe or its components appear. ISP 33, the Sears Tower in Chicago, is shown leaning at a severe angle, indicating that all is not what it appears. The same rule applies in safe burglaries; many are simulated but are in reality inside jobs. Examine carefully all of the evidence to be certain that how things appear actually reflect the facts. In all of the above photographs, records chests and floor safes have been subjected to simulated attacks. Courtesy of Illinois State Police, Bill Sherlock.

35_10.2.2 Fire Safes

- **If a fire safe has been burglarized, is there evidence of a prior burglary;**
- **If the contents of a fire safe have been destroyed**

by fire, is there evidence of a prior drilling to effect entry. If so, is there evidence of a repair and the replacement of insulation to factory specifications. One hole in a fire safe can destroy the contents if not repaired correctly. There may be an insurance liability issue if proper repairs were not completed;

- **Was a torch utilized to penetrate the safe. This would be indicated by external criteria, as well as moisture content of the materials contained in the container;**
- **Insulated safes can be easily moved and attacked from the bottom.**

35_10.2.3 Identification of the Perpetrator

- **Did an amateur or professional effect entry. Opening safes can be a highly technical operation, especially for a professional. There are many sophisticated mechanisms, and all are different. If a professional did the job, then the perpetrator may have had a background as a locksmith, safe technician, military technician, intelligence officer, or mechanic. Was the burglary of the safe a crime of opportunity that occurred during the burglary of the premises? Did the burglary appear to have specific knowledge of the safe and the tools that would be required for entry? Did the perpetrator have the correct tools to effect entry? Did the burglar leave his tools and all indicia that could link him to the crime;**
- **Did the method of entry or the use of tools indicate special knowledge that minimized the damage, expedited the opening, or demonstrated expertise;**
- **If explosives, drills, or cutters were used, it is likely that insulation material will attach to the perpetrator, his tools, or clothing. Keep samples of all materials from the scene. The presence of diatomaceous earth, Portland cement, vermiculite mica, gypsum, wood chips, paint, and other materials can identify the burglar. This is because most manufacturers utilize unique materials, mixtures, and particle size. Botanical experts may be**

employed with respect to the identification of certain compositions, especially if infected with a fungus;

- **Record all tool marks;**
- **Search for fingerprints;**
- **Search for blood;**
- **Search for fragments of skin on glass or other surfaces;**
- **Paint transfer may occur between tools and other surfaces that can allow for identification;**
- **Was the dial pulled off the safe, but entry not made through the front, but rather the side or back. This would indicate that the perpetrator had special knowledge and measured the distance from the face of the door to the back of the lock case, using a fine wire;**
- **Samples of metal chips from drilling hard plate and the oil residue from the drill can be matched with those found on a suspect;**
- **Examine the lock case for burned paint that was caused by excessive heat, dull bits, or a negative rake on the bit. Does it appear that a carbide bit was used to penetrate the lock case, rather than a sharp HSS bit;**
- **How much pressure was used during drilling. If there is a hole in the lock case, is there damage to the nose of the lever or wheels. Is any of the plastic wheel pack melted;**
- **Was the back cover of the lock case knocked loose;**
- **Was a thermal relock trigger fired and which was caused by heat from drilling;**
- **Was a second hole required because of incompetence;**
- **Were drill bits left at the scene that can be linked to a perpetrator;**
- **How was the dial removed. Did the removal of the dial indicate lack of experience or knowledge. Dials made of brass, bronze, and steel, Group 1 dials (S&G 8500, or TL rated), or certain manufacturers (Mosler 302, for example) cannot be pulled with a slam hammer or dial puller. If the dial is threaded or pinned, it likewise cannot be pulled;**
- **Drilling generates fine dust. Check the clothes,**

hair, and fingernails of a suspect;

- What information and prior knowledge was required to plan the attack;
- Was prior knowledge of the container required;
- Has the owner been having trouble opening the container, and has a locksmith recently been called;
- Were relockers engaged, indicating lack of expertise.

35_10.2.4 Other Physical Evidence

- Tool marks on any surface;
- Scrape marks on sides of safe and handle, indicating the use of a drill rig with chains;
- Magnetic images on face of safe;
- Metal chips on floor in order to determine the type of drill;
- Broken bits left at scene in order to indicate make and manufacturer of drill.

35_10.2.5 Tools

- Was a hole saw used to reduce the dial size. Was there any damage to the drive pins or flys. If not, the wheels may have been spun several times prior to drilling. This practice protects components from shock, thus indicating expertise of the burglar;
- Was entry effected by an amateur or professional;
- If the lock case was penetrated, does it appear that a sharp drill bit was utilized. A dull bit will force material ahead and form ridges or bubbles on the inside of the lock case wall that can bind or rub against the bottom wheel. Examine for such indicia;
- Did the burglar drill through the dial and hit the mounting screws. This would indicate a lack of knowledge, especially with regard to the bottom screw, because of the potential of dropping the screw-head into the wheel pack;
- Were mounting screws drilled in an effort to bypass hard plate to reach the lock case;

- **Were professional tools employed to manipulate internal components. Often, burglars will remove the dial and punch the spindle. Then, tools are used to align the gates and defeat relockers. Tool marks may be present in the lock case or on the wheels;**
- **Drilling can be dangerous, especially if a bit breaks. This can cause the motor to fly and hurt someone. Is there evidence of personal injury;**
- **Are there multiple drill marks on the face of the door, indicating lack of proper tools and that the work was performed by an amateur;**
- **Was a professional drill press utilized;**
- **If a magnetic drill press or template was attached, then magnetic fingerprint powder, copy toner, or spray material will show magnetized spots on the surface of the safe;**
- **Was a robot dialer, such as the ITL, utilized. Are there any clamp or suction marks on the dial;**
- **Was a diamond-tipped drill bit utilized. If so, was it run at low RPM and light pressure, indicating expertise;**
- **Are there any broken bits left at the scene, indicating difficulty in penetrating hard plate or lack of expertise;**
- **Does it appear that expensive tools were required to effect entry. Do such tools leave distinctive marks;**
- **Were tools broken, indicating lack of experience;**
- **Was an incorrect drill bit utilized;**
- **Was an improper drilling technique utilized;**
- **Was an incorrect cutting tip for an oxyacetylene torch used;**
- **If a torch was used for penetration, was the door welded shut due to excessive heat;**
- **How precise were drill points. Exact location would indicate the use of a drill template and expertise;**
- **Was the dial removed, indicating lack of experience.**

35_10.2.5.1 Tools in the Possession of Suspects

The characterization of an implement as a "burglary tool" is somewhat illusive. However, the following devices will generally meet the statutory criteria, depending upon where found, combination of tools, circumstantial evidence and direct evidence of use:

- **Bellows;**
- **Borescope or special viewing device;**
- **Containers of gunpowder;**
- **Drills;**
- **Explosives;**
- **Fur muff, carpet, or other sound baffling material;**
- **Fuses;**
- **Hole-saws;**
- **Jimmies, in various lengths;**
- **Levers;**
- **Lights;**
- **Maps and blueprints;**
- **Rubber hose;**
- **Spatula to open window fasteners;**
- **Specialty pulling tools;**
- **Tubes for blowing powder into openings;**
- **Wedges;**
- **Wrenches.**

35_10.2.6 Drilling

- **What was the drilling technique;**
- **Did the perpetrator have prior knowledge of the container;**
- **Did the perpetrator understand the proper use of his tools;**
- **Did the perpetrator bring the proper tools to do the job;**
- **Did the perpetrator utilize tools in an incompetent manner;**
- **What was the accuracy;**
- **Was a drill template used;**
- **Was the hole drilled at an improper angle;**

- **Were relockers triggered, indicating lack of knowledge;**
- **Were holes drilled in the wrong place;**
- **Was there damage done to the lock;**
- **Was the diameter of the hole too great or too small;**
- **Were bits stuck in the hole;**
- **Was a magnetic template used on the face of the safe;**
- **Was special knowledge required for a particular type of lock to drill it properly;**
- **If hard plate in a burglary-resistant container was drilled was the drilling angle 90°. If not, the perpetrator may not have had prior knowledge of the construction of the container.**





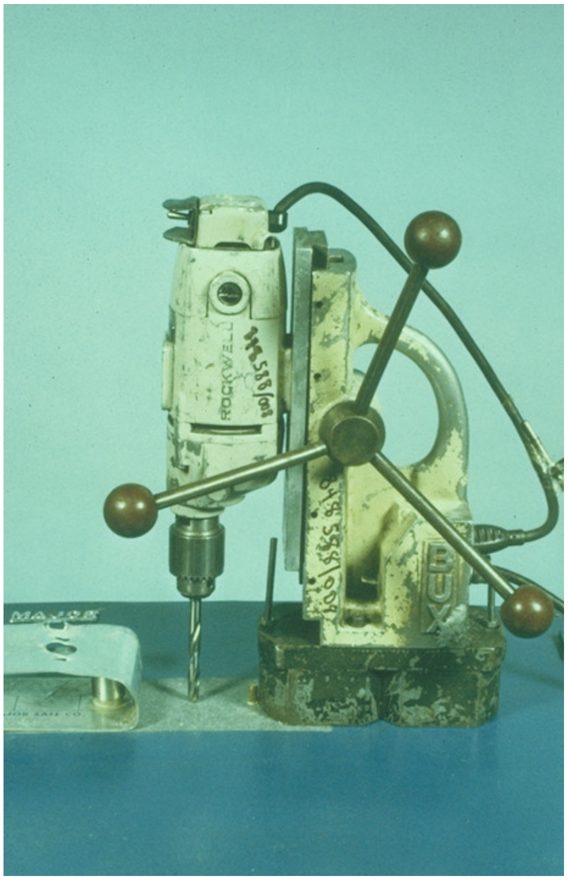


Figure LSS+3554 (left, ISP 90-3563; center, ISP 92-3563; right ISP 93-3563). In 90, the burglar uses a drill without much knowledge of the safe. In 91, 92, this was a safe at a fast food restaurant chain, showing that the thief had no idea where to drill. In 93, a mock drill point is shown to demonstrate lack of competence upon the part of the burglar. Courtesy of Illinois State Police, Bill Sherlock.

35_10.2.7 Modus Operandi

- **What is the primary method of operation: apparent and real;**
- **If the container was drilled, for what purpose;**
- **Does the technique indicate expertise. If so, why;**
- **Was the lock drilled under the dial ring, then replaced to mask the fact of entry;**
- **If drilling was under the dial ring, is the lock unique or difficult to obtain;**

- **If an electronic lock such as the Mas-Hamilton X-07 was replaced, was special knowledge required in order that the combination not be disturbed;**
- **Did the perpetrator have sufficient time to use his knowledge and tools successfully;**
- **Did the perpetrator have the proper tools to complete the task;**
- **Did the perpetrator have sufficient knowledge about the safe.**

3563-15 Individual must have knowledge

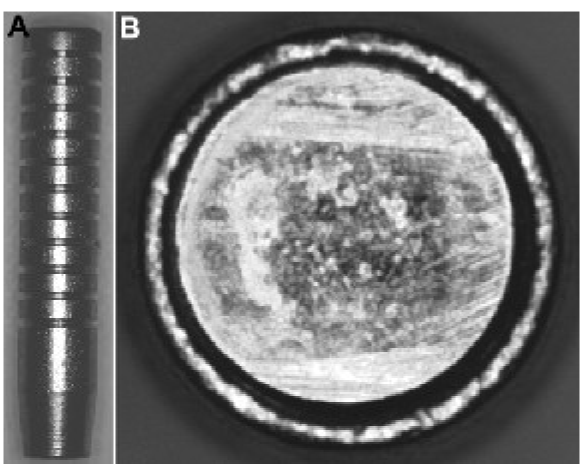
3563-16 Tool knowledge of the burglar

3563-17 Time limit for burglary

3563-1819 Proficiency in burglarizing types of safes

35_10.2.8 Prior Repairs to the Door

Government organizations have strict requirements with regard to the repair of containers. High-security GSA containers, for example, are not designed to be money containers or fire chests; they are essentially file cabinets. They are specifically designed **not** to be repaired because the fact of penetration needs to be discovered.



Improperly completed repairs can result in different ramifications that can affect the investigation of entry. These include:

- **Within a fire safe, destruction of contents due to channeling of high temperatures to the interior;**
- **Insurance liability issues;**
- **Ease in subsequent penetrations at the same point of entry;**
- **Loss of security rating or UL classification.**

The basic rule of repair is to make it more difficult to effect subsequent entry at the same drill point. Repair criteria and protocols have been standardized and require the following procedures:

- **Ream the hole;**
- **Fit the pin into the hole for precise mating. The pin should completely conceal the edges;**
- **Clean the hole;**
- **Fill the hole using a tapered, hardened tool steel pin and large ball bearing. Be sure that it is a tight fit. A hole may also be filled with pro-epoxy 20 to act as a binding agent. It may also be welded with a plug;**
- **A hole may be filled using a setscrew. This requires that the opening be tapped about three quarters through. A grade-8 bolt is screwed into the hole, with torque applied;**
- **Weld the hole from each side, first placing ball bearings, broken files, and other materials in the center;**
- **Grind smooth the weld, trimming any protrusions;**
- **Use a rubber rotary disc, emery, or fine grit to remove all grinding marks;**
- **Paint over the hole or refinish the door so that the repair is invisible. Then use oil and fine emery cloth to polish. Automobile trunk paint can be used;**
- **Texture the finish;**
- **Replace the dial ring, if necessary.**

35_10.2.8.1 Evidence of Current Repair

- **Was a repair made to cover the fact of entry;**

- **Was the lock replaced and reprogrammed;**
- **Has any portion of the lock been replaced recently;**
- **Is there any indicia of repair in the form of physical evidence, such as metal filings, paint flecks, or drilling tails;**
- **Is there evidence of drilling in the form of a tapered pin, plug, epoxy, solder, or other filling compound;**
- **Has the safe been repaired on previous occasions;**
- **Was solder used to fill a hole, rather than a tapered pin;**
- **Has the dial ring been burnished or cleaned with a file, wire brush, sand paper or steel wool;**
- **Examine the paint finish for differences in texture or color;**
- **Has the index marker been altered or refilled with paint;**
- **Can the type of paint be identified, if used to retouch a dial or door surface;**
- **Look for drill indications and the use of plugs or pins, especially under the dial. Examine very carefully because such indications can be masked, making them difficult to observe;**
- **Examine similar containers as a comparison;**
- **Check for a new dial. It may be necessary to remove the dial and check for replacement;**
- **The dial ring is attached with screws. Check to see if they have been replaced;**
- **Repairs to government containers require a certification describing the alteration. There is no such regulation in the commercial sector. Federal rules also require that no indication be present that the lock had been penetrated.**
- **Although there is no UL specification for repair once a container has been penetrated, it cannot be fixed and retain its label.**

35_10.2.9   Use of Explosives

- **How much explosive was used;**
- **Was substantially too much explosive utilized,**

indicating lack of expertise. In the alternative, was just enough material utilized, indicating prior experience and expertise;

- **Have similar entries been performed using the same explosive, or technique.**

35_10.3 Tool Mark Evidence

Many types of implements can create tool marks. Jamb spreaders, crowbars, pry bars, wedges, screwdrivers, hacksaw blades, punches, and like tools will also leave marks on doors, locks, and frames. See **Chapters 23-27** for a detailed discussion regarding tool marks.

CHAPTER THIRTY-SIX: COVERT ENTRY

Non-Destructive Methods of Entry

Master Exhibit Summary

A discussion of Mas-Hamilton and the Soft Drill, by Harry Sher

Background on Mas-Hamilton and the development of the Soft Drill, by Harry Sher

36_1.0 Introduction

This chapter is about the techniques used to open safes and vaults, of which movies are made. Much of what the public believes to be true about manipulation and other forms of covert or surreptitious entry is in reality only partially accurate. However, as the reader will learn, very sophisticated techniques are available for opening the most secure containers without leaving any evidence.

In this chapter, the various methods to bypass combination locks without damage or evidence of doing so are examined. Without question, some of the techniques are very sophisticated. There is no doubt that as the technology of digital image and sound capture is integrated into future robotics designs, the ability to compromise today's mechanical locks will mandate that electronic devices be utilized for any secure container. Some forms of silent entry require sophisticated and expensive equipment and very specialized knowledge. Radiographic imaging is such a science. Other techniques are less complex but equally effective. All of the principal methods of non-destructive entry are surveyed in this chapter, prior to a detailed analysis of traditional manipulation techniques.

The chapter concludes by exploring the art, science, and technology of manipulation. The technique, in one form or another, has existed since the advent of the modern combination lock itself. Today, there are professional safe technicians, government agents, and criminals who are extremely adept at opening a lock by feel and sound. Notwithstanding the belief by some British safe manufacturers to the contrary, manipulation done by a skilled technician can allow most locks to be compromised. Manipulation requires a great deal of training and experience to open safes consistently and successfully. As will be shown, other forms of non-destructive entry do not require such expertise. The ITL robot dialer, for example, will open virtually any Group 2 lock if programmed properly and left for a sufficient period.

This chapter is not intended as a detailed treatise on covert

non-destructive bypass. It will provide a working knowledge of the subject, sufficient for the conduct of forensic investigations or as a reference for further study by the safe and vault technician. Our prime focus is manipulation and its underlying theories, thus providing a working knowledge of the subject for the reader. Lockmasters, MBA (Mark Bates), Bennie Wells and Martin Newton (UK), Ken Dunckel and Skip Eckert (U.S.), and other recognized experts provide intensive training schools, consultation, and reference materials on the subject. The reader is also directed to **Chapter 38** for an expanded discussion of certain physical security devices.

36_1.1 Factors Affecting Entry Method

Every covert entry situation is different. Which technique is selected will depend upon many factors. These include:

- **Primary classification of lock: mechanical or electronic;**
- **Type of mechanical lock: combination or lever;**
- **Type of electronic lock: high-security equivalent to Group 1, such as Mas-Hamilton, S&G, LaGard, or lower security rating equivalent to Group 2, or no security rating;**
- **Security and UL rating of the lock;**
- **Security rating and design of the container;**
- **Special entry tools available for specific type of lock;**
- **Prior reconnaissance of lock and container;**
- **Access parameters:**
  - **Maintenance and lockout condition;**
  - **Law enforcement operation with warrant, not covert;**
  - **Law enforcement covert operation;**
  - **Covert intelligence operation;**
  - **Limited window of opportunity;**
  - **No time limit of access;**
  - **Secure site, no problem leaving automated equipment;**
  - **Non-secure site;**
  - **Operation may be performed with several attempts at different times;**

  - **Operation must be performed in one session;**
  - **Mission is critical as to when it must be accomplished;**
  - **Mission is non-critical in nature; time not an issue;**
  - **Physical danger involved in the operation;**
- **Access to facility requires special entry team and use of covert techniques;**
- **Likelihood of success for specific techniques;**
- **Equipment and special tools required for bypass;**
- **Number of operatives required for bypass of container.**

36_2.1 Covert Methods of Entry: A Survey

There are many covert methods of entry available to the safe technician, intelligence agent, investigator, and burglar. This Section will summarize the principal techniques used for opening safes and vaults in a non-destructive manner. For a discussion of specific techniques relating to key locks, see **Chapter 29.** An analysis of the diamond theft in Antwerp, Belgium also provides an insight into the compromise of combination locks. See section **40_5.0.** There are at least twenty recognized methods to bypass the lock on a security container. The use of a particular technique will be based upon one or more factors, conditions, or circumstances as outlined above. The principal methods of entry include:

- **Capture of individual, bypass, or master codes;**
- **Capture of remote authorization or log in;**
- **Decoding the lock;**
- **Deduction of combination through physical means:**
  - **Paper marking;**
  - **Fingerprints;**
  - **Audio capture;**
- **Employee compromise;**
- **Position of dial after entry of combination;**
- **Factory tryout combinations;**
- **Impressioning the lock;**
- **Manipulation, using sound, feel, and touch;**
- **Picking the lock;**

- **Radio frequency energy interception;**
- **Radio frequency interference or disturbance;**
- **Radiographic imaging;**
- **Reversal of day locking;**
- **Robot dialing;**
- **Simulated burglary or maintenance to secure information;**
- **Observation of combination through surveillance;**
- **Vibration;**
- **Wear of internal components;**
- **User negligence;**
- **Use of the Mas-Hamilton Soft Drill manipulation system.**

36_2.1.1 Capture of Individual, Bypass, or Master Codes

Minimum-security safes used in hotels, lockers, public places, businesses, and homes utilize computer-based systems in conjunction with various authentication technologies. Magnetic stripe credit cards and magnetic spot (barium ferrite) cards are perhaps the most popular, although other schemes are also in use. Many of these systems can be compromised by decoding cards, locks, or memory devices within the CPU.

The author has worked many investigations involving these types of containers. In several instances, it was possible to remove non-volatile memory from a safe, decode the master password, and create a magnetic stripe credit card that would open all containers within a massive complex. All this was accomplished covertly and within a few minutes. Once the location of bypass codes within a memory device is determined, it can be a relatively simple matter to decode and re-encode that information. See www.security.org for specific security alerts for these types of devices.

36_2.1.2 Capture of Remote Authorization or Log-in

Fast-food restaurants, truck stops, and other locations with a high incidence of armed robbery have begun using remote-controlled cash containers. These systems require a host or control center to transmit an authorization via dial-up telephone circuit before the safe can be opened. If this

information exchange is captured and decrypted, the process can be simulated.

36_2.1.3 Decoding the Lock

The subject of decoding was fully presented in **Chapter 31** with regard to mechanical key locks. This technique is equally applicable to lever locks that are popular for use on safes. Decoding involves the analyses and extrapolation of information derived from individual levers, wafers, or tumblers. The data can be obtained in a variety of ways, including the use of an impressioning compound, optical viewing device, feeler gauges, or specially designed instruments.

John Falle produces an extremely sophisticated array of decoding tools, together with training for the professional safe technician and intelligence operative. His **pin lock** and **lever lock decoders** are legend within the military, government, and intelligence communities. Using them, virtually any lever lock can be bypassed covertly. As described in **Chapter 31**, these tools determine with absolute precision the position and travel of each lever to the fence or shear line. Some devices are so sophisticated that they will allow the highest security locks to be opened within a few minutes without trace of entry. These instruments can then decode and replicate each bitting position of a key in order to produce a duplicate.

36_2.1.4 Deduction of Combination Through Physical Means

A combination can be deduced through a variety of physical techniques without leaving a trace. Touch-sensitive materials, such as fingerprint powder and ultraviolet indicators, can provide useful information about a target lock and specific details of how it was opened. UV powder, for example, can display which keys of a touch pad were depressed when the lock was opened.

Use of ultra violet to determine which keys have been depressed on a keypad. Courtesy of Don Shiles.

36_2.1.4.1 Marking Material

Marking material such as foil, wax, or paper can be secreted under the dial to indicate stop-points for each revolution during entry of the combination.

36_2.1.4.2 Fingerprints

Fingerprints can be captured and later observed with ultra violet markers and an illumination source. This technique is especially useful for push button locks.

36_2.1.4.3 Audio Capture

This procedure is useful with combination locks that generate audible clicks for each number division. A microphone is hidden in close proximity to the lock to record the entry of the number sequence. If the dial is zeroed or set to a known marker position, then the recording can be interpolated and the combination decoded.

36_2.1.5 Position of Dial or Entry of Combination

The final number of the combination can often be observed, because it is common practice to leave the dial set at this position during the day. Once one of the numbers has been compromised, it is much easier to manipulate the lock or open it with a robot dialer. Dial marker position can be acquired through casual viewing, or with the aid of remote video, pinhole cameras, or borescopes. High-resolution cameras make possible the capture of such information from several feet away. In some cases, it is also possible to observe an authorized individual actually opening a safe. In this manner, the complete number sequence can be obtained.

36_2.1.6 Employee Compromise

Information regarding combinations may be obtained from employees, with or without their knowledge. An unauthorized person can obtain the data and compromise security.

36_2.1.7 Factory Tryout Combinations

Many safe manufacturers generate random combinations by computer. Often, number sequences are linked to the serial number for a particular container. Some vendors have adopted default sequences to open all locks shipped in their original configuration. Unfortunately, many unskilled technicians will install a new lock or container without reprogramming the factory combination. There is a comprehensive list of these number

sequences for all major locks on **www.security.org**. In the event that original combinations have not been altered, the manufacturer will usually provide the information as well as drill points to authorized technicians.

36_2.1.8 Impressioning the lock

Mechanical key locks can be impressioned, as well as decoded and picked. The subject was thoroughly reviewed in **Chapters 29-30-31.** Even a nine-lever high-security mechanism can be compromised in this manner.

36_2.1.9 Manipulation by Sound, Feel, and Touch

The art and science of manipulation is more thoroughly discussed later in this chapter. The technique involves the use of sight, touch, and hearing, combined with a detailed knowledge of the lock. A competent technician can often open a Group 2 lock in less than four minutes. The procedure is actually quite simple and relies upon the failure of lock manufacturers to achieve perfect tolerances between wheels, lever fence, and gates. Production imperfections are exploited to determine the gate position of each wheel.

36_2.1.10 Observation and Surveillance

While the container is being opened, direct observation or remote surveillance of an employee can yield the combination sequence. With the availability of extremely small video devices, a camera can often be placed in such a position as to afford a direct view of the dial. High-resolution cameras make possible the capture of such information from several feet away. This information can be recorded or directly seen. Borescopes may also be utilized as pinhole cameras. Techniques for obtaining information through surveillance include:

- **Secrete persons or cameras in ceilings;**
- **Observe safe being opened at close range;**
- **Audio or video plants in order to derive the combination or information about it. Devices will include video, film cameras, or audio recorders, long-range lenses, telescopes, or binoculars.**

36_2.1.11 Picking the Lock

As described in **Chapter 29**, almost all lever locks can be picked. The process involves the manipulation of each lever until all are aligned with the fence. Regardless of the security rating and anti-pick features, the vast majority of these mechanisms can be compromised.

36_2.1.12 Radio Frequency Energy Interception

Most electronic locks emit some form of electromagnetic energy at radio frequencies. In some cases, a spectrum analyzer and data recorder can be used to decode information about the combination. Certain systems will also utilize passive and active code devices embedded in keys or electronic cards. Although minute levels are present, there is data being transmitted to the central processing unit from such devices. Capture and decoding of this data will yield information that can be of value.

36_2.1.13 Radiographic Imaging

General techniques of radiographic imaging have been described elsewhere in this text. X-ray is used to observe internal components of a lock, normally shielded by metal surfaces. A radiation point source, using x-ray, gamma ray, beta ray, neutron bombardment, or ultrasound can be used to create a shadow and image of a wheel pack, and display the relationship of the wheels to the fence. Even low-density wheels made of delrin or similar materials can be photographed with neutron bombardment techniques.

Traditionally, a radiation source would be placed at the back of the safe, with film in front of the lock. Although focusing is a major problem, with proper training and expertise the photographs can yield sufficient data to allow a determination of the gate position of each wheel. Harry Miller, of S&G, was the first to experiment with radiation resistant locks in 1947. Group 1R locks were patented about the same time, and incorporated delrin wheels made of low-density material, to combat the threat. Initially, it was thought that the introduction of scattering and shielding material into a lock would make radiographic imaging unreliable as a decoding technique.

With the advent of the portable isotope in 1953, the United States government became concerned about the potential for compromise of high-security locks. At that time, the isotope could be contained in a small lead container weighing no more

than sixty pounds. With a three to five million volt power supply, the equipment was safe to use and ideally suited to radiographic imaging of locks. Miller found that a three-wheel lock could be decoded by exposing each wheel movement separately. A correlation would then be made with each individual piece of film.

The differences in photographic density that resulted from the effects of the high-density metallic tumblers and voids at the location of the gates could be correlated to different dial positions. The typical method to decode locks using radiation would require that a film magazine first be placed in a special holder that was attached to the dial. This would allow the dial and film to rotate in unison. The radiation source would be placed at the rear of the safe. If the dial and film holder were synchronized and rotated at a uniform rate while being radiated, it would be possible to decode the gate positions.

Even in low-density locks containing scattering material, a uniform background on the film is produced except for the gate locations of the wheels. With suitable markers on the film, the combination can be established as one of six possible sets of numbers. Miller found that the use of stationary scattering and shielding material and low-density tumblers did not afford adequate protection against compromise. SAIC and other manufacturers produce portable radiation devices that are suitable for field operations, and can provide valuable information in order to open safes and vaults.

After extensive testing, Harry Miller patented the first lock to use lead bearings behind the dial in order to deflect any radiated source (2970217, **3024640(408)**). In 1962, Miller incorporated several unique features in his lock to distort x-ray and like radiation energy patterns. This would prevent decoding of the combination. Today, his technique is rarely employed due to the use of DuPont delrin wheels.

Ultrasound, as a less sophisticated alternative, has also been utilized but found unreliable in most cases. A multiplicity of air gaps in differing materials within the lock produce results that are usually inconsistent.

36_2.1.14 Reversal of Day-Locking

Upon opening a safe, many employees will not fully rotate the dial to scramble the wheel pack. Rather, they will turn the dial

a few numbers, just sufficient to move the lever above the gates. However, the interrelationship between each wheel and the position of the pack remains undisturbed. To open the safe, all that is required is to turn the dial back to the drop in point, thus defeating all security measures of the lock and container.

36_2.1.15 Robot Dialing

ITL (Canada) originally introduced the computer-controlled robot dialer. These devices are designed to physically link a stepper solenoid and a computer to the dial. Upon proper programming, they will exploit the tolerance errors for a particular lock in an attempt to determine the true combination. Every possible number sequence will be dialed and tested until the proper sequence is found.

Locks can be opened in less than 45 minutes if one of the three numbers of an opening sequence is known for a 100-segment dial. Otherwise, up to about twenty-nine hours may be required to run every permutation. The equipment and process is more fully examined later in this chapter. See the Wilson patent, granted in 1984, for a method of automatically dialing combinations (**4433563(409)**).

36_2.1.16 Simulated Burglary or Maintenance

A simulated burglary or action that causes maintenance to be performed can be used as a subterfuge to learn the combination. Thus, a malfunction may be feigned in order that a locksmith is called. Information can then be obtained from that person about the safe.

36_2.1.17 Strong RF Field Disturbance

In some poorly designed electronic combination locks, a strong RF field may be employed to scramble the CPU, logic unit, or bolt mechanism. The result can be a corruption of data in memory, or the inducement of voltages that are sufficient to trigger solenoids or other bolt control devices. The author has employed this technique using high-power portable transmitters to accelerate timing lockouts, defeat combination locks, or alter the clock frequency on processors.

36_2.1.18 User Negligence

Convenience often takes precedence over security. Selection of

combinations based upon birth dates, social security numbers, telephone numbers, easily remembered sequences, or patterns are too often used. The burglar can sometimes guess these and open the lock.

36_2.1.19 Vibration

Although not a significant problem today, older combination locks can be opened through the introduction of constant vibration. This was a particular problem aboard ships, where engine tremors were transmitted throughout the vessel. In time, each of the wheels would be self-rotated to where the gates were in the position to allow the fence to drop. The problem was solved with the introduction of balanced wheels.

In practice, many older safes can be opened by the following procedure utilizing vibration:

- **Determine the location of the tip of the fence;**
- **Tilt the entire safe so the fence location constitutes the most vertical position of he lock;**
- **Set the dial to the drop in point;**
- **Tape the dial to prevent rotation;**
- **Attach a transducer to the dial. The transducer must be excited with a low frequency, high energy sound wave. Thirty cycles per second, or within that range should be sufficient;**
- **Apply energy for at least ten minutes, and each of wheels should be vibrated so that the gate is positioned under the fence;**
- **The lock should open.**

36_2.1.20 Wearing of Internal Components

In some inferior quality UL Group 2 locks, the dial can be spun at high RPM with a drill motor for several hours in an effort to create excessive wear upon components. This will lessen critical tolerances or cause seizure. Likewise, a high-speed router capable of operating at 20,000 RPM can explode a wheel pack or separate the individual wheels. The U.S. government has a specification for Group 1 locks that requires the mechanism to be impervious to this form of attack, for a minimum of eight hours at 600 RPM. The lock must still function after that time and be resistant to manipulation. S&G, in response to this specification, have changed the lubrication to allow perfect

operation after eight hours. There **is** a risk that thermal relockers may fire due to heat build-up.

This particular technique was foreseen in the design of the Mas-Hamilton X-07 and is guarded against through both hardware and software. In that lock, there is a threshold of dialing attempts within a predetermined timing window. If the number is exceeded, the lock will shut down.

36_3.0 High-Technology Bypass of Combination Locks

The following material describes the current high-technology devices for opening combination locks. A discussion of instruments used for key locks is presented in **Chapters 29-31.** Certain methods for opening GSA enclosures have been omitted intentionally. The following information has been gathered from manufacturers, government agencies, and the United States and British patent offices.

36_3.1 Tools for Determining Safe Lock Component Positions

36_3.1.1 Direct-Drive Locks

Simple tools have been designed and patented for determining the gate positions in direct-drive combination locks (**4056956(410)**). Generally, these instruments measure the movement of the handle when torque is applied. In these mechanisms, the tailpiece position will change slightly when it is pressed against the gate of a wheel.

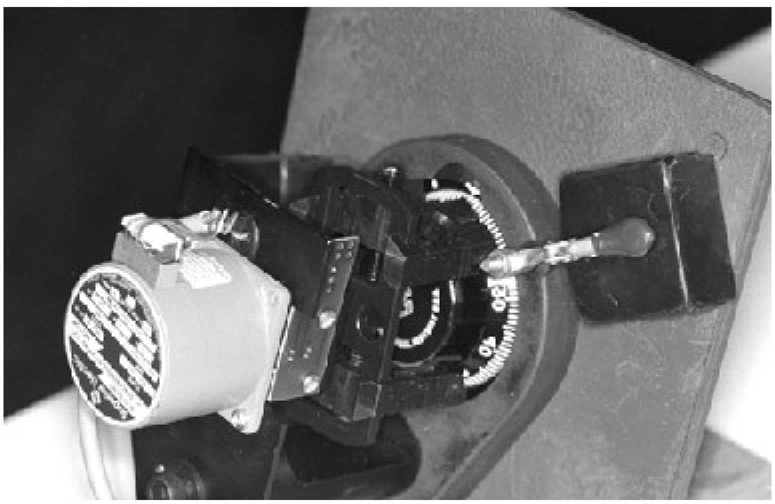
36_3.1.2 Robot Dialers

2963-42 The use of robot dialers

Computer-based automatic control mechanisms can be attached to the dial of a Group 2 combination lock to open it. They can be programmed to sense gate position, or the location of the drive cam with respect to the fence. They will detect when all wheels are aligned and the lock can be opened. The reader may be interested to read a description of an **automaton** robot dialer that was developed more than one hundred fifty years ago to

manipulate lever tumbler locks. This is described in the Hobbs book, contained within this Infobase. Robot dialers are designed to perform two distinct functions. Either they can open the lock by exploiting tolerance errors and testing each permutation of the combination, or they can replicate the actions required in manual manipulation.

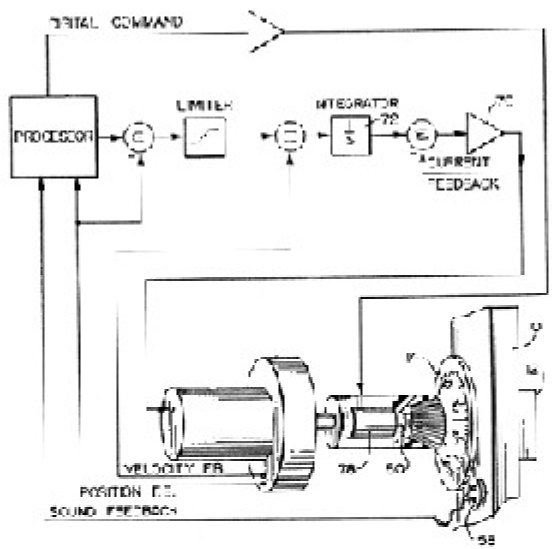
There have been many patents issued for such devices and related technology (534650, 1064608, **2974517(411)**, 3222922, 3633388, 3694637, 4017851, **4056956(412)**, 4126821, 4319223, 4377847, **4433563(413)**, 4591774, 4769583, 4777603, **4803860(414)**, **4905490(415)**). Recent inventions reflecting current technology are described in this chapter. See **www.security.org**.



Devices currently under development or being tested will bring sophisticated enhancements to the relatively imprecise present manipulation process. Instrumentation that senses and process audio and video will be available that will open Group 1 and Group 2 locks, with the exception of the X-07.

The Mas-Hamilton X-07 is virtually impervious to manipulation attempts and robot dialing. It is estimated that it would take the ITL approximately 190 days to open the X-07 in single mode, and 250 years if dual mode has been implemented. At the University of California (Irvine), for example, a robot was constructed as part of an engineering project to open safes. The device utilized sophisticated audio and noise analyses with an electro-optical link. The link eliminated noise coupling that created artifacts during processing. It is estimated that when the unit is developed, it will weigh five pounds and be

completely portable.



36_3.1.2.1 Automatic Permutation Sequencing

A number of decoders have been developed for automatically sequencing a lock to test all possible combinations until an opening occurs. In 1958, Jacobs (**2974517(416)**) developed a machine to exploit vibration as a means for manipulating open a lock. The problems associated with vibration were discussed in **Chapters 34-35**, specifically with regard to safes located on ships. It will be recalled that wheels within the wheel pack would vibrate to a position wherein their gates were aligned with the fence. This problem was corrected with the introduction of balanced wheels. Jacobs developed a device to impart random vibration and oscillations in order to induce movement of each wheel until the lock opened.

In 1984, Wilson (**4433563(417)**) developed a device that could be programmed for a specific algorithm, depending upon the fence-gate tolerances of a given lock. His instrument would ignore "illegal" combinations such as in the forbidden zone, thereby reducing the time required to find the correct sequence. The tool could be programmed to skip overlapping numbers, also making the process faster. Finally, the wheels would only be turned to test the next number in the series, rather than redialing the entire number sequence. This allowed a fully automated system that would sense when the correct combination was determined, although the device was incapable of determining

the gate position of each wheel independently.

In 1991, Heinzman was granted a patent (**5017851(418)**) for an opening device that could store many combinations for different safes within a complex. This completely portable unit could be programmed for a variety of modes, depending upon individual requirements. The instrument did not determine gate positions, but rather it could be used as a secure memory device to allow one individual to access many locks.

36_3.1.2.1.1 ITL Robot Dialer

ITL (Vancouver, Canada) produced the first microprocessor-based portable robot dialer available in the commercial market. This device is described in detail here because of its unique design and utility to the professional safe technician.

Robot dialers can perform one of two functions: **permutation sequencing, or manipulation.** The ITL unit is programmed to sequence a particular lock through all possible number permutations until the mechanism is opened. Using the ITL, a lock can be compromised in between four and forty hours, depending upon many factors. If one of three numbers has been determined through manipulation or other means, then the process can require less than one hour.

The device dials a predetermined sequence of combinations, based upon the following information that is entered into the computer:

- **Type of lock;**
- **Number of wheels;**
- **Location of drop in point;**
- **Precise location of left and right contact point;**
- **Position of the zero-marker position or other defined location;**
- **Tolerance or overlap between numbers;**
- **Forbidden zone and unusable numbers;**
- **Known numbers in combination;**
- **Range of numbers to test;**
- **Sequence of numbers per individual wheel.**

Lock manufacturers, to test their products and determine reliability, also utilize robot dialers. These devices provide a means to study how locks perform when users enter combinations.

Programs can vary speed, motion, and delays during the entry process. In this way, failures can be detected and corrected based upon individual user profiles.

36_3.1.2.1.1.1 ITL 9000 Operation

The ITL can be set to dial any sequence of numbers for each individual wheel. A different combination will be dialed every second until a torque change is sensed, indicating that the lock has been opened. Presently, these units will only function with a single-action combination lock that retracts the bolt through the dial action.

The dialer is comprised of a stepper-motor that is mechanically linked to the dial and controlled by a portable CPU. The entire assembly is magnetically coupled to the safe-body for stability. This device will operate in an unattended mode; once the lock is opened, the dialer stops and displays the last number entered.

36_3.1.2.1.1.2 Theory of Operation

All permutation sequencing robot dialer designs are based upon the same principle: mechanical combination locks have tolerance errors between individual wheels that are inherent in the manufacturing process. Dialers exploit these errors by reducing the number of permutations that must be tested in order to determine the correct combination. The gate tolerance for Group 1 locks is ±.75-0.875 from the target number; in a Group 2 lock, it can be up to ±1.25. UL allows ±1.25 from the edge of the target; S&G, from the center of the gate. Each manufacturer takes full advantage of these specifications.

The tolerance for a given lock will determine the actual number of permutations, and thus security. This factor is also affected by wear and will be altered over time. If the fence is close to the gate, it can be vibrated into position, thereby further exploiting tolerance errors. Every 100-division three-wheel lock has 1,000,000 theoretical permutations. The actual number may be less than 240,000, correcting for tolerance errors and unusable numbers. The time required for a dialer to open a lock is based upon a simple calculation. It is a function of the number of real permutations, divided by non-overlapping unique positions and the amount of time required to dial each permutation.

Smart dialers, such as the ITL, will move each individual wheel to the next number to be tested in about one second. Thus, the

combination is actually entered sequentially on an individual wheel basis at high speed. In this manner, these devices can test hundreds of thousands of number sequences in a relatively short period. The actual time required for each test is based upon the coefficient of friction of the wheels.

The probability percentage of opening a lock will increase as more numbers are tested. Thus, in a lock with 240,000 actual permutations, the probability of opening the lock on the first tested combination is extremely low. The curve, however, is linear as one progresses through the number sequences, plotting numbers against time. In a Group 1 lock, there is a probability that a lock can be opened in twenty hours, assuming that the dialer is capable of working on this type of mechanism.

36_3.1.2.2 Instruments for Determining Contact Points

Manipulation is a precise art, requiring a great deal of skill. Simple aids have been developed such as magnifiers, filtered audio amplifiers, scales, and special illuminators. All of these devices are utilized in an attempt to define contact points.

As the reader shall learn, more sophisticated automated devices have also been proposed and developed. Combination lock decoders have been designed to sense dial positions and contact points in an attempt to automate the manipulation process (**4905490(419)**). For example, one major lock manufacturer has produced an instrument that utilizes electro-optical sensing, coupled with extremely sensitive and filtered audio to indicate the position of contact points.

Moore, in 1989 (**4803860(420)**), received a patent for an electronic device to assist in the manipulation process by obtaining accurate contact readings. His invention employed an optical scanner integrated with an audio detection and discrimination system to quantify the information normally interpreted by the safe technician during manipulation. This system, however, did not take advantage of microprocessors or memory technology. The Moore device was not intended to replace the technician or the required detailed knowledge of the manipulation process. Rather, it was designed to enhance the ability of a skilled professional to manipulate open a safe.

In one invention (**4905490(421)**), Wilson designed a device that would accurately sense dial position within one tenth of a digit,

and open many locks within one hour, including Group 1 devices. The invention relied upon the manufacturing tolerance errors that occurred in the production of wheels and the fact that they can never have precisely identical diameters. The inventor used the physical contact between the nose of the lever and each wheel to provide data that could be interpolated by his decoder.

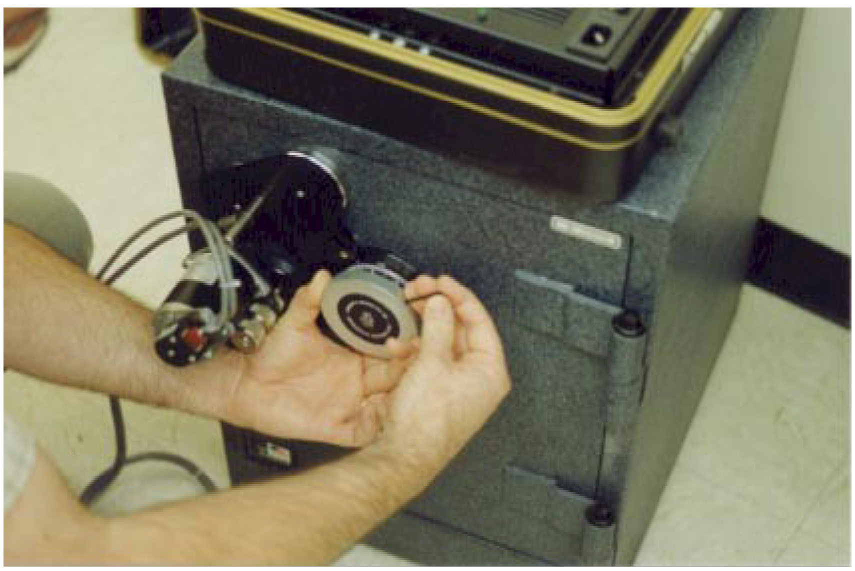
The physical and electronic design of the decoder is typical of the state of the art. A frame is secured to the container in a fixed position, and a gripper links the dial to the servomotor and associated control circuitry. A rotary encoder is coupled to the servo in order to indicate the exact position and velocity of the dial. Also connected to the lock and the processor is a sensitive sound transducer to provide an indication of contact points.

In the Wilson invention, the processor and control circuitry can be programmed with a manipulation algorithm for each lock in order to decode the opening combination. The device will continue to dial thorough all permutations until the lock opens.

36_3.1.3 Mas-Hamilton Soft Drill Manipulation System









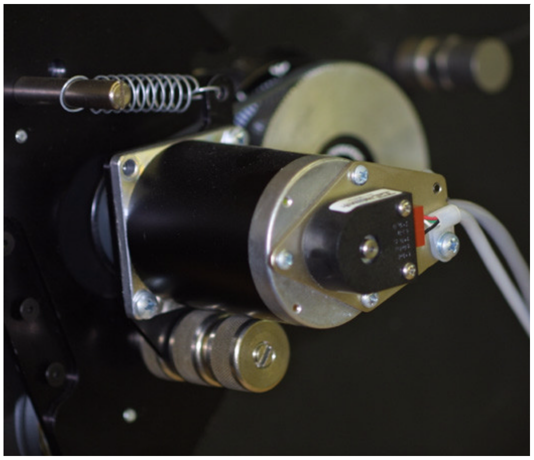




Figure LSS+3601 The Mas-Hamilton Soft Drill system is self-contained and integrated a laptop computer with sophisticated sensors that are attached to the front of the safe.
Courtesy of Mark Bates.

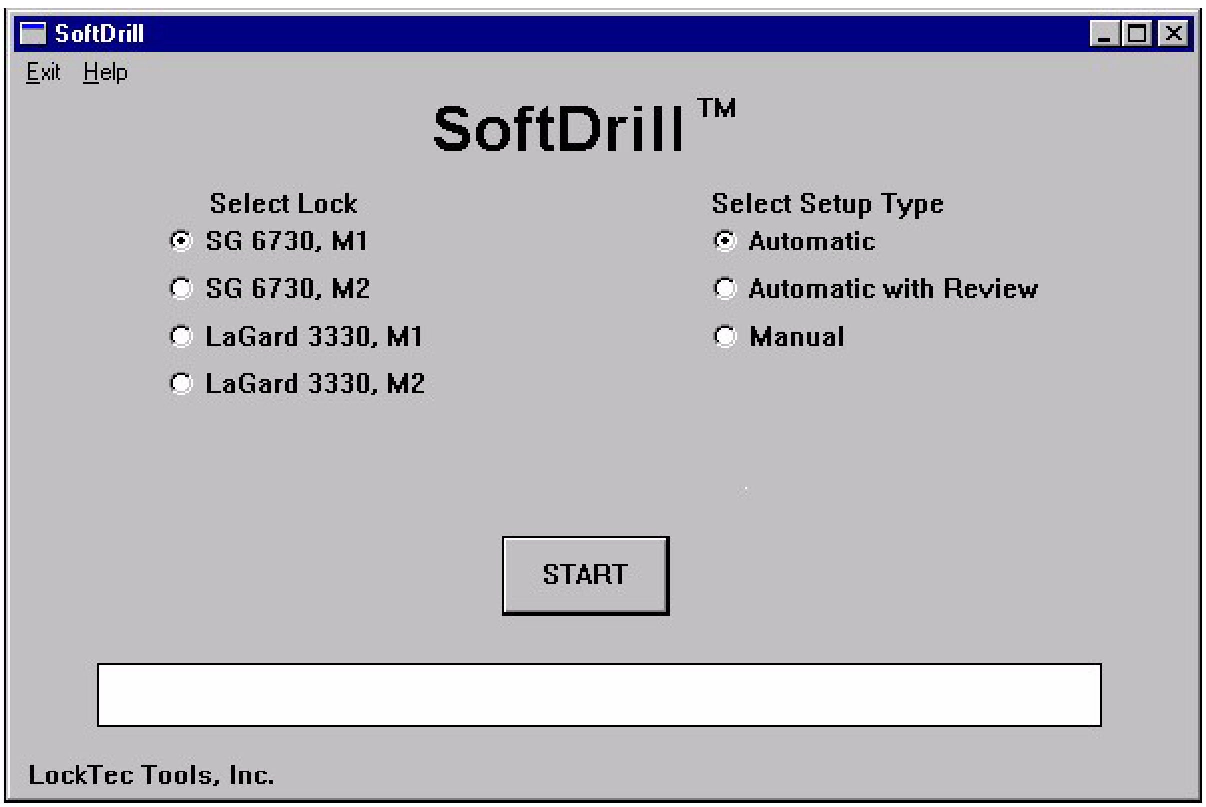
LSS201: Mark Bates on the Soft Drill

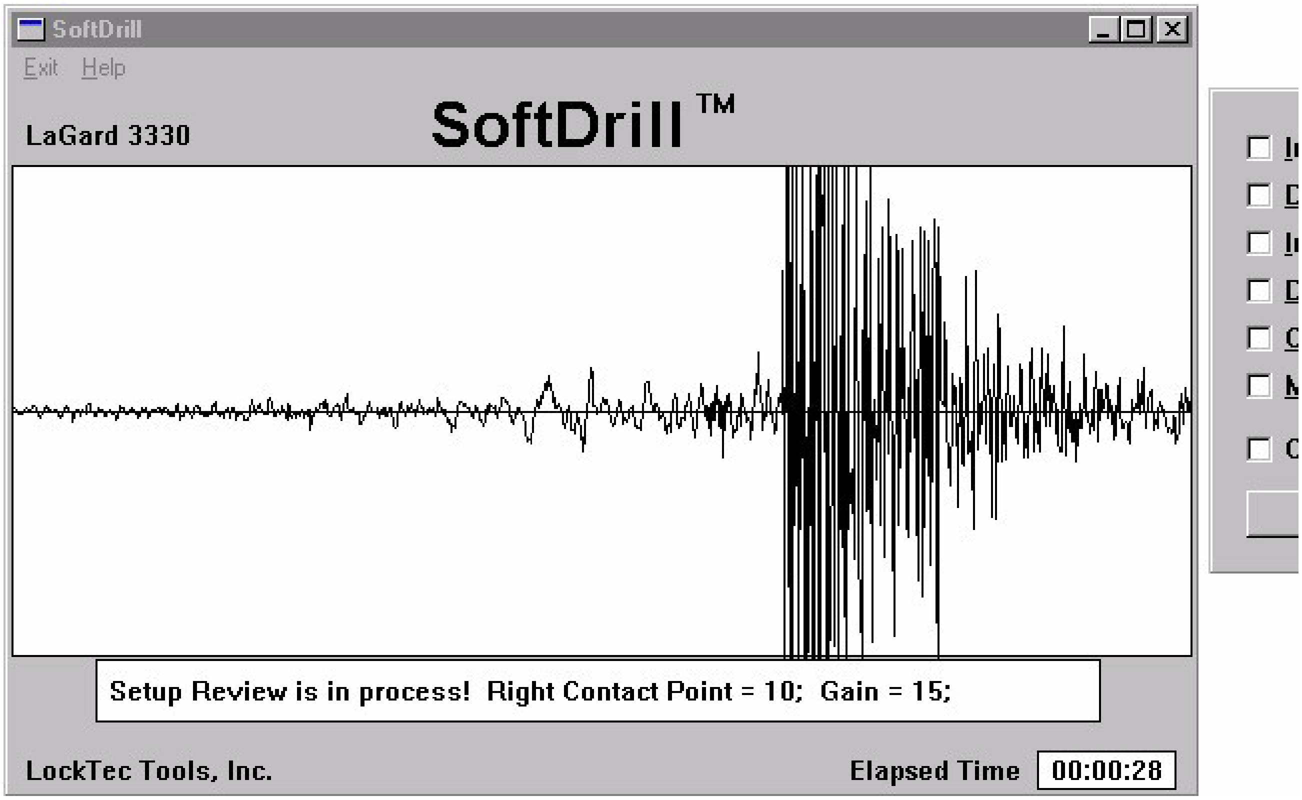
A discussion of Mas-Hamilton and the Soft Drill, by Harry Sher

Background on Mas-Hamilton and the development of the Soft Drill, by Harry Sher

Since the printing of the Second Edition of ***Locks, Safes, and Security***, Mas-Hamilton has introduced the **Soft Drill** (r) system for manipulating certain Group 2 combination locks. The technology is based upon mechanical and acoustic sensors that can replicate traditional manipulations techniques. Complete documentation of this system is contained in this section, together with a multimedia demonstration of the opening of a S&G 6730.

Presently, software is available to open the S&G 6730 series and the LaGard 3330. The Soft Drill system provides a sophisticated integration of computerized sensing technology with extremely advanced hardware to detect sound and movement to replace manual manipulation. This system is not a robot dialer, but rather a stand-alone process to determine the correct combination and open certain locks.




SoftDrill
Exit Help
LaGard 3330
SoftDrill TM
Setup Review is in process! Right Contact Point = 10; Gain = 15;
LockTec Tools, Inc.
Elapsed Time 00:00:28

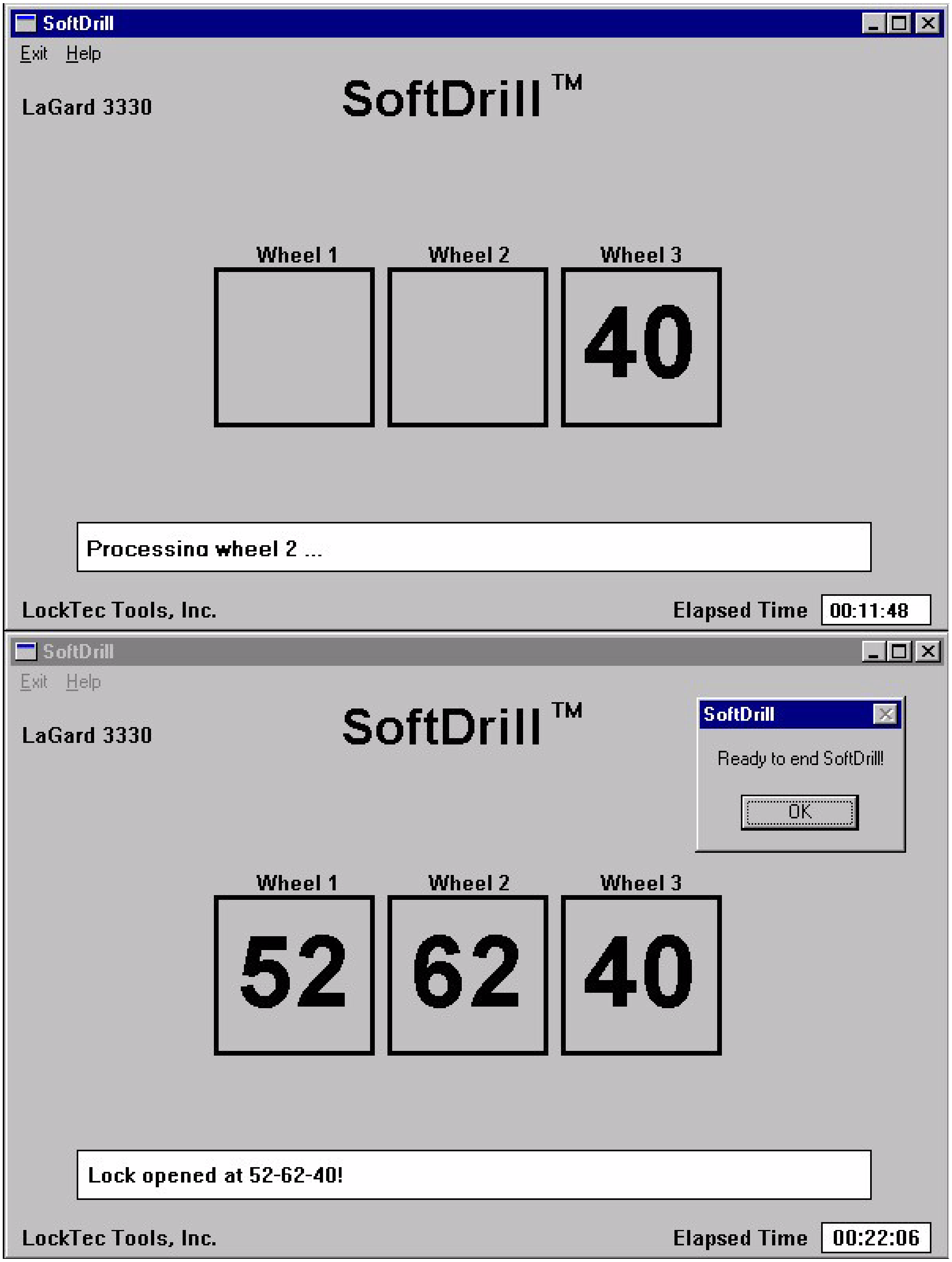

SoftDrill
Exit Help
LaGard 3330
SoftDrill TM
Wheel 1
Wheel 2
Wheel 3
40
Processing wheel 2 ...
LockTec Tools, Inc.
Elapsed Time
00:11:48
SoftDrill
Exit Help
LaGard 3330
SoftDrill TM
SoftDrill
Ready to end SoftDrill!
OK
Wheel 1
Wheel 2
Wheel 3
52
62
40
Lock opened at 52-62-40!
LockTec Tools, Inc.
Elapsed Time
00:22:06

Figure LSS+3602 The Soft Drill system provides detailed prompts and status information for the technician during the setup and manipulation process.

A number of patents have been granted for this system, including the primary inventor, Wilson in 1990 (**4905490(422)**), Jacobs (**2974517(423)**), Gilliam (**4056956(424)**), Caruso (4319223), Daniel (4377847), Wilson (**4433563(425)**), Goor (4769603), Woodman (4777603) and Moore (**4803860(426)**). See also Audenard (**4423634(427)**) for a method of measuring acoustic emission by detection of background noise,

The applicable prior art patents for the Soft drill include the following:

(3427865, 3486616, 3489241, 3548648, 3554012, 3560844, 3580059, 3596502, 3611761, 3633388, 3653255, 3677072, 3694637, 3699806, 3745815, 3781698, 3793627, 3842663, 3914754, 3952566, 3971249, 4007630, 4020678, 4050292, **4056956(428)**, 4078434, 4089055, 4145930, 4161877, 4196629, 4213114, 4237454, 4238789, 4252023, 4261206, 4262538, 4281548, 4286467, 4317105, 4335612, 4352293, 4377947, 4387596, 4408294, 4423435, **4423634(429)**, **4433563(430)**, 4437163, 4446734, 4478082, 4479389, 4481819, 4493042, 4528852, 4530240, 4550603, 4550604, 4615216, 4649743, 4672850, 4722226, 4729239, 4730484, 4763523, 4768380, **4803860(431)**, 4875171, 4884412, 4896101, **4905490(432)**, 4931949.

Review of Soft Drill(433)

36_3.2 Defenses to Bypass Techniques

For almost every bypass technique, certain defenses can be implemented by manufacturers and security officers. The following discussion surveys countermeasures against methods of covert entry.

36_3.2.1 Improper Possession of Combination

James Sargent developed the time lock to prevent entry into a container unless the proper combination was used at the correct time. Today, electronic and mechanical time locks protect virtually every high-security safe and vault. They are even used in cash containers at locations with high robbery potential. Time locks are extremely effective in preventing certain types of robberies.

36_3.2.2 Observation of Entry of Combination

Utilize top-reading spyproof dials and covers (2836052).

36_3.2.3 Back-Dialing

Follow the correct security procedure or employ automated locking if the mechanism remains in an open state for more than a few minutes. An employee should always turn the dial at least one full revolution when securing a container. Certain combination locks will automatically reset after being in an unlocked state more than a few minutes.

36_3.2.4 Manipulation

High quality UL Group 2 locks or higher security Group 1 devices can be utilized.

36_3.2.5 Automatic Robot Dialers

Utilize dual-function Group 2 locks or Group 1 locks that are specifically protected against this form of attack. Electronic devices such as the X-07 are immune to dialers.

36_3.2.6 Fingerprints or Other Physical Indicia of Combination

Use special dust covers or random keypad numbering, such as provided by Hirsch.

36_3.2.7 Radiographic Attack

Use of radiation for imaging can be prevented or severely hampered by several techniques. These include:

- **Use of Group 1R locks;**
- **Use of low-density wheels;**
- **Incorporation of lead bearings within the lock and dial assembly (3024640(434)).**

36_3.2.8 Reset of Combination in Zero-Change Lock

The combination in a zero-change lock can be reset without knowing the original number sequence. This can be accomplished

without the knowledge of the owner of the safe. The countermeasure is to utilize a regular change lock.

36_3.2.9 Use of Factory-Default Combination

Change the combination when the lock is installed.

36_4.0 Opening Locks by Manipulation

36_4.1 Introduction

Opening safes by manipulation has been characterized in countless movies as a skill easily acquired by spies and criminals. A little bit of sandpaper, light touch of the dial, listen to the clicks, and in a few seconds the container is opened. All quite elementary!

In reality, manipulation is an art, technology, and a science. The process allows a lock to be opened without any prior knowledge as to the combination and absent any trace of entry. It is a silent skill that will cause no damage to the lock or container. It does not require force, extra tools, or special equipment. Moreover, it has existed for about four thousand years in various forms.

Knowledge of the techniques of manipulation is mandatory for any professional safe technician. The process makes drilling and other forms of forced-entry unnecessary, and it can be invaluable in analyzing the cause of lockouts. However, manipulation will not work in all cases. Damage, wear, malfunction, or design parameters can obscure contact indications.

The forensic examiner and security officer is concerned about manipulation, as it is used for surreptitious entry involving sophisticated thefts. Although over ninety-eight percent of all entries are accomplished by force, major thefts, especially of classified information, are often carried out using this technique.

With the proper skill and knowledge, the procedures outlined below can allow a technician to open most Group 2 locks in relatively little time. However, there are no shortcuts. The art must be learned, based upon a detailed working knowledge of locks. To properly manipulate can require a great deal of time and patience, and adherence to a strict regimen. The talent is

not easily acquired, nor will it work for every lock. Each opening will present a new challenge and potential problems.

In the following discussion, the underlying theories and principles of manipulation will be explored, together with proper procedures and guidelines to allow for a successful and expedient opening. The materials are not intended as an exhaustive treatise on the subject; many books and courses teach the art in far greater detail.

The principles of manipulation are logical, straightforward, and easy to learn. They can be succinctly stated in just a few pages. The translation of that knowledge into a useable skill that will ultimately open a locked safe is another matter. Just knowing the principles does not mean that a particular technician can open a lock.

Our discussion concentrates on theory, rather than an in-depth examination of all of the different variables that can occur for specific types of locks. In the view of the author, it is more important that the reader acquire a sound theoretical basis for the principles of manipulation. Many references provide detailed information regarding opening procedures for each type of mechanism. Gaining proficiency in the art is far less challenging with a thorough understanding of the underlying theory of the technique.

36_4.2 Listen to the Lock: It Will Speak to You

The portrayal in film of combination locks being opened by listening to telltale clicks is pure Hollywood. The "clicks" provide no useable information. In fact, the lock within most of the high-security safes is usually very quiet during movement, as they are often shielded by up to 8" of metal.

"Listening to the lock" means letting it provide information about itself as the dial is moved and various diagnostic procedures are performed. If the mechanism is thoroughly understood and one pays attention to its clues and signals, it will disclose how it can be opened. This will be a one-way conversation to be sure, for there is nothing that can be **told to** the lock. To be effective, the technician must be "at one" with the internal mechanism, and in harmony with it.

36_4.3 Prerequisites to Successful Manipulation

Three primary skills are required for successful manipulation:

- **Visualization of internal components;**
- **Sensory skills;**
- **Logic and judgment.**

36_4.3.1 Visualization

Visualization is the ability to translate sensory information obtained from sound and touch into mental images of internal components. The process must be based upon a detailed understanding of the lock and the integration of that knowledge with sensory data. The technician must know the placement of every internal part and understand its function and purpose. A cutaway model is ideal for this purpose, especially for the novice. It can provide a reference during manipulation and is recommended to be included as part of a basic tool kit.

36_4.3.2 Sensory Skills

During manipulation the technician must process sensory input from the lock in the form of sight, sound, and touch. This information must be integrated into a mental image of the internal components.

36_4.3.2.1 Visual Skills

Manipulation is based upon minute variances in the position of the dial marker, at the left and right contact points. The ability to accurately discern this information is critical. The problem is often complicated by imprecise markings with respect to their width, consistency, and placement.

Dial markings must be observable to a resolution of .05 (1/20) of one marker or division. That means that in order to obtain sufficient data, the dial must actually be divided into two thousand segments. Accurate and consistent extrapolation of marker information is an absolute necessity.

The technician must be able to adequately observe markings. Poor eyesight, inadequate lighting, distortion in eye wear, or obstructions to vision will cause the manipulation process to fail. Visual aids are available to enhance the ability to accurately discern small variances in measurement. These devices are discussed at the end of this chapter, and should be used to

expedite the process of manipulation.

36_4.3.2.2 Touch

A delicate sense of touch is essential for determination of contact points. This requires two separate functions: **motion** and sensing of **obstruction.** The dial motion must be constant within the contact area until the left and right side of the gate physically stops the nose. The amount of motion and torque must be slight; just enough for the nose to make physical contact, but not enough to lift it. A slight, even, and consistent sliding movement is required.

The second component of touch involves the determination as to the exact point where the physical contact occurs. This is a quite delicate sensation and is often enhanced with a filtered audio amplifier. The drive cam is moved ever so slightly at the left and right contact points in an effort to determine when the nose **touches** the gate, but goes no further. This location is the contact point. Any further movement will skew the reading.

The goal is to precisely locate and measure the exact position of the drive cam boundaries, using the nose of the lever as the reference. One simply wants to **abut** the lever against the left and right side of the drive cam channel without disturbing its vertical position. This concept is critical, because **manipulation relies upon the vertical position of the nose within the channel.** Any lifting of the nose, caused by excessive torque, will make the readings worthless.

36_4.3.2.3 Logic and Judgment

Logic and judgment cannot be taught but must be acquired through experience. They are essential to successful manipulation, because they control how a lock is to be opened. Logic and judgment dictate simple rules with respect to opening locks:

- **Do not rely upon preconceived ideas;**
- **Do not rely upon unproven or unsubstantiated data;**
- **Only rely upon information from the lock;**
- **Be flexible in formulating approaches to opening the lock.**

36_4.4 Theory of Manipulation: An Overview

Virtually every UL Group 2 listed lock can be opened by manipulation. This category includes about ninety percent of the devices used on **B** or **C** rated containers, as well as **TL-15** and **TL-30** rated safes. Regardless of the mechanical design, the fundamental theory by which a lock is bypassed is essentially identical. Design deficiencies or tolerance errors in machined components permit all combination locks to be manipulated.

Almost every Group 2 lock will yield the required information to allow bypass, because their design and operating principles are quite similar. Although the placement of components may vary, the way that they interact to accomplish locking is the same. In manipulation, the safe technician is searching for minute discrepancies or irregularities based upon manufacturing tolerances for each part, in order to deduce the combination. The ways in which engineering and manufacturing problems are exploited is the subject of the remainder of this chapter.

Manipulation theory is based upon the following principles and design criteria. Each must exist, with respect to critical locking components, in order that the lock will yield information:

- **The establishment of the individual sequence of numbers that comprises the combination of the lock must be based upon the gate position of each wheel as referenced to the spline;**
- **The combination must be determined solely by the mechanical position of each wheel with respect to the fence;**
- **Bolt retraction must be based upon the position of the lever fence with respect to the gate in each wheel;**
- **The fence must fully enter the drive cam gate in order that the bolt can be withdrawn;**
- **The circumference of each wheel must vary, if only minutely, in order that individual wheels can be isolated;**
- **There must be a definable correlation between the position of the lever fence in the drive cam and each wheel gate;**
- **As the fence is aligned in succession with the gate of each wheel, the distance between the left and**

right contact points of the drive cam will diminish;
- **Each individual wheel must be rotated to precisely the correct position to allow gate alignment;**
- **The lever fence must attempt to enter each of the gates simultaneously in order to allow bolt retraction;**
- **The width of each gate must be uniform with respect to each wheel;**
- **There must be a direct mechanical relationship or link between the fence and contact points when the drive cam is rotated to the drop in point. Any obstruction or shrouding of the gate area, such as found in Group 1 locks, will defeat the manipulation process because measurements cannot be obtained as to the width of the gate for an individual wheel;**
- **The contact points must be formed by the left and right edges of the drive cam gate.**

36_4.4.1 Design Deficiencies

Deficiencies can be defined as mechanical configurations inherent in the design of the lock that make the process of manipulation both possible and easier to accomplish. A few examples illustrate the problem.

In older combination locks, the fence was allowed to rest on all of the discs all of the time. This created a critical weakness that allowed direct sensing of gate position. False discs were incorporated in the design, but that technique was neutralized with a high-speed drill or other procedure. Keeping the lever fence clear of the individual discs prevented direct sensory access to the wheel pack.

The direct-drive fence provides another example. Because of its design, it is a great deal simpler to bypass than the traditional lever fence. This is because pressure can be applied directly to the wheels through the bolt in order to determine contact points.

36_4.4.2 Tolerance Errors

Tolerance and clearance errors in machining and manufacturing processes must occur and will create the minute differences in individual components. A certain degree of clearance is required in order that parts can move freely. Thus, for example, the

inside diameter of the wheels must be approximately .005” larger than the wheel post to allow unrestricted motion. Without such errors, manipulation would be impossible. The process involves the sensing of these variances in order to ascertain the position of the lever with relation to the contact points. One or more of the following tolerance errors can provide enough data about the lock for manipulation to occur:

- **Differences in the width of the gating of each wheel and drive cam;**
- **Differences in the wheel post diameter;**
- **Differences in the diameter of the lever screw and mating hole;**
- **Differences in the eccentricity of each of the wheels;**
- **High or low wheel;**
- **Variances in the distance between the nose of the lever and the fence;**
- **Differences in the diameter of the drive cam;**
- **Shape and square of each gate and fence;**
- **Angle of the fence, referenced to the lever and top of the wheel pack (should be precisely 90º from the edge of all wheels);**
- **Fence protrusion warped;**
- **Fence tip warped;**
- **Lever body not exactly parallel to the plane of the wheels.**

36_4.5 Locks Subject to Manipulation

Certain locks can be manipulated; others cannot. Some have been specifically designed to be manipulation resistant and are employed in high-security applications. Other locks, by virtue of their design, are extremely receptive to the process.

36_4.5.1 Locks that are Easy to Manipulate

There are certain inexpensive locks that can be manipulated quickly and without much training because of their mechanical design. Burglary and fire safes sold in large retail outlets, for example, will generally offer poor resistance to manipulation because their mechanical designs are rudimentary and tolerances inexact. In one very popular but poorly designed mechanisms, only

the sequence, rather than the combinations for each wheel, can be reset. In such cases, permutations of a combination can be entered based upon the sequence of digits. This can result in the lock being opened quickly.

Likewise, some extremely popular and inexpensive round safes that are designed for mounting in floors can be opened in less than five minutes. They can be identified easily, because they usually contain two wheels and a drive cam. The manipulation procedure is illustrative of the simplicity with which such locks can be opened, although to the unknowledgeable they may appear secure. In these kinds of safes, once the drive cam gate area is determined, the wheels are rotated **AWR** or **AWL** every 2.5 or 5 numbers with a return to the right-contact point. The contact area will be .5 less for the correct gate position. Testing and parking of each wheel can isolate the gate.

Surplus government safes can often be opened easily by knowing that most agencies have a requirement that locks must be neutralized to a standard combination. GSA should be consulted to determine current practice.

36_4.5.2 Manipulation-Resistant Locks

A UL Group 1 or Group 1R designation means that a lock has been specially designed and engineered to be manipulation-resistant. The principal difference between Group 1 and Group 2 mechanisms relates to the tolerance errors identified later in this chapter.

In Group 1 locks, maintaining the tolerance between components becomes of critical importance. In addition, certain mechanical design changes have been incorporated to isolate the lever nose from the drive cam. The higher security Group 1 devices (1R) have the same basic design, with the exception that the wheel pack is made of delrin or similar low-density material. UL specifications require that these locks shall resist manipulation or penetration for a period of time, measured in man-hours. As will be noted, however, companies have developed machines capable of automatically opening some of these high-security locks. **Chapter 37** provides information about UL and other standards relating to manipulation resistance of combination locks.

S&G, LaGard, Mosler, Diebold, American Security Products and others have all produced such mechanisms, although S&G appears to be the most widely used in government service. In fact, in May 1989, the GSA specified that only S&G 8400 and 8500 series locks

were acceptable for use on certain high-security containers. Subsequently, Mas-Hamilton received approval as the sole vendor for its X-07 electronic lock for safes containing top secret information.

Harry Miller (S&G) is credited with inventing and patenting the MP 6700 in 1948, and then the MP 6730. These were the first MP locks ever produced. Several improvements were made to the design in the R6700 (1962) and the T8400 (patented in 1965). The current version of this lock is the 8550 M.P.

The unique butterfly lever in the center of the dial of earlier models can readily identify the manufacturer. This thumbscrew mechanism prevented manipulation by controlling access to the gate of the drive cam through an inner-spindle. After the last number had been entered, the dial was set to zero, held in one position, and the thumbscrew turned to its stop. The lock could then be opened. In the later model 8550, there is no longer a thumbscrew and internal spindle mechanism. Rather, the dial is set to the zero index marker after the last number is entered. The dial is then physically depressed which releases an accelerator spring, thus allowing the lever to drop into the drive cam gate.

Mosler produced the **MR-302(435)** and **MRK302** (key change) MP locks, based upon a patent issued to Potzick in 1963. It had the same features as the S&G with respect to a shutter that protected the drive cam.

LaGard introduced their version of the MP lock, known as the 1980-A RL, in 1980. This was actually a modified 1800 series Group 2 mechanism and incorporated plastics to prevent radiographic imaging and a "lever trigger plate" to thwart manipulation. It consisted of a pivoting arm that was connected to the nose by a spring. As in the S&G design, the lever was blocked from the drive cam except when the gate was directly under the lever.

Some Group 1 locks can be manipulated, but with extreme difficulty. In order to open them, a machinist dial indicator must be mounted on the safe, with its tip touching the outermost portion of the dial. This device will be utilized for taking readings, with the lowest indication **possibly** identifying a gate.

Manipulation procedure is similar to Group 2 locks, with the exception that each time a reading is obtained, the dial must be

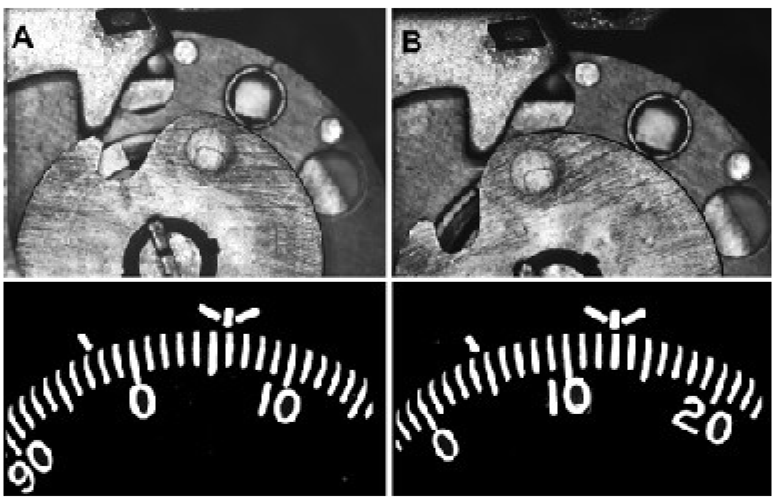
set to 100 and then depressed in order to permit the fence to contact the wheels. The dial is allowed to retract until the lever makes contact with the beveled edge of the drive cam.

36_4.6 Definitions

Certain terms and concepts relating to manipulation are unique within the safe and vault profession. These require definition in order to enhance an understanding of the detailed theory and process of manipulation which is explained later in this chapter.

36_4.6.1 Contact Area

The contact area is identified as the range of movement of the nose between contact points.



36_4.6.2 Contact Points

The contact point describes the physical interaction between the nose of the lever and the edges of the drive cam gate. The points are further defined as either left or right; they denote which side of the drop in area is being sensed. Although the nose is the component that actually “contacts” the drive cam gate, its depth of penetration into that gate is a function of the position of the ridge of the fence as it touches each wheel.

36_4.6.3 Drop-In Area



The nose must enter the drive cam gate to allow contact readings to be obtained during manipulation. The place where the nose **first** enters the recessed portion of the cam is defined as the drop in area.

36_4.6.4 Manipulation

Manipulation is the process by which a combination lock can be opened through information derived from visual, auditory, and tactile senses because of design deficiencies and tolerance errors within the lock. Manipulation is both an art and a science.

36_4.6.5 Parallax Error

Manipulation is based upon minute variances in the position of critical components. Quantification of such measurements can be especially difficult, especially if normal dial markings are utilized. The problem is compounded, based upon the viewing angle. Because fractional partitions of dial marker positions are utilized as a standard, the method and angle of viewing must remain constant. Otherwise, the data derived from each contact reading will not be reliable.

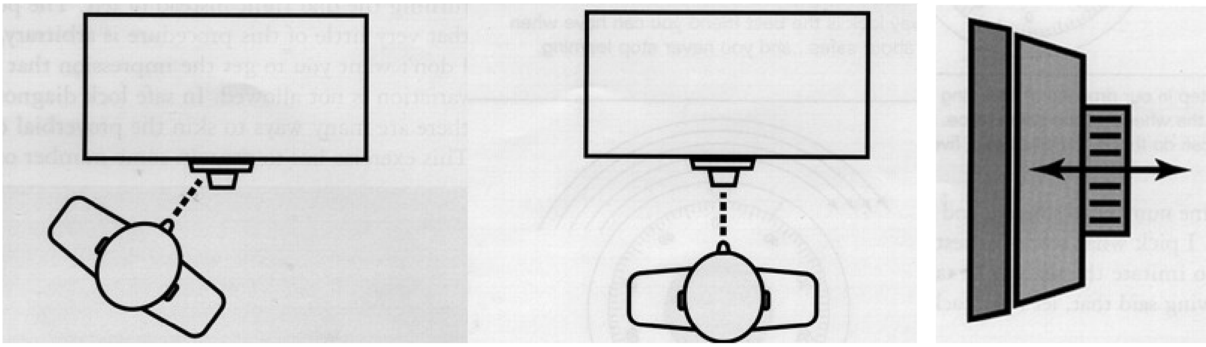


**Figure LSS+3603 Parallax error must be eliminate in the manipulation process if
accurate readings are to be obtained. Dial markings must be viewed perpendicular
to the dial, without adding the distortion of a viewing angle.**

A parallax error will occur if the operator does not look straight at the lock when taking readings. The problem is not limited to safe technicians but is inherent to anyone attempting to take measurements based upon a specific angle of view. Photographers who utilized older cameras that required two images to be overlaid for focusing often experienced the same difficulty.

36_4.6.6 Right and Left Contact Points

The process of manipulation requires continued testing of the relationship between the nose of the lever and its position within the drive cam gate. Information regarding that relationship is derived from the physical contact between the nose and the left and right sides of the gate. Thus, the **left** contact point is defined as the location, referenced to the dial marker, when the dial is rotated to the **right** and is engaged by the gate. The right contact point would constitute the opposition position.

36_4.6.7 Shadowing

This common problem is encountered during manipulation. It relates to **blocking** by an adjacent wheel, thereby obscuring a contact reading. The condition occurs when one disc is higher or lower than the wheel that is being read. In effect, the adjacent wheel will prevent the nose of the lever from dipping to its lowest depth, because it is being held up by the next wheel.

36_4.7 Detailed Theory of Manipulation

LSS201: Mark Bates on Manipulation

The process and theory of manipulation can be stated succinctly as a series of logical steps. These steps are based upon the premise that the fence, linked to the nose of the lever, will drop further and further into the gating of the wheel pack and drive cam as each gate is properly aligned. The purpose, then, of manipulation is to discover the low spots on the wheels. The assumption is that these spots either are a gate or dip in the edge of the wheel that will allow the fence to make contact with the edge of the next lowest wheel. Simply stated, the technician must keep working toward the lowest point within each wheel. **All gates must be correctly identified, in the proper sequence, to open the lock.**

The fence will continue to drop farther, so long as the correct sequence of wheels and their gating is determined. Thus, although gate positions can be tentatively identified for each wheel independently, the process requires that the **proper sequence** be established, based upon the **diameter** of each wheel, or other tolerance error.

Remember that manipulation is only possible because of tolerance errors or design deficiencies. The most crucial tolerance error is the **concentricity** of each wheel. In order to identify their order within the wheel pack, there must be a slight variance in the diameter of each. **This error allows the nose to drop farther into the drive cam as each gate location is identified.**

36_4.7.1 Manipulation: A Detailed Procedural Overview

The information that follows outlines the conceptual steps required to open a three-wheel lock by manipulation. Manipulation aids may be employed, based upon personal preference. The following procedure is premised upon the theory that as each wheel is aligned with the fence, the nose of the lever will enter the drive cam gate to a deeper level. As this occurs, the distance that the nose can be moved by dial rotation between the right and left side of the gate channel will decrease. This will cause the contact points, as referenced to the dial marker, to decrease in a linear fashion or become **closer together.** The summary procedure to manipulate a three-wheel lock requires the following steps:

- **Determine the type of lock;**
- **Determine the exact number of wheels;**
- **Determine the drop in area within the drive cam;**
- **Determine the contact points and take the first contact area reading;**
- **Graph each contact point as it is read;**
- **Test all numbers for number-one wheel, based upon 1.25, 2, 2.5 segment spacing, and log contact readings;**
- **Determine gate position for number-one wheel;**
- **Locate the true gate position of one wheel;**
- **Run test numbers and identify whether the wheel is the first, second, or third in the sequence of the combination;**
- **Set number-one wheel, then test all numbers for number-two wheel, and log contact readings;**
- **Determine gate position for number-two wheel;**
- **Identify the true gate position of a second wheel;**
- **Determine the position of that wheel within the wheel pack;**
- **Set number-one and number-two wheel, then test all numbers for number-three wheel, and log contact readings;**
- **Identify the true gate position of a third wheel;**
- **Determine the position of that wheel within the wheel pack;**
- **Enter the correct combination and open the lock;**
- **If the lock will not open, use vibration and oscillation of each wheel when testing each number. This is called "walking the dog" and requires the rapid rotation of the dial back and forth to drop the fence into the gate when its position is slightly off-center.**

Manipulation can be an extremely tedious process. In high tolerance locks, the procedure may require several hours to successfully complete.

36_4.7.2 Rules for Manipulation

The following mechanical relationships, procedures, and rules have been developed and refined during the past fifty years and are applicable to all mechanical combination locks. Adherence to these standards will help to assure success in deriving the combination for any lock.

- **Do not rely upon any input from anyone regarding a safe to be opened. The combination must be derived solely through manipulation techniques;**
- **Run all diagnostics prior to making a determination to manipulate or drill;**
- **Dial the lock as prescribed by the manufacturer. If the lock dials to the right, then do it that way during manipulation;**
- **The lock must be in operating order to be manipulated;**
- **Resetting the wheel pack, beginning with all wheels left (AWL) or all wheels right (AWR), is optional prior to manipulation;**
- **There must be a 1:1 ratio between movement of the dial and drive cam;**
- **The contact area must be defined precisely prior to manipulation;**
- **A decrease in the elevation of the nose of the lever within the drive cam gate must result in a lessening of the contact area;**
- **Contact points must be precisely determined for each test position;**
- **The left contact point is less significant than the right;**
- **Use the right contact for fast manipulation and to provide precision information about the dimension of the gate channel;**
- **If wheel number two is the first one to be identified, then wheel number three should be the next number tested;**
- **Determination of the position of flys can vary by ±1.5;**
- **The resistance of a wheel will change as a fly is engaged for the next wheel;**
- **The contact area can change between two locks produced by the same manufacturer;**

- **Movement of the detent ball and spring may cause an error in readings of 1 to 2 numbers, thus requiring the bolt to be stabilized. This can often be accomplished by placing pressure on the handle;**
- **Out-of-round wheels can cause a problem in contact readings, which can be remedied by a process known as shadowing. The operator can bypass this difficulty by moving one wheel around to the left of the fence;**
- **Oscillation of wheels is very important during manipulation in order to drop the fence into the gate when it is slightly off-center. This is accomplished by rapidly rotating the dial back and forth within the contact area;**
- **Gates will generally have a width of 4 to 8 numbers;**
- **Rarely will the correct combination be found by manipulation, although the lock will open. Thus, do not provide the information derived in this manner to the customer. The lock should be reprogrammed or taken apart in order that the correct number sequence is precisely determined;**
- **False gates can assist in determining true gate position. Look for the greatest depth.**

36_4.7.3 Identification of the Contact Area

The most common mechanical design for a Group 2 lock is the **drop lever**, which can be readily identified by its contact points. The S&G 6730, LaGard 3330, Ilco 67, and many others are based upon this configuration. We shall use an S&G 6730 for our example.

The contact area lies between the left and right contact points and equals the dimension (width) of the drive cam gate. In order to locate its position, turn AWL four times and stop at 50 (assuming the number 50 is not part of the combination). Next, turn the dial to the right. Within the **first revolution**, stop at 10. Now, if the dial is gently rotated between 90 and 20, the edge of the left and right side of the gate will obstruct and stop the dial from moving. These obstructions are the contact points, from which all measurements are taken. Sensing contact points can be simplified by grasping the dial with one finger and the tip of the thumb. Optimally, very little finger contact should be maintained between the technician and the lock.

36_4.7.3.1 Observing Contact Readings

Two technicians observing the same contact points will likely disagree as to their exact fractional number. This is due to individual visualization and extrapolation differences and is not relevant so long as the method utilized by each craftsman remains consistent. Thus, viewing of the dial marker must be done straight on, without creating a parallax error. Numbers should be recorded in .10 divisions of markers.

The use of standard dial markings can pose problems because of their irregularity. To assure consistent readings, the edge of engraved lines should be used for fractional determinations of .25 or less. Centering between divisions provides ½ markings.

36_4.7.3.2 Quantifying Contact Point Measurements

Manipulation is based upon the precise reading of the right and left contact points for each test position of a wheel and its gate. Accuracy in these readings must be to within .05 of a dial marker division for optimum result. Each of the contact points is charted to determine low and high spots.

The accurate and reliable sensing and recording of contact points can pose considerable difficulty. This can lead to lengthy delays in a successful opening or a complete failure. Because of issues relating to the measurement of contact points, manipulation may not work every time, for all types of locks.



Many causes can be attributed to the failure to obtain reliable and precise readings. These include:

- **Inaccuracies in the consistency, placement, spacing, width, or printing of dial markers by the manufacturer;**

- **Poor lighting conditions;**
- **Vision problems;**
- **Close mechanical tolerances;**
- **Improper rotation motion of the dial and a failure to use even-handed pressure and steady rate;**
- **Loose, sluggish, or sticky dials;**
- **Manipulation-proof locks;**
- **Locks with anti-manipulation protective mechanisms;**
- **Different degrees of wear within individual gates.**

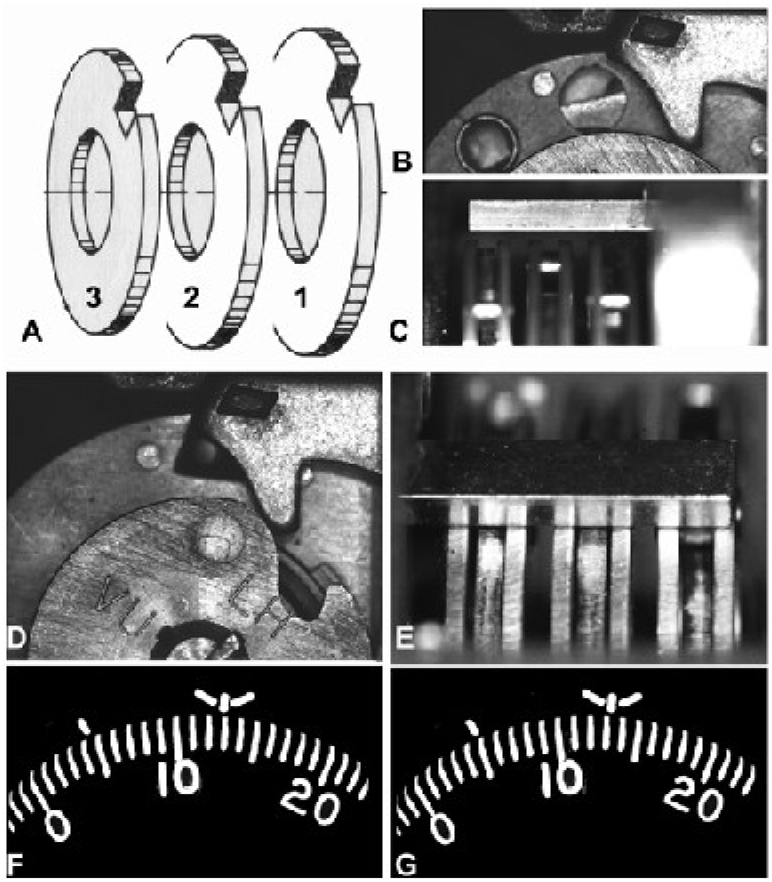
Both right and left contact points can be used for measurement. Experts disagree as to which is more significant, although the primary indicator is generally thought to be the right contact. There is a difference in the quality of information provided by each contact point. The **left** provides the best "indication" of position, while the **right** offers more quantitative data.

The best **indication** of presence and position is the left reading (dial turned to right). The contour of the drive cam gate causes the physical contact between nose and entry area to be more pronounced. This is due to the relatively sharp angle on the left side. The design of the right side of the gate channel offers detailed information regarding slight changes in the depth of the nose and results from the linear angle of the slope. For this reason, the right contact can be used for more accurate charting and faster manipulation.

Reliance upon the right contact point is premised upon a lock having a right-hand design. Most mechanisms, with the exception of vault doors, are constructed right hand, although mounting may be in any orientation. In the rare instance that the lock has been constructed left hand, the contact points are reversed. Prior to taking a reading, the dial should be oscillated across the drive cam gate to float or work the fence to its lowest point. This will provide a closer reading.

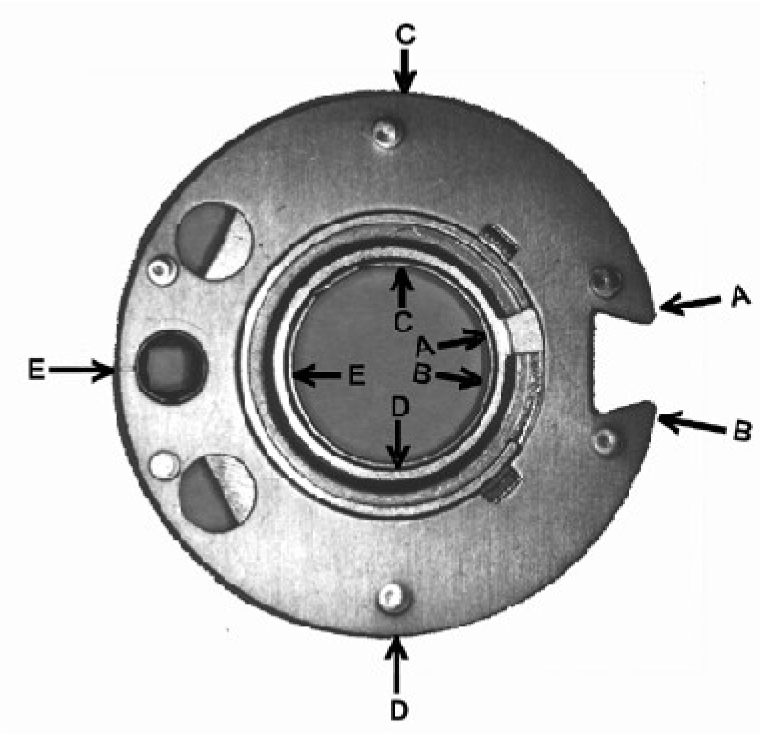
36_4.7.3.3 Geometry of the Contact Area

The geometry of the drive cam gate determines the significance of contact readings. The channel formed by the gate is precisely defined by the manufacturer, based upon criteria relating to interaction of the nose of the lever.



A right-hand design requires that the left contact be sharp and almost perpendicular to the edge of the wheel. For this reason, the left contact point provides a clearer indication that the nose has **touched** the gate. The right contact point provides more data with respect to the depth and position of the nose within the channel. The reading, however, is more difficult to obtain. This is because the nose is striking the channel at an angle that narrows toward the center of the cam. There is not as much metal contact between the two components and, hence, not as definitive an indication as with the left contact points.

Contact readings are a representation of the width of the drive cam gate and offer a linear reflection of the true contour of the edge of the wheel. Manipulation is possible because the width of the gate must change as the gate channel nears the center of the drive cam. A change in dimension between contact points can be directly correlated to the vertical position of the lever.



In most modern locks, the fence does not ever contact the edge of the wheels until the drive cam gate is within the contact area. It is only in this position that measurements can be obtained. For this reason, the dial must always be returned to that area during the sequencing of test numbers.

The process of manipulation is actually comprised of a series of measurements of the drive came gate. A description that compares the drive cam geometry and measurement correlation illustrates the ideal sequence of events that must occur in order that the lock can be opened. This example assumes that each wheel is tested **in descending order** with respect to concentricity errors. In the ideal world of manipulation, the number-one wheel would have the greatest diameter, the number-two wheel slightly smaller, and the number-one wheel even smaller. Of course, this is rarely the case.

36_4.7.3.3.1 Drive Cam Geometry and Contact Measurement Correlation

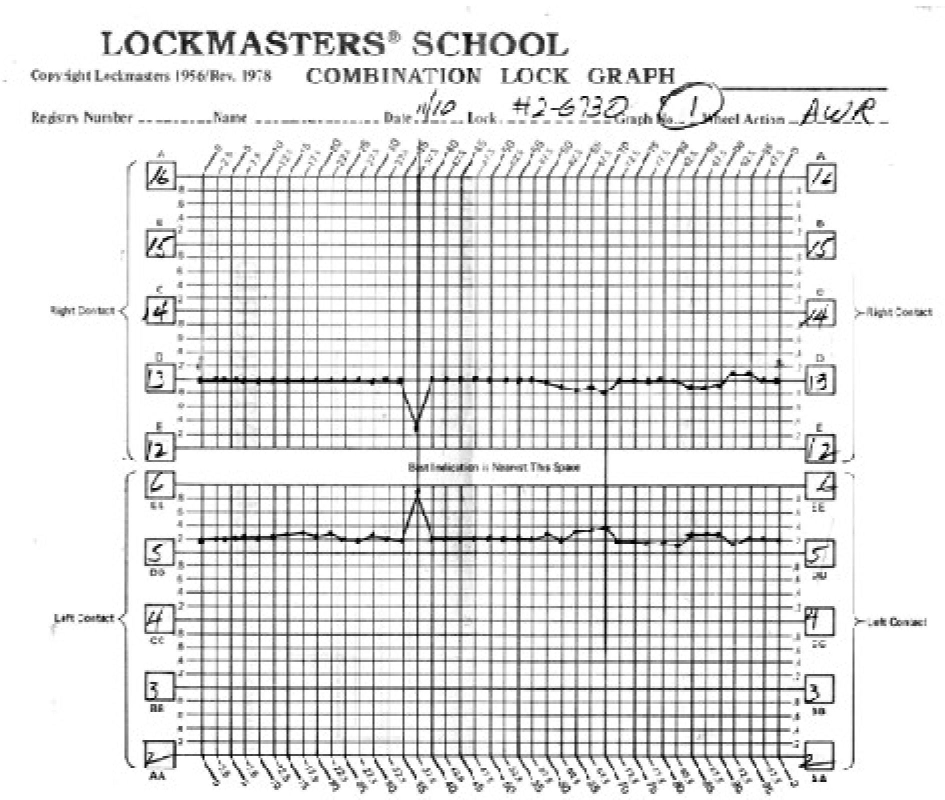
A manufacturer must adhere to several drive cam design parameters if the lock is to operate smoothly and reliably. The dimensions, rotation angles, motion requirements, and component placement

within the lock establish these measurements. The opening to the drive came gate is widest at its mouth, much like a funnel. It narrows toward the center. Fence movement and the resultant contact readings will diminish as gate positions are identified and the fence sinks deeper into the cam.

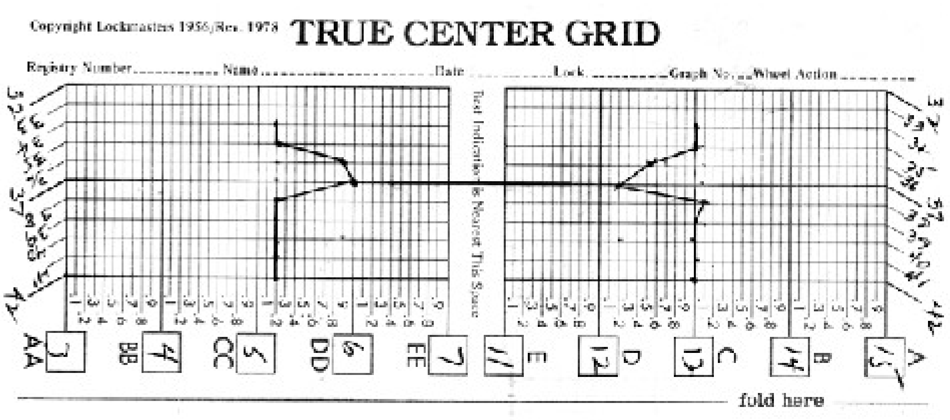
The right and left slopes of the gate are designed for smooth operation. The rounded sides at the mouth of the channel assure that the nose will not be trapped upon entry. Ramp angles are required to properly eject the lever when the mechanism is locked.

36_4.7.3.4 Charting Contact Points

Readings can be charted or remembered as they are tested. For the beginner, it is recommended that contact points be charted in 2.5 number increments around the dial. The process of charting requires that the technician make an extrapolation of fractional dial marker divisions. Either paper or a computer will produce a graphic display that represents the contour of the wheel and the width of the drive cam gate. If done correctly, it is a simple matter to interpret gate positions for each wheel from a narrowing of the contact area.



In practice, the readings for each number position is plotted on specially formatted chart paper provided by Lockmasters or other companies. When all 40 positions (for 2.5 number divisions) have been noted, the dots are connected for left and right contact points. A narrowing between the two, at any position, will indicate the possible location of a gate. Both sharp and gradual declines and rises can be significant. It is the lowest point that will indicate a possible gate position. In some cases, readings will have to be repeated after studying charts in order to determine which of several indications are "true." It is simply a process of elimination to find which wheel provides the best indication.



36_4.7.3.5 Determining Which Wheel is Indicating

In most cases, the number-three wheel usually indicates first. This, however, is not always true and is based upon issues relating to tolerance. There are simple procedures for correlating a gate to a specific wheel after a series of readings have shown the presence of a low spot. In order to make the determination, the gate position must be tested through a process of "parking" the other two wheels with a test combination. To correlate gate position to a specific wheel, a matrix is created wherein two of three wheels are parked at the known gate reading. The third wheel is then tested with a bogus combination to determine if it is the one that is "indicating."

36_4.8 Data Collection and Test Procedures Prior to Manipulation

The following materials outline the required steps that must be followed prior to attempting to manipulate a lock. They relate to obtaining needed information about the lock and its normal use. Any possible malfunctions that are causing a lockout must also be assessed.

36_4.8.1 Introduction

Manipulation is required in two situations. In the first instance, a lockout occurs due to mechanical malfunction. In other cases, the correct combination is unknown, not available, or will not open the lock. This situation might include covert entry, execution of legal warrants, burglary, or a lost combination.

Prior to attempting manipulation, information must be gathered and certain tests performed. In many cases, such procedures can eliminate the necessity to fully manipulate the lock altogether. Data required to assess and diagnose lockouts was examined elsewhere in this chapter. Other information about the lock and its operator can often be helpful and is detailed below.

36_4.8.2 Data Regarding the Lock

The process of manipulation must begin by learning everything that the lock can tell about itself. This information is essential and can determine whether the technique will be successful. With a detailed understanding about the mechanical components and their interrelationship, the following information should be obtained before attempting to open the lock:

- **Manufacturer;**
- **UL classification: Group 1 or Group 2;**
- **Is it possible that the lock contains four or more wheels;**
- **Contact area and contact points;**
- **Design of the drive cam area;**
- **Has the manufacturer changed the spline position on any locks;**
- **Drop in point location;**
- **Number of wheels, derived through transmission of motion;**
- **Wheel pickups: fixed or moveable flys and whether they are functioning properly;**
- **Type of wheels (moveable fly, screw change);**
- **Loose spline key;**
- **Stuck fly;**
- **Unlocked wheels;**
- **End pressure on the bolt;**
- **Loose back cover;**
- **Identify low areas on wheel pack;**
- **Identify "out of round" wheels, commonly referred to as eccentricity errors;**
- **Note unlikely number positions that take into account the forbidden zone, ascending or descending order, consecutive numbers, and adjacent numbers**

within ten digits.

36_4.8.3 Information about the User of the Lock

Information about the regular operator of a lock can possibly yield clues as to the combination, based upon work habits. The following questions should be asked in an effort to derive the correct number sequence:

- **Was the operator a methodical person;**
- **Did the operator establish a combination based upon a rigid pattern of numbers;**
- **Was the operator imaginative;**
- **What was his date of birth;**
- **What was the date that the combination was set;**
- **Did the operator have a favorite or lucky number.**

36_4.8.4 Lockouts, Diagnostics, and Manipulation

The process of manipulation encompasses more than just the technique for opening a lock. It is a methodical scientific procedure for determining malfunctions and potential causes of a lockout. In this section, the use of manipulation as a diagnostic tool is discussed. "Manipulation" is a combination of skill, knowledge, and analytical ability that provides the platform or vehicle through which locks can be opened. For the safe technician, these skills are generally called into service when there is a lockout. For the intelligence agent or law enforcement officer, opening the safe is secondary to obtaining access to the contents.

The important thing to remember is that "manipulation" is the use of sight, sound, and touch to learn information about the lock. It is also a **diagnostic tool.** A comprehensive discussion of lockout problems and related diagnostics was presented in **Chapter 35**. Whether the lock is to be opened simply to obtain access to contents or due to a lockout, virtually the same mental processes are required. Prior to engaging in manipulation, a preliminary analyses of basic facts and issues is necessary in order to assess the following:

- **Why is the safe locked;**
- **When was the safe used last;**

- **Has the correct combination been entered;**
- **Have factory tryout combinations been tried, including the following: 25-50-25, 50-25-50, 10-20-30, 20-40-60, 20-60-40,40-20-60, 40-60-20, 60-20-40, 60-40-20;**
- **Have all multiples of 10 and 50 been factored into test combinations;**
- **Consider the lighting that illuminates the dial. Is it dim, making the zero marker difficult to see and thereby resulting in potential entry errors;**
- **Is the combination written near the safe in plain sight on a bulletin board, adding machine tape, wall, door frames, top or sides of the safe, in personal phone books, or other places nearby;**
- **Are there scratch marks or inked-in index marks on the dial;**
- **Was the safe working properly when last opened;**
- **Is there a record of the correct combination stored anywhere;**
- **Are there any maintenance issues or problems that will prevent accurate contact indications during manipulation;**
- **Is there a preferable alternative to manipulation;**
- **Is there any reason why manipulation is not an acceptable course of action.**

If access to the contents of the safe or vault is the objective and there are no other known maintenance problems, then the lock can be manipulated. Of course, if a lockout exists, other factors come into play.

36_4.8.4.1 Mechanical Malfunctions

A lockout condition may require drilling. The following errors and malfunctions can render manipulation useless:

- **Errors in entering or changing combination, including maintenance errors involving changing three wheels on a four tumbler lock;**
- **Wheel related problems, including wheels becoming disengaged;**
- **Lever-related problems;**

- **Dial movement errors, including binding, seizure, non-linkage with drive cam, loose spline key, loose drive cam or broken dial;**
- **Fired relockers and relock triggers caused by shock, vibration, heat, concussion, and loose mounting screws;**
- **Stuck or broken drive pins and flys on wheel or cam;**
- **Improper or inoperative handle and bolt action;**
- **Failure of the correct combination to open the lock;**
- **Bolt linkage problems;**
- **Bolt end pressure;**
- **Improper drive cam rotation.**

36_4.8.5 Planning and Strategy

Before attempting to open a lock by manipulation, the technician should devise the methodology by which he will proceed. This will take into account the following issues, based upon previously discussed diagnostics:

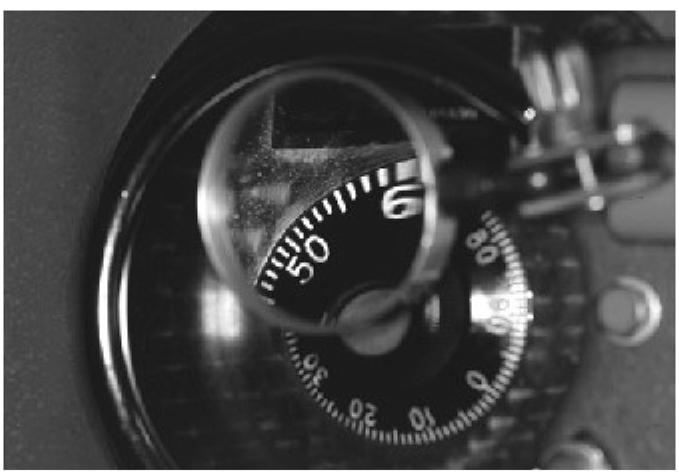
- **Which contact points will be read and charted: right, left, or both;**
- **Will wheels initially be moved left or right;**
- **Will one, two, or all three wheels be moved initially;**
- **What increments will be utilized for testing the contact points: 1, 1.25, 2, 2.5;**
- **What compensation will be made for fixed flys.**

36_5.0 Aids to Manual Manipulation

Many aids to manipulation can enhance learning of the art, as well as the visualization and sensing process. These devices and materials allow greater precision in the measurement of contact points by using audio and visual representations. Especially for older technicians, these tools can be extremely effective. They include:

- **Optical aids for magnifying marker positions, including magnetically attached magnifying glasses, glasses or optivisor that is worn by the technician;**
- **Illuminator;**

- **Pointer extensions that are attached to the safe dial;**
- **Handle wheel meters with long wire and which are used to test against each number for movement;**
- **Replacement vernier dial markings that create a more precise set of indicators;**
- **Audio amplification devices;**
- **Oscilloscope with audio amplifier and storage capabilities;**
- **Video capture devices, including macro camera heads that can be used to observe contact points more precisely;**
- **Software programs that can be used in conjunction with camera heads to capture and analyze contact point data, and to automatically chart contact area;**
- **Software programs useful for training;**
- **Cutaway combination locks;**
- **Torque measurement kits;**
- **Lubricant;**
- **Lint-free wiper rags;**
- **Mallets and dead blow hammers;**
- **Comfortable chair;**
- **Office supplies;**
- **Tool case;**
- **Basic hand tools;**
- **Specialty tools.**



36_6.0 Learning Manipulation

The art of manipulation is not mastered quickly; rather, it requires a great deal of practice with many different locks. Accomplishing successful openings is based upon many essential skills:

- **Logic and judgment;**
- **Visualization skills;**
- **Sense of touch;**
- **Steadiness of hand;**
- **Precise movement of the dial;**
- **Correlation of sounds to touch;**
- **Location of contact points;**
- **Understanding of the theory of manipulation;**
- **Self-confidence and positive attitude about opening locks;**
- **Eye, ear, and hand coordination;**
- **Ability to interpret and correlate information provided through the integration of sight, sound, and feel;**
- **Ability to perceive exceedingly slight movement of the dial marker with respect to the contact points;**
- **Patience;**
- **Intuition with respect to lockout problems;**
- **Detailed knowledge and understanding of the mechanical design of combination locks;**
- **Ability to visualize the movement and position of internal locking components;**
- **Ability to compute tolerances;**
- **Working knowledge of the concepts of contact points, forbidden zone, and drop in point;**
- **Detailed and working knowledge of common mechanical failures that can cause lockouts.**

There are many classroom and correspondence courses offered by **Lockmasters**, **MBA**, and other professionals. These can teach the basic procedures and theory of manipulation. Expertise and self-confidence, however, can only be gained by the actual opening of many locks. Classroom instruction is, in the view of the author, the most efficient way to begin learning the

techniques collectively called manipulation. Once instruction in theory has been completed, the real learning phase begins.

The author was trained at Lockmasters, using cutaway S&G 6730 locks with the fence bent slightly downward or upward. This technique would define which wheel would indicate first and was an extremely helpful learning tool. Once the contact points of a modified cutaway lock can be uniformly identified, another lock is modified to a lesser extent. The process is repeated until production models can be opened.

BOOK FOUR: METHODS OF PROTECTION

Security

CHAPTER THIRTY-SEVEN: WORLD STANDARDS

Standards and Testing

Master Exhibit Summary

Figure LSS+3701 UL Label
Figure LSS+3702 UL Label designations and nomenclature
Figure LSS+3703 SMNA Label designations
FF-L-2740 Federal Specification for Combination Locks

37_1.0 Introduction

All locks, safes, and enclosures are defined and classified by standards relating to their ability to resist attack by forced and surreptitious means. The rating process analyzes the security of a device from a number of different perspectives. These encompass and take into account the various methods of entry,

different levels of sophistication of tools and techniques, and overall resistance to bypass. This chapter provides an overview of the security classifications that have been developed and promulgated by the primary ratings organizations in the United States and Europe. Underwriters Laboratories (UL), the American National Standards Institute (ANSI), the American Society of Testing and Materials (ASTM), and Safe Manufacturers National Association (SMNA) have been primarily responsible for developing comprehensive evaluation criteria for security devices.

Within Europe, many different entities have traditionally rated locks and safes. A comprehensive set of standards has been developed over the last seven years by the Comite European de Normalisation (European Committee for Standardization), CEN, for all EU countries. All ratings organizations have adopted essentially the same methods to evaluate products to insure security for a defined level of protection. These protocols provide the most comprehensive and reliable method to gauge the indestructibility of a device for both the government and private sector.

This chapter is organized by rating organizations and the standards that have been promulgated by them for each type of device. Summaries of the current burglary and fire standards for UL and the CEN are detailed, together with applicable testing protocols. Extensive hyperlinks to world standards organizations including UL, ASTM, ISO, ANSI, and BSI can by found at www.security.org.

37_1.1 Testing and Classification of Safes, Vaults, and Related Hardware

Safes and vaults were originally tested by an organization known as the Safe Manufacturers National Association (SMNA) for insurance companies. Their labels can still be found on thousands of containers and are identified later in this chapter. SMNA was a service bureau of insurance companies that eventually gave way to UL as the primary testing organization. In the United States, the classification of security containers and devices is primarily the responsibility of Underwriters Laboratories and the General Services Administration (for military and federal government). In addition, the Insurance Services Offices (New York, New York) define and rate mercantile and bank safe insurance classifications.

The U.S. government relies upon UL standards in promulgating its specifications and requirements, although it is not bound by them. There are two subclassifications for UL ratings: **burglary** and **fire** resistance. In Europe, the CEN is now responsible for developing a rating and testing system for security devices in all EC countries. In England, the British Standards Institute (BSI) was previously responsible for the development of performance tests for locks and safes. Many other countries have their own standards organizations that perform similar tasks to UL and CEN.

37_2.0 Underwriters Laboratories

Underwriters Laboratories was founded in 1847 by William Henry Merrill, an electrical inspector in Chicago. Originally known as the Underwriters Electrical Bureau, its function was to perform tests regarding the safe use and operation of electricity. The name was changed to the Electrical Bureau of the National Board of Fire Underwriters, and finally to Underwriters Laboratories in 1901. From its inception, the mission of UL was that of an independent testing agency, having no financial ties to any manufacturer. Their goal was to develop standards for quality assurance and safety of products in order to protect the public.

The UL certification process is based upon three critical elements: development of an applicable standard, evaluation of a product according to the corresponding standard, and follow-up testing and other services at the manufacturer's location. A certification attests to the security of a product; it is relied upon by the public and risk underwriters. The names of manufacturers who have demonstrated an ability to produce products meeting UL requirements are published annually in the following product directories:

- **Building materials;**
- **Fire protection equipment;**
- **Fire resistance;**
- **Recognized component;**
- **Electrical appliance and utilization equipment;**
- **Electrical construction materials;**
- **Hazardous location equipment;**
- **General information from electrical construction materials and hazardous location equipment;**
- **Marine products;**

- **Automotive, burglary protection, and mechanical equipment;**
- **Gas and oil equipment.**

37_2.1 UL and Security Testing

It appears that the first time UL became involved in testing of security-related products was in 1921, when it was named as the official testing facility for burglar alarms and locking devices. Then, in 1923, the first safe was evaluated for burglary resistance. In 1925, the organization began testing vault doors.

Since that time, UL has developed many testing standards for locks and safes, including:

- **UL 140 Relocking devices for safes and vaults;**
- **UL 608 Burglar-resistant vault doors;**
- **UL 687 Burglar-resistant safes;**
- **UL 768 Combination locks;**
- **UL 437 Key locks;**
- **UL 786 Key locking systems;**
- **UL 887 Time lock;**
- **UL 2058 High-security electronic locks;**
- **UL 72 Tests for Fire Resistance of Record Protection Equipment.**

Today, UL is responsible for promulgating standards for testing mechanical and electronic locks, safes, vaults, time locks, relockers, and associated devices. A UL standard contains basic requirements for products covered by a certification. The observance of such requirements by a manufacturer is a condition of continued coverage. Although a product may comply with the text of a standard, that is no guarantee of certification. It is up to UL to determine if other features might impair the level of safety or security contemplated by the requirements.

The promulgation of standards are based upon sound engineering principles, research, records of tests, and field experience. UL, in consultation with and based upon information obtained from manufacturers, users, inspection authorities, and other having specialized experience, derives an appreciation of the problems of manufacture, installation, and use of a product to be tested.

Standards are always subject to revision as further experience and investigation may demonstrate as necessary or desirable.

Underwriters Laboratories does not assume or undertake any liability for reliance upon its product evaluation or standards. The opinions and findings of UL represent its best professional judgment. It is given with due consideration to the necessary limitations of practical operation and state of the art at the time the standard is processed.

37_2.2 UL Specifications for High-Security Locks and Safes

The term "high-security" has been defined throughout this book to describe locks and containers that present various levels of difficulty in covert and forced methods of entry (generally referred to as burglary). The term, of course, is relative and depends upon many factors. Underwriters Laboratories sets the performance standard within the United States for different classes of security. Once a product passes the tests associated with a specific classification, it is entitled to bear a label attesting to the fact.

Specific tests are developed based upon a perceived need for a certain level of protection. Such definitions change as methods of entry become more sophisticated. Thus, in the 1980s, the jewelry industry required tougher standards due to the economic prosperity of the time. The result: the **TL-30x6** classification was developed. This standard was originally contained in UL 687 (Standard for Safety for Burglary-Resistant Safes) issued in 1938. Since its original issuance, testing for the rating has changed dramatically.

For all classifications, a consensus is required from an independent advisory committee. Industry is consulted and then the proposed standard is submitted to ANSI for approval. Any UL rated device must meet the latest standard, which automatically expires in seven years.

37_2.3 UL Burglary Ratings for Safes and Vaults

Safes are classified for their resistance to forced-entry (burglary). See **Chapters 32** and **35** for methods for forcible entry. Certain security ratings are required for each type of use as determined by insurance companies and regulatory agencies.



Figure LSS+3701 An example of a UL label for a safe lock. Courtesy of Mark Bates, The National Locksmith Guide to Modern Safe Locks.

37_2.3.1 General Construction Requirements

Depending upon classification, one or more of the following general construction requirements apply to all burglary resistant safes. The UL specific paragraph number appears in parenthesis.

- **(1) UL 768 rated Group 2, 1 or 1R combination lock;**
- **(2) All iron and steel parts painted, plated, or equivalent to protect against corrosion;**
- **(3) 750 pounds minimum weight or anchors, with instructions for anchoring in a larger safe, concrete blocks or on the premises where used;**
- **(4) Materials other than solid metal may be used for body construction, provided that the material has resistance to attack equivalent to at least 1″ open hearth steel with a minimum tensile strength of 50,000 PSI;**
- **(5) Walls fastened in a manner equivalent to continuous ¼″ penetration weld of open-hearth steel with minimum tensile strength of 50,000 p.s.i.;**
- **(6) One hole ¼″ or less, to accommodate electrical conductors anywhere, except in the door, and arranged to have no direct view of the door or locking mechanism;**
- **(7) Clearance between the door and jamb not greater than .006″; or designed so that no direct access is provided through the door and jamb.**

37_2.3.2 General Performance Requirements:

Three forcible entry methods are specified in the ratings,

depending upon security classification:

- **Entry Means (A): Opening the door or making a rectangular shaped opening 6″ square in an area or a circular opening 2.76″ diameter entirely through the door or front face;**
- **Entry Means (B): Opening the door or making a rectangular shaped opening 2″ square in an area or a circular opening 1.6″ diameter entirely through the door or front face;**
- **Entry Means (C): Opening the door or making a rectangular shaped opening 2″ square in an area or a circular opening 1.6″ diameter entirely through the door or body.**

37_2.3.3 Tools of General Design Used for Forced-Entry

Tools used for forced-entry attempts include:

- **Common hand tools;**
- **Picking tools;**
- **Mechanical or portable electric tools;**
- **Grinding points;**
- **Carbide drills;**
- **Pressure-applying devices or mechanisms (drill rigs).**

37_2.4 Burglary-Resistant Safe Classifications

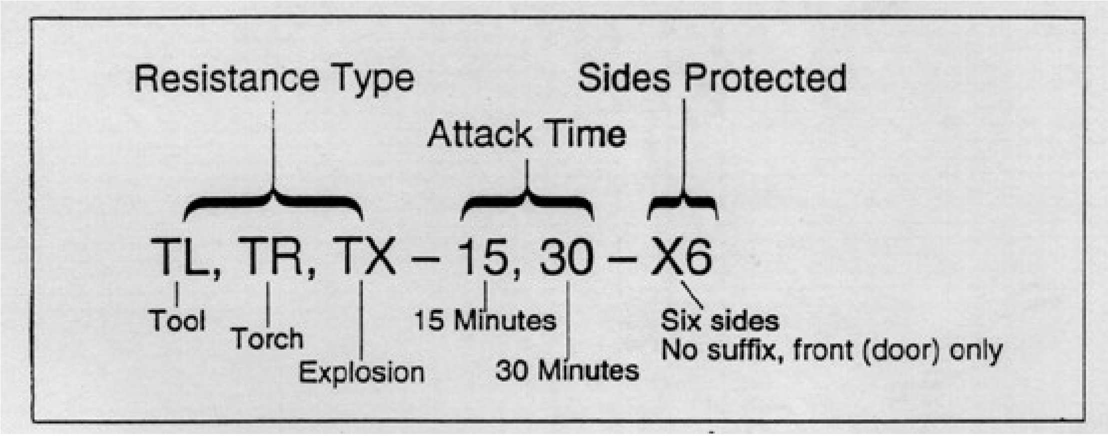


Figure LSS+3702 A UL label diagram denoting the designation for each component.

37_2.4.1 TL-15: Tool-Resistant Safe

A combination-locked steel chest or safe will offer a limited degree of protection against expert burglary by common hand or electrical tools. The safe will weigh at least 750 pounds or shall be equipped with anchors. All safes having this classification are equipped with a relocking device. The units are constructed of open-hearth steel, either cast or welded plate construction, combined with materials to resist carbide drills.

37_2.4.1.1 Specific Construction Requirements

Requirements (1) through (6).

37_2.4.1.2 Specific Performance Requirements

- **Successfully resist Entry Means (A) for a net working time of 15 minutes;**
- **Use of all general tools.**

37_2.4.2 TL-30: Tool-Resistant Safe

This is a combination-locked safe or chest, which offers a moderate degree of protection against expert burglary by common mechanical and electrical tools. The safe shall weigh at least 750 pounds and have adequate anchoring. In addition, the safes in this class are equipped with relocking devices and are constructed of open-hearth steel, either cast or welded plates, in combination with special materials to resist carbide drills and abrasive cutting tools. The door lugs should be of solid design, with the door machine ground to fit.

37_2.4.2.1 Specific Construction Requirements

Requirements (1) through (7).

37_2.4.2.2 Specific Performance Requirements

- **Successfully resist entry means (A) for a net working time of 30 minutes;**
- **Use of all general tools with the addition of**

abrasive cutting wheels and power saws.

37_2.4.3 TRTL-15x6: Torch- and Tool-Resistant Safe (six sides)

This rating signifies a combination-locked safe designed to offer protection against entry by common mechanical and electrical tools and cutting torches and any combination of these means.

37_2.4.3.1 Specific Construction Requirements

- **Requirements (2) through (7);**
- **Equipped with a UL 768 rated Group 1 or 1R combination lock.**

37_2.4.3.2 Specific Performance Requirements

- **Successfully resist entry means (C) for a net working time of 15 minutes;**
- **Use of all general tools, with the addition of abrasive cutting wheels, power saws, impact tools and oxy-fuel gas cutting or welding torch;**
- **Test gas limited to 1,000 cubic feet combined total oxygen and fuel gas.**

37_2.4.4 TRTL-30: Torch- and Tool-Resistant Safe

This is a combination-locked chest or safe designed to offer a moderate degree of protection against expert burglary by common mechanical and electrical tools and cutting torches. The safes are to be encased in no less than 3” of reinforced concrete or in a larger safe or other container. The safe should weigh at least 750 pounds. All containers within this class have a relocking device and are constructed of open-hearth steel, either cast or welded plate, combined with special materials to resist torches, carbide drills, and abrasive cutting tools. In addition, the door lugs are made of substantial design, and the door is machined to fit.

37_2.4.4.1 Specific Construction Requirements

- **Requirements (2), (4), (5), (6), (7);**
- **Equipped with a UL 768 rated Group 1 or 1R**

combination lock;

- **Encased in not less than 3″ of reinforced concrete or in a larger safe or other container;**
- **The safe as encased shall weigh at least 750 pounds.**

37_2.4.4.2 Specific Performance Requirements

- **Successfully resist entry means (B) for a net working time of 30 minutes;**
- **Use of all general tools with the addition of abrasive cutting wheels, power saws, impact tools and oxy-fuel gas cutting or welding torch;**
- **Test gas limited to 1,000 cubic feet combined total oxygen and fuel gas.**

37_2.4.5 TRTL-60: Torch- and Tool-Resistant Safe

This classification encompasses a combination-locked steel chest or safe which is designed to offer high resistance to expert burglary methods by common mechanical and electrical tools and cutting torches. Safes shall be encased in concrete and will weigh at least 750 pounds with the concrete. All safes in this class are made of open hearth steel, either cast or welded plate, in combination with special materials to resist torches, carbide drills, and abrasive cutting tools. The door lugs should be of solid design and the doors machine fit.

37_2.4.5.1 Specific Construction Requirements

- **Requirements (2) through (7);**
- **Equipped with a UL 768 rated Group 1 or 1R combination lock.**

37_2.4.5.2 Specific Performance Requirements

- **Successfully resist entry means (C) for a net working time of 60 minutes;**
- **Use of all general tools with the addition of abrasive cutting wheels, power saws, impact tools and oxy-fuel gas cutting or welding torch;**
- **Test gas limited to 1,000 cubic feet combined total oxygen and fuel gas.**

37_2.4.6 TRTL-30x6: Torch- and Tool-Resistant Safe (Six Sides)

This class signifies a combination-locked safe designed to offer protection against entry by common mechanical and electrical tools and cutting torches and any combination of these means. The container provides protection on all faces (top, bottom, sides).

37_2.4.6.1 Specific Construction Requirements

Same requirements as TRTL-60

37_2.4.6.2 Specific Performance Requirements

Same requirements as TRTL-60.

37_2.4.7 TXTL-60: Torch-, Explosive-, and Tool-Resistant Safes

Safes within this classification are combination locked and have relocking devices. They are of steel construction, and offer high resistance to expert burglary by common mechanical tools, cutting torches, high explosives, and any combination of these means within practical limits. Safes encased in concrete will weigh not less than 1,000 pounds. Cast open-hearth steel is combined with special materials to resist torches, carbide drills, and abrasive cutting tools. The thickness and strength of the material in the door, lugs, and the body, and the clearance between the door and jamb shall resist entry with mechanical tools, torches, and high explosives. The door lugs should be made of solid design and the door machine fit.

37_2.4.7.1 Specific Construction Requirements

- **Requirements (2), (4), (5), (6), (7);**
- **Equipped with a UL 768 rated Group 1 or 1R combination lock;**
- **Shall weigh at least 1,000 pounds.**

37_2.4.7.2 Specific Performance Requirements

- **Successfully resist entry means (C) for a net working time of 60 minutes;**
- **Use of all general tools with the addition of**

abrasive cutting wheels, power saws, impact tools, oxy-fuel gas cutting or welding torch, and may further include nitroglycerine or other high explosives;

- **The total quantity of explosive employed may not exceed eight ounces. Not more than four ounces is to be used in a single charge.**

37_2.4.8 KL Burglary-Resistant Container

Identification on safes of this classification are generally manufacturer's labels with the **KL** designation. Burglary classification (**KL**) signifies a key-locked safe designed to offer protection against entry by common mechanical and electrical tools and any combination thereof.

37_2.4.8.1 Specific Construction Requirements

Must meet general construction requirements (2) through (6). In addition the safe shall be equipped with a UL 437 rated two-key lock or changeable key lock with a minimum of one million changes.

37_2.4.8.2 Specific Performance Requirements

Successfully resist entry means (**A**) for a net working time of 15 minutes. Use of all general tools.

37_3.0 Specific Standards: UL 437 and UL 768

Standards promulgated by Underwriters Laboratories relating to locks, safes, and security are summarized in this section. Although many of the terms have been defined in other chapters, the specific UL definition is repeated in order to facilitate understanding. A glossary of terms appears at the end of the summary.

The following UL standards are summarized in this Section:

- **UL 768 Combination locks**
- **UL 437 Key locks**

37_3.1 UL 437 Standard for Key Locks

The primary standard for locks is **UL 437.** The requirements cover door locks, locking cylinders, security container key locks, and two-key locks.

37_3.1.1 Definitions

Underwriters Laboratories defines the different types of locks for which the specification applies.

Product: This refers to any type of lock or component defined within the standard:

Door Lock: This is a rim or mortise-type locking assembly that is used on doors to deter unauthorized opening by one or more of the following means:

- **Jimmying the door;**
- **Picking;**
- **Impressioning techniques;**
- **Driving the locking cylinder or assembly;**
- **Sawing or drilling the lock bolt;**
- **Pulling the lock cylinder;**
- **Other methods that involve the use of small hand tools.**

Locking Cylinder: A key cylinder that is used within door locks, alarm control switches, alarm shunt switches, utility locks, and similar devices to resist unauthorized opening by one or more of the following techniques:

- **Picking;**
- **Impressioning techniques;**
- **Forcing methods;**
- **Pulling;**
- **Drilling the cylinder.**

Security Container Key Lock: This is a lock that is designed for use on key-locked safes, collection safes, and similar security containers to resist methods of entry that include:

- **Picking;**

- **Impressioning;**
- **Drilling;**
- **Pulling;**
- **Punching;**
- **Forcing methods.**

37_3.1.2 General Construction and Operating Requirements

UL specifies a number of requirements that relate to the construction and operation of any lock that is certified under this standard. These include:

- **The product shall be constructed so that it may be readily and conveniently operated when the proper key or keys are used;**
- **The lock must be practicable for installation by a trained locksmith and able to be installed in a position or location that does not degrade its burglary-resistant qualities;**
- **Parts must maintain a high degree of tolerance and uniformity. This is especially important with regard to bittings.**

Locks tested under UL 437 must be constructed of brass, bronze, stainless steel, or equivalent corrosion-resistant material or shall have a protective finish that meets salt spray tests. There are a number of common standards relating to locks and security containers, including requirements relating to non-metallic parts, corrosion protection, and salt spray. These are described in UL 768.

37_3.1.3 Specific Requirements for Locks

37_3.1.3.1 Differs

Door locks and cylinders must be capable of at least 1000 key changes. Security containers must achieve significantly higher security levels, providing at least 1,000,000 differs for any design. Two-key locks require a minimum of 64 guard key changes and at least 15,000 customer key changes for any design.

37_3.1.3.2 Security Container Key-Locks

Specific requirements for locks that are utilized on security containers include:

- **Key shall be field changeable;**
- **The bolt lever must fit snugly on its post and shall be secured tightly;**
- **The fence face shall be perpendicular to the plane of the tumblers;**
- **The wheels, tumblers, levers, or pins shall run true and be at right angles to their mounting post;**
- **Within a combination lock, the clearance between the fence face and the tumbler wheels shall not be less than .025″ (0.64 mm) when the bolt lever is raised by means of a driver cam, and not less than .015″ (0.38 mm) when the bolt lever is raised by means other than a driver cam;**
- **Mechanical means must be provided that immobilizes the bolt if the lock is punched or pulled;**
- **The tolerance between plug and shell in a pin tumbler lock must be less than one cut depth.**

37_3.1.3.3 Endurance Test

The lock shall function as intended during 10,000 complete cycles of operation at a rate not exceeding 50 cycles per minute. A lock having a changeable core or field-changeable key design shall operate as intended after each of 50 changes of the core or key.

37_3.1.3.4 Attack Resistance Tests

Attack resistance tests encompass setup requirements, use of specified tools, timing, and entry methods.

37_3.1.3.4.1 Test Requirements

A number of tests have been defined to ascertain the attack resistance of a lock. UL 437 requires that a device cannot be opened or compromised as a result of the application or use of tools and techniques set forth in the standard and are summarized here.

Specific protocols have been devised with respect to mounting of samples to be tested. Door locks must be installed, in accordance with the lock manufacturer's instructions, in a 1-1/2" (38.1 mm) solid hardwood door of average size. The door is mounted in a 1-1/4" (38.1 mm) thick wood frame and reinforced as if actually installed. Door locks that are designed specifically for a certain door construction are to be tested in that mode.

The following test requirements apply for attack ratings:

- **The tools used for these tests include any common hand tools, hand or portable electric tools, drills, saw blades, puller mechanisms, and picking tools. For door locks only, pry bars up to three feet (.9 meter) long are also to be employed;**
- **Tools that are used on two-key locks must not include saws, puller mechanisms, or portable electric drills;**
- **Common hand tools are defined as chisels, screwdrivers no more than 15" (380 mm) long, hammers having three-pound (1.36 kg) head weight, jaw-gripping wrenches, and pliers;**
- **Puller devices are to be either a slam-hammer mechanism, having a maximum head weight of three pounds (1.36 kg), or a screw type;**
- **Picking tools are common or standard patterns, as well as those designed for use on a particular make or design of cylinder;**
- **Portable electric tools are identified as high-speed handheld drills that meet the following criteria:**
  - **Operate at a maximum of 1900 RPM;**
  - **Maximum ¼" (6.4 mm) chuck size;**
  - **Use high-speed drill bits;**
  - **Utilize electrically operated vibrating needles.**

37_3.1.3.4.2 Test Time for Attack Resistance

Net times in minutes are specified for each type of test and the lock upon which the procedure is to be performed. The sequence is not relevant, nor the number of methods to be applied. Samples

may be tested for several techniques, or a new specimen may be utilized for each procedure.

Test	Door Locks/ Cylinders	Security Container Key Locks	Two-Key Locks
	(Net working time in minutes)		
Picking	10	30	45
Impressioning	10	30	45
Forcing	5	30	5
Drilling	5	30	NA
Sawing	5	30	NA
Prying	5	30	NA
Pulling	5	30	NA
Driving	5	30	NA

37_3.1.3.5 Test Methods

There are eight methods of forced and direct entry that are defined within the standard: **picking**, **impressioning**, **forcing**, **drilling**, **sawing**, **prying**, **pulling**, and **driving**. These have been previously described in **Chapters 29-32**.

37_3.1.3.5.1 Picking

Picking tools are employed in an attempt to align the active components, including tumblers, levers, wheels, or pins, in order to open the lock.

37_3.1.3.5.2 Impressioning

Methods of impressioning, as defined in **Chapter 31**, are employed in an attempt to produce working keys.

37_3.1.3.5.3 Forcing

Rotary forces are applied with the test tools in three critical areas in an attempt to open the target lock:

- **In the key slot;**
- **On the exposed part of the cylinder;**

- **On the exposed portions of the lock assembly.**

37_3.1.3.5.4 Drilling

Drilling requires that a drill and one or more bits are utilized to attack the plug, exposed lock body, and other parts in an attempt to compromise critical components to effect an opening.

37_3.1.3.5.5 Sawing

A saw is employed in an effort to cut, compromise, remove, and open critical components, including the plug, body of the cylinder, and lock bolt.

37_3.1.3.5.6 Prying

Tools are utilized in an attempt to pry the bolt out of engagement with the strike opening within a door lock assembly.

37_3.1.3.5.7 Pulling

Techniques of pulling are directed at critical locking components including the plug, body, bolt, or other areas in order to compromise and open the device.

37_3.1.3.5.8 Driving

Driving is the opposite of pulling. Tools are utilized in an attempt to drive or force the plug, body of the lock, lock bolt, or other part to allow bypass of the mechanism.

37_3.2 UL 768 Standard for Combination Locks

UL 768 provides the testing protocol for combination locks used on security containers. Specifically, the standard applies to locks designed for attachment on doors of safes, chests, vaults and the like to provide a means of locking the boltwork against unauthorized opening. They are intended to test the ability of combination locks to resist unauthorized manipulation and derivation of the number sequence by sense of sight, touch, or hearing. The standard does not address forced opening.

Locks are classified by UL as **Group 1**, **Group 1R**, or **Group 2.** These are defined as follows:

- **Group 1: Those locks that have a high degree of resistance from expert or professional manipulation. The protection against expert manipulation includes advanced design features not found in conventional designs;**

- **Group 1R: Those locks that have a high degree of resistance to expert manipulation, including use of radiological means;**

- **Group 2: Those locks that have a moderate degree of resistance to unauthorized opening.**

37_3.2.1 Resistance to Manipulation

The essence of the standard relates to protection against surreptitious and covert manipulation. In order for a lock to be listed, it must meet the requirements outlined below. Numbers in parenthesis indicate the specific UL paragraph within the standard.

37_3.2.1.1 Group 1

- **A Group 1 lock shall resist unauthorized opening by expert or professional manipulation for a period of 20 man-hours (10.1);**
- **The time specified in paragraph (10.1) may include one man working 20 hours, two men working together 10 hours, or the like. Lock experts may be called upon to assist in these tests (10.2);**
- **Tests on Group 1 locks shall involve (1) expert manipulation techniques, including walking the tumblers, feeling the tumbler gates, sighting variations on the dial, or (2) any other techniques that may develop as a result of the examination (10.3);**
- **The protection against expert manipulation shall include advanced features not found in conventional designs (10.4);**
- **The combined weight of instruments or detection devices used in this test is not to exceed 50 pounds (22.7 kg) (10.5);**

- **A three-tumbler lock shall not open if the dial is turned more than one full dial graduation on either side of the proper graduation for each tumbler wheel. A four-tumbler lock shall not open if the dial is turned more than 1 1/4 dial graduations on either side of the proper graduation for each tumbler wheel (10.6);**
- **Punching of a Group 1 or Group 1R combination lock shall result in the lock bolt becoming immobilized by mechanical means (10.7);**
- **The immobilization by mechanical means is not required on an offset-spindle type of lock in which punching of the spindle does not defeat the locking action.**

37_3.2.1.2 Group 1R

- **A Group 1R combination lock shall comply with all of the requirements for Group 1 locks and in addition shall be secure against radiological attack for 20 hours with a radioactive source not exceeding the equivalent of 10 curies of cobalt-60 at a 30″ (762 mm) distance (10.8).**

37_3.2.1.3 Group 2

- **Testing of Group 2 locks shall consist of setting the tumblers to various combinations to determine that the lock will operate as intended but will not open with the dial turned beyond the tolerances specified in paragraph 10.10 (10.9);**
- **A three-number wheel lock shall not open if the dial is turned more than 1 1/4 dial graduations on either side of the proper graduation for each tumbler. A four-tumbler lock shall not open if the dial is turned more than 1 ½ dial graduations on either side of the proper graduation for each tumbler (10.10).**

37_3.2.2 General Construction and Performance Standards

The following requirements pertaining to construction, performance, strength and marking apply to combination locks that

are certified under UL 768.

37_3.2.2.1 Construction

- **A lock shall permit a choice of at least 1,000,000 combinations;**
- **The lever shall fit snugly on its post and shall be secured tightly. The fence shall be perpendicular to the plane of the tumblers;**
- **The clearance between the fence and the tumbler wheels shall be not less than .025″ (0.64 mm) when the bolt lever is raised by means of the driver cam, and not less than .015″ (0.38 mm) when the lever is raised by means other than the driver cam;**
- **Tumblers shall run true, and be at right angles to the tumbler post.**

37_3.2.2.2 Non-metallic Parts

- **Factors taken into consideration when judging the acceptability of non-metallic parts are (1) mechanical strength, (2) resistance to impact, (3) moisture absorptive properties, and (4) resistance to distortion of the material under conditions of normal or abnormal usage. Tests of polymeric materials are defined below, and appear in Section 13 of the standard.**

37_3.2.2.2.1 Strength

- **The mechanical strength and resistance to impact of parts made of polymeric material are to be considered as acceptable for the intended use on the basis of satisfactory performance in the Operation Test, Section 9, and Endurance Test, Section 11.**

37_3.2.2.2.2 Age-Stress Distortion

- **There shall be no warping to the extent that intended functioning will be impaired when representative samples constructed of polymeric material are aged for seven days in a circulating-air oven maintained at 90°C (194°F).**

37_3.2.2.2.3 Moisture Absorption

- **Polymeric materials shall function as intended after three representative samples, previously conditioned as described in paragraphs (13.2-13.4) are exposed for 10 days to warm moist air having a relative humidity of 98 percent at a temperature of 140° F (60° C).**

37_3.2.2.2.4 Corrosion Protection

- **All working parts of the lock mechanisms shall be constructed of brass, bronze, stainless steel, or equivalent corrosion-resistant materials, or shall have a protective finish that permits the lock mechanism to comply with the requirements of the Salt Spray Corrosion Test.**

37_3.2.3 Operation

- **The lock shall operate as intended on the combination to which it is set.**

37_3.2.4 Endurance Test

- **The lock shall operate for 10,000 complete cycles of running the combination at a speed not exceeding forty-eight revolutions per minute.**

37_3.2.5 Salt Spray Corrosion Test

- **A combination lock constructed of materials other than brass, bronze, stainless steel, or equivalent corrosion-resistant materials shall operate as intended, following a seventy-two hour exposure to salt spray (fog) as described in the Standard for Salt Spray (Fog) Testing, ASTM B11-73 (1979);**

- **During this test the locks are to be operated once during each twenty-four hour period;**

- **Following the exposure, the lock is to be allowed to dry for twenty-four hours in a room having an ambient temperature of 25°C (77° F) and then is to be tested for operation.**

37_3.2.6 Marking

UL requires specific marking on each listed lock in order to identify the manufacturer and security rating. Information must be visible regarding:

- **The manufacturer's or private labeler's name or identifying symbol;**
- **The model, style, or catalog identifier;**
- **The designation of Group 1, Group 1R, or Group 2;**
- **If a manufacturer produces combination locks at more than one factory, each lock shall have a distinctive marking, which may be in code to identify it as the product of a particular factory.**

37_3.2.7 Glossary of Terms Relating to Combination locks

In order to interpret UL 768, the following definitions apply:

- **Drive Cam: A component that engages the tumblers and moves the bolt during the ordinary opening or closing procedure;**

- **Drive Pin: A protrusion on or through a cam or tumbler that engages the adjacent tumbler;**

- **Fence: A part of the lever that fits into the tumbler gates, permitting the lever to engage the drive cam;**

- **Gate: The cutout in the periphery of the tumbler that is engaged by the fence on the lever assembly;**

- **Lever: A component that retracts the bolt;**

- **Tumbler Pack: An assembly of tumblers, flys,**

washers, springs, and rings;

- **Tumbler Post: A component, integral to the lock case or cover, on which the tumbler pack is assembled and about which the tumblers rotate;**
- **Tumbler Wheel: An assembly, usually in the form of a circular disc, having a gate and drive pin whose location may be set to selected positions to permit the user to change the combination.**

37_4.0 UL Fire Ratings

There is a great deal of misunderstanding as to the relationship between the burglary and fire resistance of a container; generally, the two do not go hand in hand. Ordinarily, a safe or vault is primarily designed for **one** rating, although there are exceptions such as the Chubb Planet. Fire-rated safes and vaults contain special doors and bodies that are rated in terms of hours of resistance to heat.

Two hundred years of testing has been carried out by safe manufacturers, notably Chubb, in developing fire-resistant materials and overall approaches to protecting valuables against the effects of high temperature. Safes are routinely subjected to heat and cold, explosion, and impact during an actual fire. These conditions are simulated during testing. General guidelines require a one-hour UL or SMNA rating for light fire conditions, a two-hour rating for moderate fire conditions, and a four- to six-hour SMNA rating for severe fire conditions.

Fire safes will have a minimum amount of metal as compared to a burglary safe: thus their lower security rating. Special insulation is used to draw heat away from the metal surfaces within these containers. The insulation is designed to retain the heat, rather than allow the metal to transmit it to the safe's contents. Older safes are inherently unreliable because the insulation becomes dry after a period and loses its properties.

37_4.1 Fire Testing Criteria

Safes that carry UL fire ratings must meet three primary tests: **endurance**, **impact**, and **explosion** hazard. The **fire endurance** test requires that a safe must withstand up to one-half hour of

incineration at up to 1550° F, or up to 1700° F for one hour, depending upon the rating. The product must maintain interior temperature below 350° F, thereby safeguarding documents from damage.

The **fire impact** test requires that when a safe is heated to 1550° F, then dropped nine meters and reheated to 1550° F for one-half hour, that the safe stays locked and internal temperatures never exceeding 350° F. The **explosion hazard** test requires that when the safe is subjected to 2000° F flash fire, it will not rupture or explode.

37_4.2 Specific Fire Ratings

CLASS C: One-hour resistance of fire reaching 1700° F, with internal temperature remaining less than 350° F. The safe is also tested for combined explosion and impact. One test requires that the units are preheated to 2000° F for thirty minutes, then hoisted thirty feet and dropped. After cooling, the safe is again heated to 1500° F.

CLASS B: Two-hour resistance to 1850° F with interior temperature not exceeding 350° F, with the same explosion and impact requirements for a Class **C** container.

CLASS A: Minimum four-hour resistance to 2000° F, prior to the interior temperature rising above 350° F. A **Class A** safe is also tested for explosion and impact.

37_4.3 UL Fire-Resistive Container Classifications

See **Chapter 33** for detailed information regarding the construction of fire safes and vaults. The following material takes into account the specifications in UL 72, Tests for Fire Resistance of Record Protection Equipment.

37_4.3.1 General Construction Requirements

The insulation used in record protection devices must be capable of retaining its heat- insulating properties equivalent to Portland cement, concrete, or gypsum concrete. All mechanical

components of record protection storage devices must be constructed so that normal and repeated operation can occur without damage to the insulating and fire-resistive qualities.

37_4.3.2 Specific Testing Protocols

The UL test protocols are similar to those developed by SMNA.

37_4.3.2.1 Explosion Hazard Test

A furnace is preheated to 2,000° F. An empty sample is closed, locked and placed into the furnace for thirty minutes (twenty minutes for units rated one-half hour) and if no explosion results, the unit is allowed to cool without opening the furnace doors. After cooling, the container is opened and dismantled. An examination is conducted to determine the heat-insulating properties of the sample. This evaluation includes:

- **Condition of interior finish;**
- **Security of interior equipment;**
- **Locks;**
- **Part fastenings;**
- **Any signs of undue transmission of heat or moisture.**

37_4.3.2.2 Fire Endurance Test

The contents are placed inside the container so that the material contacts the interior walls to allow heat transfer. The unit is then closed, locked, and exposed to uniformly distributed fire, the temperature of which is regulated and increased according to the standard time-temperature curve summarized below.

The application of flame and temperature is continued for the period required for the desired classification, and the container is allowed to cool without opening the furnace. The interior temperature is recorded throughout the test and during the subsequent cooling period until a definite decline is noted. The internal temperature of the container must never exceed 125° F, 150° F, or 350° F, depending upon rating.

After cooling has occurred, the container is opened, dismantled and its contents examined for usability. The locking mechanisms and part fastenings are evaluated for security and the interior scrutinized for any visible evidence of undue heat transmission.

This procedure must be repeated one year subsequent to the first test to insure compliance after aging of materials.

37_4.3.2.3 Relative Humidity Test

After preconditioning, the unit is heated for twelve hours to obtain an interior temperature of 70° ± 5° F and a relative humidity of 50 ± 5 percent. The unit must successfully maintain an interior relative humidify less than 80 percent of 85 percent during its respective Fire Endurance Test and during that part of the cooling period when the interior temperature is above 120° F. Units are also examined for any signs of moisture penetration into the interior.

37_4.3.2.4 Combined Explosion Hazard Impact Test

The container is heated to 2000° F for thirty minutes. If no explosion results, then the temperature is reduced to the standard time-temperature Curve and the fire continued for another fifteen or thirty minutes, depending upon rating. The test sample is then withdrawn. Within two minutes, the unit is dropped from thirty feet into a pile of brick on a heavy concrete base. The safe is examined, reheated and reexamined as per the requirements of the Fire and Impact Test.

37_4.3.3 UL Label Type Classifications

UL classifies containers based upon the time they will withstand exposure to high temperatures. The following table provides a summary of ratings and requirements.

Class 125 Insulated Record Containers/Fire-Resistant Safes

½ hour IT1, T1, F1, E1, FI4
1 hour IT1, H2, T1, F1, E1, FI4
2 hours IT1, H2, T2, F1, E1, FI3
3 hours IT1, H2, T3, F1, E1, FI2
4 hours IT1, H2, T4, F1, E1, FI1

Class 150 Insulated Record Containers/Fire-Resistant Safes

½ hour IT2, T1, F1, E1, FI4
1 hour IT2, H1, T1, F1, E1, FI4

2 hours IT2, H1, T2, F1, E1, FI3
3 hours IT2, H1, T3, F1, E1, FI2
4 hours IT2, H1, T4, F1, E1, FI1

Class 350 Insulated Containers/Fire-Resistant Safes

½ hour (old UL label E) IT3, T05, F1, FI5
1 hour (Insulated filing drawers) IT3, T1, F1, E1
1 hour (old UL label D Fire Resistant Safes) IT3, T1, F1
1 hour (old UL label C) IT3, T1, F1, E1, FI4
1 hour (old UL label D Insulated filing devices) IT3, T1, F1, FE1
2 hours (old UL label B) IT3, T2, F1, E1, FI3
4 hours (old UL label A) IT3, T4, F1, E1, FI2

37_4.3.3.1 UL Test Protocols

IT1 Interior temperature less than 125° F
IT2 Interior temperature less than 150° F
IT3 Interior temperature less than 350° F
H1 Interior relative humidity <85 percent (class 150)
H2 Interior relative humidity <80 percent (class 125)

T4 time-temperature curve four hours to 2000° F
T3 time-temperature curve three hours to 1925° F
T2 time-temperature Curve two hours to 1850° F
T1 time-temperature curve one hour to 1700° F
T05 time-temperature curve one-half hour to 1550° F

F1 Fire Endurance Test

FE1 Fire Endurance and Explosion Test (no explosion through 30 minutes of exposure to a 2000° F fire)

FE2 Fire Endurance and Explosion Test (no explosion through 20 minutes of exposure to 2000° F fire)

E1 Explosion Hazard Test

FI1 Fire and Impact Test (no explosion after 30 minutes of exposure to 2000° F, immediate 30-foot drop, standard reheating for 60 minutes to 1700 F.)

FI2 Fire and Impact Test (no explosion through 30 minutes of exposure to 2000º F, 30 minutes of standard exposure to 1700º F, an immediate 30-foot drop test, and a standard reheating for 60 minutes to 1700° F.)

FI3 Fire and Impact Test (no explosion through 30 minutes of exposure to a 2000º F, 15 minutes of standard exposure to 1638° F, an immediate 30-foot drop test, and a standard reheating for 45 minutes to 1638° F.)

FI4 Fire and Impact Test (no explosion through 30 minutes or exposure to a 2000º F, an immediate 30 foot drop test, and a standard reheating for 30 minutes to 1550° F.)

FI5 Fire and Impact Test (no explosion through 20 minutes of exposure to 2000° F).

Time-Temperature Curve

Minutes	Temperature °F
5	1000
30	1550
60	1700
120	1850
180	1925
240	2000

37_5.0 Safe Manufacturers National Association (SMNA)

The Safe Manufacturers National Association established specifications for fire, burglary, and robbery-resistive containers. SMNA is no longer in business, but containers carrying its ratings are still in use. For that reason, information regarding SMNA classifications is presented here.

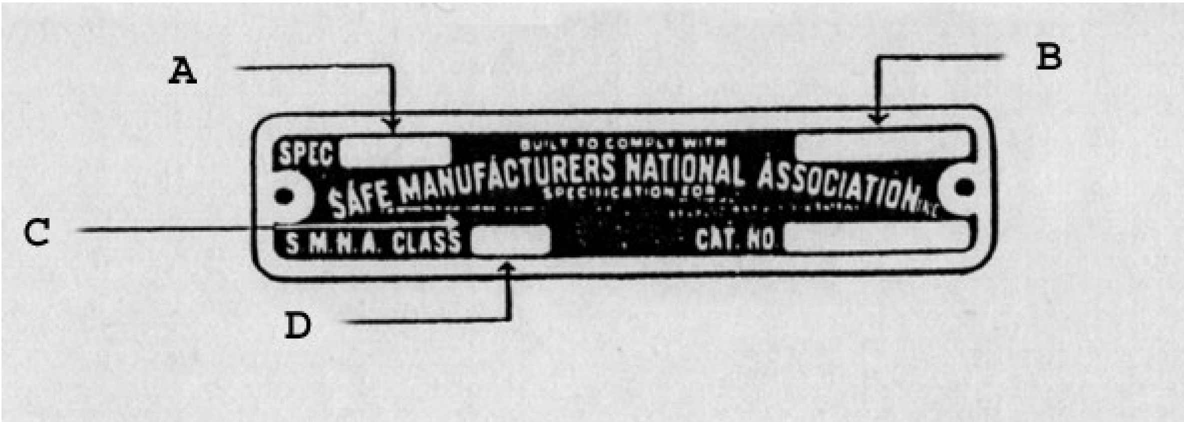


Figure LSS+3703 The SMNA label components: "A" is the specification, such as F1-D; "B" is the SMNA designation, such as "Y" or "W"; "C" is the type of label, such as fire-resistant safe, or fire-insulated vault door; "D" is the SMNA classification, such as Class "A" or "B."

All SMNA labels have a green, black or red background. A green background was used on most fire-insulated containers; all SMNA labels for money chests and burglary-resistive containers have a red or black background. Each label contains the following information:

- **"Safe Manufacturers National Association";**
- **SMNA specification;**
- **Type of label;**
- **SMNA classification;**
- **SMNA designation.**

The SMNA designation "W" or "Y" indicated the cost of a container. A "W" denoted a retail list price of $75 or less; containers that cost more were assigned the "Y." Labels used on fire-insulated **containers** defined one of the following SMNA classifications: **A, B, C, D, E,** or **150.** Fire-insulated **doors** had one of four classifications: **one hour, two-hour, four-hour,** or **six-hour.** Money chests and burglary or robbery-resistive products were classified by one of the following groups: **"U-1"** through **"U-10",** or **"U-12."**

Burglary and robbery classifications were based on test data or SMNA construction specifications that conformed to the National Bureau of Casualty and Surety Underwriters' requirements. Fire-resistive classifications for safes, chests and insulated record containers were based on tests conducted by Underwriters

Laboratories.

37_5.1 Burglary and Robbery-Resistant Containers

Specifications for SMNA-rated burglary and robbery-resistant containers are detailed as follows:

Group 3: Round door chests, body thickness 1″ minimum, door thickness 1 ½″ exclusive of boltwork and locking mechanism. Locking mechanism to be lug or bolt-type. If lug-type, bolts to be protected by drill-resistive inserts or pins, outside surface of body and door to be case- hardened or of equivalent drill resistance. Body to be made of one piece, SAE 1020 or equal steel casting, forging or rolled steel. Door to be made of one piece of equivalent material. Fit of door, equipped with combination lock, to be not more than .004″ clearance between door and jamb at any joint, with hinge removed.

Group 4: Round door chests, body thickness 1″ minimum, door thickness 1 ½″ exclusive of boltwork and locking mechanism, locking mechanism to be lug or bolt-type. If lug-type, bolts are to be protected by drill-resistive inserts or pins. Body to be of cast or welded construction or a combination of cast and welded construction. Cast bodies to be SAE 1020 or equal steel, welded bodies to be of commercial steel. Doors to be of steel equivalent in strength of that used for bodies, fit of door to be not more than .004″ clearance between door and jamb, with hinge removed. Door to be equipped with combination lock.

Group 5: Rectangular door chests. Body to be 1″ minimum, door to be 1½″ minimum exclusive of boltwork and locking mechanism. Body and door to be of commercial steel plates of laminated or welded construction, equipped with combination lock.

Group 6: Round or rectangular door chests. Body thickness ½″ minimum, door thickness 1″ minimum exclusive of boltwork and locking mechanism. Constructed of commercial steel, laminated or welded. Door equipped with a combination or key lock.

Group 9: Containers consisting of wall safes and similar products with body thickness not less and ¼″ and door thickness not less than ½″. Door equipped with a combination or key lock.

Group 10: Containers such as lockers, truck boxes, etc. Door equipped with a combination or a key lock.

Group 12: Any industry product in any class that is equipped with a deposit slot that is
accessible from the exterior of the container. The slot voids any fire or burglary
rating to which the product would otherwise be entitled. Note that the term “thickness”
applies to thickness of steel, which may be solid or laminated. SAE means Society of
Automotive Engineers.

37_5.2 Money Chests and Robbery-Resistive Products

UB 1: Burglary-resistive chest, Groups U-1-2-4-5-6-7, Y, Burglary-resistive Underwriters Laboratories Labeled chest, red. The fire resistant vault door is green.

BR 1: Burglary/Robbery-resistive container, Groups 3-4-5-6-9-10, Y, Burglary/Robbery-resistive container, black

M 1: Deposit chute container, Group 12, Y, deposit chute container, black.

37_5.3 SMNA Specifications for UL Labeled Chests

SMNA labeled Burglary-resistant chests carry the following UL classifications:

- **Group U-1: TXTL-60**
- **Group U-2: TRTL-60**
- **Group U-4: TRTL-30**
- **Group U-5: TL-30**
- **Group U-6: TL-15**
- **Group U-7: “KL”.**

37_5.4 Fire Tests: Endurance, Impact, and

Explosion

Three types of fire testing were done by SMNA: **endurance**, **impact**, and **explosion**.

37_5.4.1 Fire Endurance

The Fire Endurance Test measured the ability of a product to withstand heat and flame. A container was lightly loaded with papers, loosely distributed throughout, and allowed to touch the internal walls. The safe was then placed in a furnace and the temperature raised in accordance with the American Standard Time-temperature Curve, according to the product class being tested. There were five classifications:

- **Class A: to the 4 hour-2000° F point;**
- **Class B: to the 2 hour-1850° F point;**
- **Class C & D: to the 1 hour-1700° F point; and**
- **Class E: to the ½ hour-1550° F point.**

The interior of the test sample is measured on a regular basis until the maximum temperature is reached. So long as the inside of the safe does not reach 350°F, the papers can be handled normally without breaking and information on the pages can be easily read; the safe is said to have passed the test.

37_5.4.2 Impact Protocol

The impact protocol simulates conditions during a fire: the test consists of three parts. The product, heavily loaded with papers, was placed in a testing furnace and the temperature elevated, based upon classification of the container:

- **Class A: to the 1 hour, 1700° F point;**
- **Class B: to the 3/4 hour, 1640° F point; and**
- **Class C: to the ½ hour, 1550° F point.**

The sample, while still in a highly heated condition, was removed from the furnace, hoisted to a height of thirty feet and dropped, bottom downward, onto a bed of broken brick covering a thick concrete base. After allowing to cool to a normal temperature, the sample was subjected to the final phase of the procedure.

The container was again placed into the furnace, bottom upward, and the temperature raised to the required level for the particular class being tested. The furnace was shut down and the sample allowed to cool. The container was considered to have withstood the test if the papers inside were capable of ordinary handling without breaking, and were decipherable by normal means.

37_5.4.3 Explosion Hazard

The sudden heating of a container can generate hydrogen airstream mixtures that can cause rupture. The test was designed to determine if a product could withstand sudden heating that could impair its fire resistance. A safe was first lightly loaded with papers, loosely distributed. The container was placed in a preheated furnace, at 2000° F. The temperature was maintained for thirty minutes. If no explosive pressure developed, then the test was completed successfully.

37_5.5 Classifications and Labeling for Special Safes and Vaults

There are special insurance classifications and labeling for mercantile safes and bank safes. These are taken from the Insurance Services **Office Manual of Burglary Insurance**.

37_5.5.1 Mercantile Safes, Chest, or Cabinet

The following safe, chest and cabinet classifications are applicable to mercantile containers. Each must be equipped with at least one combination lock, except a safe or chest equipped with a key lock and bearing the label, "Underwriters Laboratories, Inc. Inspected Key locked safe **KL Burglary**."

B:	**Fire-Resistive**
Doors:	Steel less than 1" thick. Any iro safe, or chest having a through which money car deposited.

Walls:	Body of steel less than ½" thick, Any iron or steel safe having a slot through w can be deposited.
C: Burglar-Resistive	
Doors:	Steel at least 1" thick. Safe or chest the following label: "Underwriters' Laboratories, Inc. Inspected Key locke **Burglary.**"
Walls:	Body of steel at least ½" thick. Safe or chest bearing the following la "Underwriters Laboratories, Inc. Inspe Key locked Safe KL Burglary."
E: Burglar-Resistive	
Doors:	Steel at least 1 ½" thick.
Walls:	Body of steel at least 1" thick.
ER: Burglar-Resistive	
Doors and Walls:	Safe or chest bearing the following la
F: Burglar-Resistive	
Doors and Walls:	Safe or chest bearing one of the follo labels: **TL-30, TR-30, TX-60.**
G. Burglar-Resistive	
Doors:	One or more steel doors (one in front other) at least 1 ½" thick and aggrega least 3" thickness.
Walls:	Not applicable.
H. Burglar-Resistive	
Doors and Walls:	Safe or chest bearing one of the follo labels: **TX-60, TR-60, TRTL-30.**
I. Burglar-Resistive	
Doors and Walls:	Safe or chest bearing the following la **TRTL-15x6**
J. Burglar-Resistive	
Doors and Walls:	Safe or chest bearing the following la **TRTL-30x6.**
K. Burglar-Resistive	
Doors and Walls:	Safe or chest bearing one of the follo labels: **TRTL-60, TXTL-60.**

37_5.5.2 Bank Safe Classification: Safe, Chest or Security Locker

There are twelve classifications for bank safes: **A-K** and **BR.** The highest letter designation corresponds with the level of security. The specification defines the construction of walls and doors in terms of metal, thickness, and grade. Classifications **A**, **B**, **BR**, and **C** relate both to night depository receiving safes and traditional enclosures. It is interesting to note that there is no universal standard for ATM machines, although the internal safes **are** rated. The closest standard appears to be UL 291, level 1 for such devices.

Certain of the other classifications correlate to UL ratings. Thus:

Class	UL
BR	TL-15 Burglary (walls and door);
C	Equal to BR. No longer manufactured;
D	No longer manufactured;
E	No longer manufactured;
F	No longer manufactured;
G	Doors (lug type, hung) >1.5″ thick. If outside of a vault, then must be equipped with a time lock. May carry a rating of TL-30, TR-30, or TX-60;
H	Safe or chest with TX-60, TR-60, or TRTL-30 rating;
I	Safe or chest bearing a TRTL 15X6 label;
J	Safe or chest rated at TRTL-30x6 Burglary;
K	Safe or chest rated as TRTL-60 or TXTL-60.

37_5.5.2.1 Bank Safe Construction Requirements

Each door of each safe, chest, or security locker must be equipped with at least one combination lock, except a safe, chest or security locker equipped with a labeled Underwriters' Laboratories, Inc. approved key lock. The thickness of steel in doors is exclusive of boltwork and locking devices. If a safe has more than one combination-locked door (one in front of the other), the combined thickness of the steel doors, excluding any

door with less than 1" of steel, shall be used in applying the bank safe classifications.

Night depository: This unit consists of a head, chute and receiving safe in which deposits can be made from outside the bank. Deposits are made in a bag or envelope.

37_6.0 Padlock Testing and Standards: American Society for Testing and Materials (ASTM)

Extensive evaluation criteria have been developed for padlocks due to the popularity of these devices. The following ASTM standards relate to environmental, functional, operational and security requirements. The protocols encompass both surreptitious and forced-entry. Specially made padlocks that are used by the Department of Defense or other high-security locations are not included in these standards.

37_6.1 ASTM References

The following reference documents and standards are relevant for padlock evaluation:

- **ASTM F883**
- **B 117 Method of Salt Spray (fog) Testing**
- **G 53 Practice for Operating light and Water-Exposure Apparatus for Exposure of Nonmetallic Materials**
- **A 156.5 Standard for Auxiliary Locks and Associates Products.**

37_6.2 ASTM Terminology

The following terminology is utilized by ASTM in describing testing protocols relating to padlocks. These definitions are equally applicable to UL standards and descriptive materials in **Chapter 32.** Some definitions have been omitted in this discussion due to their inclusion elsewhere in this book.

Cam: The flat material fastened to or a part of the back of the cylinder plug that operates the locking and unlocking mechanism when activated by the plug.

Case: The housing for the locking assembly.

Clevis: A fastening device that joins a chain to a padlock.

Cylinder: The cylindrical subassembly of a lock containing a cylinder plug.

Cylinder Bitting: The arrangement of tumblers within a cylinder.

Cylinder Decoding: The procedure used to produce a key without having the source from which to copy.

Cylinder Picking: Operating a cylinder with tools in a non-destructive manner, rather than with the correct key.

Cylinder Plug: A portion of the cylinder that activates the lock when the correct key is inserted and operated.

Removable Cylinder: The subassembly of a cylinder containing the cylinder plug, tumbler mechanism, and keyway. It may also constitute the entire cylinder, extractable from the rest of the padlock.

Heel: The portion of a shackle permanently retained in the padlock case.

Keyway: The opening in the cylinder plug into which the key is inserted.

Padlock: A locking device made up of a case, shackle, and the shackle-retaining assembly. Components performing the same purpose of a shackle but differing in design are sometimes used instead of a shackle.

Plug retainer: The portion of the cylinder that prevents the cylinder plug from being withdrawn.

Rapping: A non-destructive procedure to open a lock by applying impact or shock.

Shackle: The component of a padlock entering the case and effecting the locking function.

Shroud: Material that is employed as added protection to a padlock in order to resist attack.

Toe: The portion of a shackle that is withdrawn from the padlock case, leaving a clear opening so that engagement in a hasp or other closure may be accomplished.

Tumbler: A moveable mechanical element that prevents operation of the cylinder plug except by activation of the correct key.

37_6.3 Classification and Grades of Padlocks

There are two classifications of padlocks: **key** and **combination** operated. Padlocks can be described within several grades of performance, listed in the order from lowest to highest:

- **Key is captive in cylinder when padlock is unlocked;**
- **Removable cylinder;**
- **Changeable combination;**
- **Combination-operated with key control;**
- **Corrosion resistant;**
- **Provided with non-ferrous shackle;**
- **Environmental resistant.**

37_6.4 Specific Tests and Protocols for Padlocks

There are several testing protocols to determine the ability to resist forced and covert entry attempts. These require the padlock to be subjected to different kinds of stresses to assess the ability of the mechanisms and materials to withstand attack.

37_6.4.1 Forcing Tests

There are six types of **forcible** tests that are performed upon padlocks:

37_6.4.1.1 Tensile Test

After being placed in a special fixture, force is applied to the padlock slowly along the vertical centerline of the lock, with a direct and equal tension to each leg of the shackle. Failure occurs if the padlock is opened.

37_6.4.1.2 Drop Test

With an impactor, the weight is dropped the required number of times on each face and side of the locked padlock case. Failure occurs if the padlock is opened.

37_6.4.1.3 Shock Test

Using the impactor, the weight is dropped the required number of times on the top of the locked padlock case. Failure occurs if the padlock is opened.

37_6.4.1.4 Cylinder Plug-Pulling Test

The keyway is drilled with a No. 20 (0.61”) diameter bit. A type AB No. 12 screw, at least 19 mm (0.75”) deep, is inserted. The required tension is applied axially between the case and the installed screw. Failure occurs if the cylinder plug or cylinder assembly completely separates from the case, or if the padlock can be opened by manipulation with a screwdriver at the conclusion of the test.

37_6.4.1.5 Cylinder Plug-Torque Test

The padlock is installed in a rigid fixture such as a vise, to support it firmly but not restrict free rotation of the plug in the cylinder. A bladed tool is inserted into the keyway so that a torque load can be applied to the plug. Failure occurs if the padlock opens.

37_6.4.1.6 Shackle Cutting Test

Shackles shall withstand cutting and severance when two shearing blades of American Iron and Steel Institute (AISI) S-2 material are positioned in a tensile loading device having a compression load capability and compressed with the required force. Failure occurs if the shackle is severed.

37_6.4.2 Surreptitious-Entry Tests

Five surreptitious-entry tests are performed on padlocks:

- **Picking and manipulation;**
- **Impressioning and decoding;**
- **Shackle shimming;**
- **Cylinder drilling and shimming;**

- **Rap tests.**

37_6.4.2.1 Picking or Manipulating Test

Cylinders and combination mechanisms within padlocks must resist picking or manual manipulation for the required time. In the case of pin tumbler locks, the plug must be loaded with one each of the longest and shortest pins that are furnished by the manufacturer. The remaining chambers must contain other sizes. Tools should not leave any visible marks that are detectable by the unaided eye.

37_6.4.2.2 Impressioning and Decoding Tests

A cylinder must resist successful impressioning and decoding.

37_6.4.2.3 Shackle Shimming Test

A shim inserted between the shackle and case in either or both shackle holes must be incapable of releasing the locking mechanism.

37_6.4.2.4 Drilling and Shimming Test

Cylinders must resist drilling with handheld tools, and shimming for a required period. Indicia of drilling must not be obvious to the unaided eye.

37_6.4.2.5 Rap Test

Rapping, as described in C**hapter 32**, requires the application of shock to the case. A padlock must resist rapping for a required time.

37_6.4.2.6 Cycle Tests

Cycle testing for cylinder locks provides that opening and closing sequences be executed the required number of times in each rotational orientation, not to exceed ten cycles per minute and without the addition of lubrication. Failure occurs if the test cannot be completed, if the padlock does not operate at the conclusion of the test, or if the key breaks.

Combination locks are cycle tested in slightly different fashion. Single-dial (multiple disc) padlocks are operated in alternate

directions for the required number of cycles at a rate not to exceed ten cycles per minute, with no more than a two seconds dwell. One cycle is equal to the number of revolutions necessary to upset all combination discs. At the conclusion of the test, the lock must open when the correct combination is dialed.

37_6.4.2.7 Corrosion and Environmental Tests

Locks must be resistant to corrosive elements, dry contaminants (such as silicon carbide grit), condensation, ultraviolet radiation, wet freezing environment, and be impervious to salt spray for the required number of hours.

37_7.0 Key or Combination Changes (Differs)

A standard (X1.7.1) has been promulgated relating to the number of "safe" key changes or differs that can be obtained from a cylinder. As has been demonstrated elsewhere in this text, the number of useable differs are limited and will vary according to the number of tumblers within a plug. Differs becomes important in a complex keying system and directly relate to security and the ability to pick or manipulate a lock. A limited number of differs can also promote the use of cross-keys within a master key system. See **Chapter 11**.

Certain locks employ special systems to increase the number of differs. Medeco is a prime example, utilizing the rotating tumbler. Unless such methods are employed, a simple six-pin master keyed system is limited to approximately four thousand safe key changes. This number can be further reduced if higher security is required. Obviously, with fewer pin positions, safe key changes are substantially reduced.

37_8.0 Americans with Disabilities Act (ADA)

The ADA requires that special hardware be employed in public accommodations in order to remove architectural barriers. All new facilities must comply with the requirements of the act. Older facilities must be modified when feasible. The relevant portions of Title III of the ADA provide:

- **"A public accommodation shall remove architectural barriers in existing facilities where such removal**

is readily achievable, i.e., easily accomplishable and able to be carried out without much difficulty or expense."

- **"Door Hardware: Handles, pulls, latches, locks, and other operable parts on accessible doors shall have a shape that is easy to grasp with one hand and does not require tight grasping, tight pinching or twisting of the wrist to operate. Such hardware shall be mounted within reach ranges. When sliding doors are in the fully open position, operating hardware shall be exposed and useable from both sides."**

37_9.0 United States Government Requirements for Security Devices

The General Services Administration (GSA), originally established in the 1950s, is the primary government agency responsible for the acquisition of security hardware for all federal agencies. Until the GSA was established, sensitive government information and assets were only protected against fire and burglary, but not sophisticated methods of attack. Pursuant to **DoD 5200.18**, the GSA "established and publishes minimum standards, specifications, and supply schedules for containers, vault doors, alarm systems, and associated security devices suitable for the storage and protection of classified information. Heads of DoD Components may establish additional controls to prevent unauthorized access."

The GSA publishes military and federal specifications that must be adhered to by all agencies within the United States government. This includes any private entity doing business with the government, if classified information is controlled by such entity. Specifications are written by the GSA, DoD, or the Interagency Committee for Security Equipment (IACE).

Before a manufacturer can be certified as compliant, its security hardware is subjected to rigorous testing by government laboratories. Containers and locks are examined at the **Army Intelligence Material Directorate**, pursuant to Federal Specification FP-L-2740. A comprehensive analysis is performed, relating to forced-entry, manipulation resistance, surreptitious and covert methods of entry, radiological tests, and general material and operational protocols. Compliant products will be

placed on the Qualified Products List (QPL).

37_9.1 Primary Manufacturers for GSA Security Hardware

There are two predominant manufacturers for Class V and VI containers: Hamilton and Mosler. Overly produces vault doors, and Schwab has also entered the GSA market. Other entrants have included Diebold, Herring-Hall-Marvin, Art Metal, and Hillside. The two major lock manufacturers are Mas-Hamilton and S&G.

37_9.2 General Requirements for GSA Containers

General requirements for marking, identification, opening and repair are summarized here. **Specifications** govern the manufacture and purchase of hardware; **regulations** control service and repair.

37_9.2.1 Marking and Identification

All GSA-approved containers must be identified by a specific label, denoting security classification. All containers will be marked on the outside of the front face of the container with a label reading "General Services Administration Approved Security Container" along with the name of the manufacturer. All containers will have a certification label affixed to the external side of the locking drawer describing the protection provided by the container.

EXAMPLE: **"This is a U.S. Government Security Container, Class 6 Cabinet, which, under the test defined in Federal Specification AAF-358-F, affords protection for:**

> **30 man-minutes against surreptitious entry**
> **20 man-hours against manipulation of the lock**
> **20 man-hours against radiological attack**
> **No forced-entry requirement."**

All containers will also bear an identification label on the external side of the locking drawer showing the model and serial number, year of manufacture and government contract number under which manufactured. GSA-approved security products include file cabinets, map and plan files, weapons cabinets, modular vaults, vault doors, and locks.

37_9.2.2 Opening in Case of Lockout

DoD 5200.1R controls service and repair of all GSA-approved containers. Other regulations may further define personnel and procedures. This order states that "neutralization of lockouts or repair of any damage that affects the integrity of a security container approved for storage of classified information shall be accomplished only by authorized persons who are cleared or continuously escorted while so engaged."

The **Industrial Security Manual for Safeguarding Classified Information**, DoD 5220.22-M, specifies how 5200.1R is to be implemented for defense contractors. They must be "specifically trained in approved methods of maintenance, neutralization of lockout, and repair of perforations."

37_9.2.3 Requirements Regarding Entry and Repair of Containers

Opening and repair is tightly regulated with respect to methods, procedures, and personnel so that the security of the device is not compromised. There are very specific requirements regarding the entry and repair of GSA containers. These include:

- **Means must be utilized that allow complete repair of containers;**
- **The container must retain its integrity, color, and condition (restored to original condition);**
- **There must be no evidence that entry has been made. If that is impossible, then a security officer must be notified so that the label may be officially removed, and the container labeled as unsuitable for storage of classified material;**
- **Old specification containers, produced prior to 10/1/1990 may be opened by drilling under the dial, although such practice is not recommended for newer containers (those built after 1990);**
- **A record of service must be maintained whenever work is performed on a container.**

37_9.3 Classification of Containers

The primary function of a GSA container is to protect against specific types of attack, mainly covert and surreptitious entry;

most commercial products do not have such requirements. The specifications can be changed to reflect increased threats because of improved penetration techniques.

Depending upon the required security, containers are classified according to the necessary level of protection. There are currently eight classes (I-VIII). Class I-IV, and Class VII containers are no longer manufactured, although they are still in use. Class V and Class VI equipment is approved for storage of classified information including top secret.

Federal Specification AA-F-358G (March 7, 1989) is applicable for non-insulated filing cabinets and security containers. It defines the construction, materials, paint, color, face hardware, internal locking components, testing, inspection, and the locks that are utilized to secure the containers.

Class I: Insulated (one-hour fire)	10 minutes forced-entry 30 minutes surreptitious
Class II: Insulated (one-hour fire)	5 minutes forced-entry 20 minutes surreptitious
Class III: Not insulated	No forced-entry requirement 20 minutes surreptitious
Class IV: Not insulated	5 minutes forced-entry 20 minutes surreptitious
Class V: Not insulated	10 minutes forced-entry 30 minutes covert entry 20 hours surreptitious
Class VI: Not insulated	No forced-entry requirement 30 minutes covert 20 hours surreptitious
Old Class VII: Not insulated	No forced-entry requirement 60 minutes surreptitious
New Class VII: 30 minutes covert	20 hours surreptitious
Class VIII: Insulated (one-hour fire)	15 minutes forced-entry 120 minutes surreptitious

37_9.3.1 Covert and Surreptitious Entry

In March 1989, AA-F-358G was rewritten to encompass and define covert entry as "a means of entry that will leave evidence not obvious to the user, but which could be detected by a qualified person." Surreptitious entry is now defined as "entry that is made in such a manner that there is no evidence apparent even to the expert that the entry was made." The rewritten specification also includes the new lock specification, FF-L-2740.

All containers are required to provide 20 man-hours protection against lock manipulation and radiological attack. Containers that were built in classes that are now defined as obsolete may continue to be utilized, if presently in service.

37_9.4 Federal Specification for Combination locks

The ANSI/UL 768 specification is utilized for combination locks. The federal requirement (FF-L-2740, October 12, 1989) covers all devices that are designed to be mounted on safes, security files, vault doors and similar items. It defines the type, styles, models, classes and sizes, as well as manipulation, radiographic and thermal resistance.

The government continually tests all qualified locks to determine whether entry protection can be improved. If it is determined that a lock fails to provide adequate protection, it will be removed from the QPL.

37_9.4.1 General Provisions Regarding Locks

- **The UL label shall not, in itself, constitute GSA approval of the lock;**
- **All containers must be equipped with a combination lock capable of resisting manipulation and radiological attack for 20 man-hours (UL Group 1R);**
- **Dial and dial ring design shall prevent casual observation of the combination during dialing;**
- **Only the knob of the dial shall be available to grasp for dialing; all other moveable surfaces shall be shielded from touch;**
- **Each lock shall be supplied with a dust cover to protect the dial and dial ring.**

37_9.4.2 Special Provisions Affecting Security of Locks

- **Bolt Lookout: The lock shall have a mechanical relock device that will block the bolt in the locked position if the lock cover plate is moved more than .10″ (2.54 mm) at any point from its normal operating position;**

- **Case and Bolt Strength: A force of 600 pounds is applied to the bolt. Any fracture or bending of the bolt or case shall be a failure;**

- **Combinations: The lock combination shall be input by dialing. The combination for opening the lock shall not exceed four numbers. Each number shall be within the range of 0 and 99, inclusive. The lock shall have as a minimum 1,000,000 operational combinations. These shall be number sequences which may be set on the lock after excluding those settings which are prohibited by the manufacturer due to the lock design. Operational combinations include those settings which are not recommended but which may be used, such as 20-40-60;**

- **Combination Redial: Once the lock bolt has been extended to the locked position, it shall not be possible to reopen the lock without completely redialing the lock combination. For purposes of this requirement, the locked position means the bolt has been fully extended;**

- **Covert Entry: The lock shall resist covert entry for a period of 30 man-minutes. For the purpose of the covert entry test, access to the lock shall be limited to the dial and spindle. The lock will be presumed to be adequately protected against viewing or physical manipulation of the lock or lock case and against punching. The lock shall resist covert opening for the period specified in (3.6.2);**

- **Dissimilar Metals: Dissimilar metals, as defined in MIL-STD-889, shall be plated or compatible to prevent operationally destructive corrosion;**

- **Emanation Analysis: The mechanism shall not emit any sounds or other signals which may be used to surreptitiously open the lock within a period of 20 man-hours;**

- **Entry: For the purpose of this specification, entry means retracting the bolt;**

- **Lock Bolt: The lock bolt's cross section shall be not less than .312″ x 1.00″ (7.93 x 25.4 mm) with a minimum projection from the case of .437″ (11.1 mm) in the locked position and flush to .062″ (1.575 mm) in the unlocked position, and shall have not less than .312″ (7.92 mm) throw;**

- **Manipulation: The lock shall resist opening through manipulation for a period of 20 man-hours;**

- **Material Deterioration and Control: The lock shall be fabricated from compatible materials, inherently corrosion and deterioration resistant or treated to provide protection against corrosion;**

- **Normal Use: For the purpose of this specification, normal use means dialing the combination, retracting the bolt, and extending the bolt;**

- **Operation Test: The lock shall be subjected to 10,000 cycles of operation without replacement of any component. One cycle shall consist of dialing the combination at a speed not exceeding 48 revolutions per minute, retracting the bolt, throwing the bolt and scrambling the combination. • Following the cycling, the lock shall be subjected to fifty combination changes, including three open and close operational verifications after each change. The lock shall then be checked to verify that the dialing tolerance is still within the**

acceptable range specified by UL 768. The lock shall operate smoothly and the dial torque shall be in the range specified in section (3.4.10). Any failure of the lock during the test shall be cause for rejection;

- **Radiological Analysis: The lock shall resist opening through radiological analysis for a period of 20 man-hours;**

- **Surreptitious Entry: Locks shall be tested for resistance to surreptitious entry. Attempts shall be made to unlock through manipulation, radiological analysis and emanations analysis and automatic dialing devices. Manipulation and analysis may include the use of computer enhancement techniques for signals or emanations. The lock shall resist opening for the times specified in section (3.6.1);**

- **Temperature: The lock shall operate in a temperature range of -10°F to 158° F (-23.3° C to 70° C). At temperatures exceeding 158° F (70° C), a thermal relock shall cause the lock to be dead bolted to prevent entry;**

- **Wear Test: The lock in the locked condition shall have the dial turned at 600 RPM for a period of not less than eight hours- four hours in a clockwise and four hours in a counterclockwise direction. At the end of eight hours, it shall not be possible to open the lock through surreptitious or covert techniques.**

37_9.4.3 FF-L-2740 Combination Locks

The full text of Federal Specification FF-L-2740 is cited below.

FF-L-2740 Federal Specification for Combination Locks

37_10.0 European Standards

There are equivalent entities in Europe that perform similar functions to Underwriters Laboratories. For example, the German Association of Good Insurers (Verband der sachversicherer e.V. (VdS)) has provided certification and testing services for many years in that country. In Japan, the Japanese Industrial Standards are relied upon by all manufacturers for containers utilized in that country.

In 1997, after more than five years of negotiations between participants, a new European standard for safe and vault door burglary resistance testing and classification was issued. Unlike its American counterpart, the CEN standards have no limitations on the types of tools, amount of fuel that can be used for torches, the size of holes, or other factors that are specified in equivalent UL attack protocols. The following European standards have been drafted. At the time of publication, **CEN 1143-1** has been ratified.

- **CEN 1300 Secure storage units: Classification for high-security locks according to their resistance to unauthorized opening.**

- **CEN 1143 Secure storage units: Requirements, classification and methods to test for resistance to burglary. Part 1: Safes, strong room doors and strong rooms.**

- **CEN 1047-2 Secure storage units: Classification and methods of test for resistance to fire. Part 2: Data rooms and data containers.**

37_10.1 Calculation of Resistance Value of Container

Unlike UL standards, CEN has adopted a Resistance Value system to assess and calculate the vulnerability of a particular security device to attack. A resistance value of a container is calculated with the equation: **VR = (sum t)(c) + sum BV**, where

VR = Resistance Value in Resistance Units (**RU**);
Sum t = total of all operating attack times in minutes;
c = highest tool coefficient of tools used for attack, in RU per minute;
Sum BV = sum of the basic values for all attack tools used

in RU.

The certification and basic values that correspond to each tool are tabulated in the standard. Once the VR is calculated, a reference table is consulted to ascertain the corresponding resistance classification. The value can range from 0-X (expressed in Roman numerals). When a container is evaluated, the team leader at the testing facility is allowed to assess the best method of attack and select optimum tools to accomplish entry with the least amount of effort and time. The resistance grade is based upon the level of success that is achieved by the entry team. The European system is far more complicated than is utilized in the United States, but may provide a more realistic approach to assessing the security of a lock, safe, or vault. The following standard has now been adopted by the CEN for locks, safes, and vaults:

37_10.2 CEN 1300 Secure Storage Units:

Classification for high-security locks according to their resistance to unauthorized opening.

This standard defines the requirements and specifications for classifying high-security locks that are used on products for the secure storage of cash, valuables and data media. The protocol addresses tests that can be carried out upon the lock, or through actions that can be influenced by or through externally accessible elements or hardware that is necessary for the operation of the lock.

Tests on optional features such as time-lock functions, facilities for integration with an alarm system, and remote control capability are not included in the Standard, notwithstanding that such functionality can influence the primary security of a lock. The performance of a device is measured by several evaluation criteria, and classification is made after testing and a comparison of the results with the specified grade requirements.

37_10.2.1 Duration of Certification of Devices

Once certified, a device is listed for five years. After that period, the lock should be reexamined based upon the last certification test. Changes in methods of entry will dictate whether the testing protocol or requirements may be modified.

37_10.2.2 Definitions

Certain definitions have been adopted in the course of drafting this standard. Those relevant to our discussion are included here.

Atmospheric, Electrical, Electromagnetic, and Physical Environmental Resistance: A lock must be able to withstand a specified range of conditions and continue to meet the security operation and reliability criteria.

Biometric: The code is operated by means of human characteristics (fingerprint, voice, etc.).

Blocking Feature: That physical part of the lock that prevents movement of the boltwork.

Code: Identification information which can be input into a lock and which, if correct, enables its security status to be changed.

Code Spying and Copying: An attack which involves identification of the correct code without having direct access to the lock.

Coding Means: Means by which the code is internally retained.

Destructive Burglary: Physical attack that damages the lock in a manner that is irreversible and cannot be hidden.

Electronic Lock: A lock that is secured partly or fully with electrical or electronic elements.

Fail-Secure: The failure of the lock system or any of its principal components must leave the lock in a secure state.

High-security Lock (HSL): An independent assembly, normally fitted to doors of secure storage units, into which a coded input can be entered for comparison with a memorized code. A correct match allows a blocking function to be released or changed.

Locking Device: That part of the lock which enables or prevents the moving of the blocking feature.

Manipulation: Any method of attack made directly against an in situ lock and aimed at removing the blocking function without causing obvious damage. This includes the case wherein a lock continues to function normally after manipulation, although its

security could be permanently degraded.

Material: The code is defined by the physical features or properties (mechanical, magnetic, electrical) of a token.

Mechanical Lock: Lock secured by mechanical elements only.

Monitoring: Spying or unauthorized recognizing of the code input by any method, including the use of instruments, and observation by human means.

Reliability: The ability to function correctly and achieve specified security criteria after a large number of duty cycles.

Token: An object whose physical form or properties define the input code, such as a key.

Useable Codes: The smallest number of code or key trials by which an expert having full knowledge of any imposed code constraints, plus details of the manufacturer's tolerances and clearances, can be certain of opening the lock.

37_10.2.3 Security Criteria

Based upon the above definitions, the standard defines criteria to assess the security of a lock in terms of manipulation resistance, destructive burglary resistance, spying resistance, as well as monitoring, atmospheric, electrical, electromagnetic, and physical environmental resistance.

37_10.2.3.1 Manipulation Levels

Four levels of security are specified that are based upon manipulation resistance: 1, 2, 3, 4, with 4 being the most secure. The resistance value that correlates to security is based upon the capability to manipulate the lock to an open condition and is measured according to the tests specified in the standard in section (9.2). The value is expressed as **resistance units** (RU) for the tools used and the time in minutes taken to open the lock.

The number of manipulation trials that can be conducted within a specified time frame are also defined based upon the security level, coding means, and technology. The maximum number of trials per hour varies from 10-300. In certain cases, there is no limit.

Manipulation Resistance Level	Accepted for Lock Class	Minimum Units Required
1	A	35
2	A,B	75
3	A,B,C	200
4	A,B,C,D	620

37_10.2.3.1.1 Security against Manipulation

All locks must provide security against manipulation. The techniques to be thwarted and commensurate level of vulnerability will obviously vary with each security level. Resistance is dependent upon many factors, including the inherent design of the locking mechanism and upon the trustworthiness of the operating staff. All security measures incorporated within the lock are to be assessed and integrated into the test protocol.

37_10.2.3.1.2 Manipulation Tests

Manipulation tests are conducted by experts during a predetermined period of time, and after investigation of the lock, and a certain number of the specified open-close cycles. Initially, three experts will conduct separate investigations and preliminary tests of each lock to be approved. The actual timed manipulation tests are carried out by one expert that is selected by the test laboratory. The experts may utilize instruments or tools that are defined in the tool table (noted elsewhere in this section). The code or key is not made available to the expert prior to the test.

37_10.2.4 Destructive Burglary Resistance

There are three primary requirements for each lock relating to destructive resistance criteria:

- **Without the use of the correct code or key, the maximum force which should be exerted against any external feature or through the keyhole must not be capable of opening the lock;**
- **For destructive tests in combination with manipulation, the same resistance value (RV) shall be required as for the manipulation levels noted elsewhere in this chapter. The resistance value is**

based upon the times during which destructive tools are used and shall be calculated at 5 RU/minute.

- **The tools that may be used for destructive attacks shall conform to category A of the Standard "Secure Storage Units: Methods of test and classification for resistance to burglary" specified in EN1143-1.**

37_10.2.5 Spying Resistance

This portion of the specification contemplates **observation** and **monitoring.**

37_10.2.5.1 Observation

- **The observation of the use of a code or key will not permit complete or partial reconstruction of the information, even with knowledge of the structure of the input device;**
- **Any input information into an electronic lock shall be unrecognizable thirty seconds after the last input;**
- **The angle from which identification can be optically observed for security classes C, D shall not be more than 30° about the centerline (total 60° included angle) in the horizontal plane.**

37_10.2.5.2 Monitoring

- **Monitoring is any process that allows the derivation of information from which a code or key can be deduced. The capability must be limited to instruments not closer than 5.0 meters to the input device for all locks of Class C, D. Monitoring may occur acoustically or by the use of radiation interception;**

- **For electronic locks higher than Class B, any cable by which the code identification is transmitted shall not be accessible without leaving damage obvious to the operator.**

37_10.2.6 Atmospheric Resistance Tests

This portion of the standard describes corrosion and temperature requirements.

37_10.2.6.1 Corrosion Test

Corrosion tests shall conform to ISO 6988:1985. The lock must be tested for three cycles with no diminishment in security.

37_10.2.6.2 Temperature

For all classes of locks (**A**,**B**,**C**,**D**), storage temperatures of -10^{o} to $+70^{o}$ are required. The lock must operate within a temperature range of 0^{o} to 50^{o}, and <70% relative humidity.

37_10.2.7 Electrical and Electromagnetic Resistance

This portion of the standard relates to operating voltages, discharge of static electricity, EMI, electromagnetic emission, and resistance to fast transients.

37_10.2.7.1 Operating Voltages

For all electronic locks that are powered from mains, proper operation must be assured with a variance of ±15% and the frequency within ±20% of the nominal value.

37_10.2.7.2 Discharge of Static Electricity

Testing is in accordance with **IEC 801-2** and ranges from 10-50 kV, with an energy level of 7.5 - 187 Jewels. In all cases, the lock must:

- **Continue to function correctly;**
- **Security shall not be affected;**
- **Security shall not be reduced even if the lock is so damaged that it ceases to operate.**

37_10.2.7.3 Electromagnetic Interference

Tests shall be in accordance with **IEC 801-3.** Tests measure frequencies from 27 Khz-1 GHz for all security classifications. The EMI requirements vary from 3-50 V/m. In all cases, the lock

must continue to function correctly and the security and functionality shall not be affected. Security must not be reduced, even if the lock is so damaged that it ceases to operate.

37_10.2.7.4 Electromagnetic Emission

All electronic locks shall conform to **EN 50081** and **EN 50022.**

37_10.2.7.5 Fast Transient

Locks are evaluated that are connected to mains power in accordance with **IEC 801-4.** Peak voltages range from 1-4 kV, with 5ns rise times. In all cases, the lock must continue to function correctly, and the security and functionality shall not be affected. Security must not be reduced, even if the lock is so damaged that it ceases to operate.

37_10.2.8 Physical Environmental Resistance

This portion of the standard addresses vibration and shock values and relates to acceleration, frequency range, and octave levels per minute. Shock resistance relates to drop testing from a height of one meter, acceleration of 50 g, and five shocks in each axis.

37_10.2.9 Reliability Testing

Reliability testing requires that the lock shall function properly and consistently and maintain security based upon the use of the right code during 10,000 cycles of locking and unlocking. Electronic locks are evaluated in combination with temperature tests. Code-changeable locks must be reprogrammed at least 100 times, carried out periodically during cycle testing. Locks cannot deviate ±1% of the total setting range.

37_10.2.10 Design Requirements

General design requirements are defined for all locks and apply to the actuation of bolts, protection of security-relevant components, and the inability to derive code information from supplementary devices fitted to the lock. Specific requirements that relate to mechanical locks include:

- **The code shall not have more than 40% of the coding**

elements (levers or tumblers) with the same depth (or height). Not more than two adjacent elements shall have the same code designation. There shall be at least 60% of the lift height difference between the highest and lowest code element;

- **There shall be no number or code on either the key or lock that identifies a permutation for the specific mechanism;**

In high-security (level **D**) locks, the following additional requirements shall be met:

- **Means must be provided by which the locking status is made obvious to the user, such as preventing removal of the key except in the locked state;**
- **Locks shall have a feature to insure that the code is scrambled after locking;**
- **The mechanism shall contain a device that signals successful scrambling to the operator.**

Electronic locks must meet a number of additional requirements. Those relevant to security are noted here:

- **For locks of level B, C, D with parallel codes, a record of the codes used for the last ten openings shall be stored; the record shall be secure for at least one year in the case of a power failure;**
- **The internal electronic circuitry or processor system shall not be capable of being communicated with to read the program during closed-door condition even on the cabling between input device and lock electronics, except for code identification and changing;**
- **For locks of level B, C and D, the input device shall not be capable of being forcibly removed without leaving such marks or damage as is obvious to the operator.**

37_10.2.10.1 Security Requirements

There are a number of specific design requirements that are based upon the type of mechanism being certified. These relate to useable codes and type of coding means, fail-secure, parallel

locks, and code changes.

37_10.2.10.1.1 Useable Codes

There should be a minimum number of useable different codes, and a sufficiently large number of permutations must be provided. This is to insure that the opening code is not discovered by expertly planned trials and a very small probability of the code being found by accident. The number of useable codes is dependent upon the security classification. Thus:

Class	Minimum number of Useable Codes
A	25,000
B	100,000
C	1,000,000
D	3,000,000

37_10.2.10.1.2 Fail-Secure

There are three requirements:

- **The entry code shall be retained as the only valid opening code until deliberately reset;**
- **A power failure in closed lock configuration shall not, for an unlimited time, affect the security or locking condition;**
- **A system that operates from commercial power only shall be relockable during a failure of the mains supply.**

37_10.2.10.1.3 Parallel Locks

If parallel locking systems are utilized for increased reliability from lockout, then all of the above requirements must be met for each security class.

37_10.2.10.1.4 Code Changes

There are two primary requirements:

- **A code cannot be altered without first entering the correct code to access the lock;**
- **In Class C and D locks that require internal access**

for code alteration (with the door open), the system must be designed to insure that the code can be changed only by the person who has knowledge of the current code.

37_10.2.11 Tool Categories

Three separate tool categories have been defined with respect to the assessment and computation of resistance units: **common hand tools**, **lock opening tools**, and **special tools**.

37_10.2.11.1 Common Hand Tools

Common hand tools can be purchased by any person from retail hardware stores. The tools are sufficiently small to be inconspicuously carried. No special skills are required for their effective use, and they do not need commercial power. Their use will not generate enough noise to attract attention. Examples of common hand tools include:

- **Screwdriver;**
- **Pliers;**
- **Tongs;**
- **Tweezers;**
- **Files;**
- **Punches;**
- **Hammers;**
- **Pocket torches;**
- **Measuring items;**
- **Magnifying glasses.**

37_10.2.11.2 Lock-Opening Tools

Lock opening tools are those that can be purchased only from specialty tool supply companies and available only to bona fide locksmiths. In order to utilize the tools effectively, special training and skills are required, together with a detailed knowledge of the internal mechanism of specific locks. Several specialized lock-picking, decoding and impressioning tools are identified in the Standard. These include:

- **Picking tools;**

- **Lock spares;**
- **Blank keys;**
- **Tryout keys;**
- **Sound amplifier and filter;**
- **Optical or fiber optic probes;**
- **Robot dialers;**
- **Electromagnetic radiation receivers.**

37_10.2.11.3 Special Tools

The category of special tools describes any lock-opening device that in its complete or entire form cannot be purchased and is specially designed, manufactured or modified for the intended use. Their design and manufacture requires considerable skill and a detailed knowledge of locks and lock-opening techniques. It is possible that these tools will be highly specific and effective against one type of lock only.

Detailed information regarding tools and their resistance units for optional tests such as chemical, x-ray, explosion and others are agreed to between the vendor and testing facility.

37_10.3 EN 1143-1:1997 Secure storage units - Requirements, classification and methods of test for resistance to burglary - Part 1: Safes, strong room doors and strong rooms.

37_10.3.1 Introduction

This European standard sets forth the criteria for testing, classifying, and determining the burglary resistance of free-standing safes, built-in safes (floor and wall), strong room doors and strong rooms (with or without a door). It is intended that the test protocols may also be utilized to aid in the design of security systems to provide certain levels of penetration resistance. It must be recognized that attack times may take longer under actual field conditions as compared to tests conducted in a laboratory environment. This is due to the competence of the criminal, conditions at the crime scene, and the availability of tools and mains power.

37_10.3.2 Definitions

A number of specific definitions have been adopted for this particular standard. The following nomenclature applies:

Accessories: Installations and devices that are contained within the structure or which pass through the structure of the strong room or strong room door(s) to provide for ventilation or for deposit of cash and valuables. Such accessories may be open or closed.

Boltwork: The complete mechanism that is utilized to activate and deactivate one or more bolts that effect locking of a container.

Built-in Safe: A safe whose protection against burglary is partly dependent upon materials incorporated into or attached to it during installation. A floor and wall safe are special types of built-in safes.

Freestanding Safe: A self-contained enclosure whose protection against burglary depends only upon the materials and construction of its primary manufacture and not upon materials added or attached during installation, such as floors, walls, or other barriers.

Lock: A device that is able to recognize a coded input and which performs a blocking function on the boltwork or the door.

Operating Time: This definition refers to the time during which a tool is used in an attempt to create a change in the test specimen.

Relocking Device: A system that is comprised of blocking and detecting elements which will prevent the boltwork from being withdrawn upon one or move events associated with a forced-entry attempt. A relocker can be **active** and comprise part of the locking mechanism, or **passive** and independent.

Resistance Grade: The classification designation to denote the burglary resistance of a container.

Resistance Unit (RU): This is a measure of burglary resistance that results from one minute's use of a tool carrying the coefficient of 1 and the basic value 0. It is the basis for producing a numerical evaluation of burglary resistance within

this standard. Factored into the value is the difficulty in transporting the container, use of forcible-entry tools at the site, and the requisite knowledge and experience for the efficient use of such tools.

Safe: A storage unit that is designed to protect its contents against burglary when closed and locked. It has at least one internal side of one meter in length.

Strong room: A storage unit that protects against burglary when closed and locked. Internal measurements will exceed one meter per side in all directions. Strong rooms may be case in-situ, constructed from prefabricated elements, or a combination of such practices.

Strong room Door: This component consists of a door, lock(s), boltwork, and frame. The door provides primary access to a strong room.

Tool Coefficient: A specified number, expressed in resistance units per minute, that is allocated to a group of tools to represent factors such as noise, smoke, fumes, sparks, flames, and other by-products that increase the likelihood of detection.

37_10.3.3 Classification Scheme

Safes, strong rooms, and doors are classified for a resistance grade, based upon specific criteria. An **EX** optional post-detonation designation may also be provided for containers that incorporate protection against explosion.

For EX designation, safes, strong room doors and strong rooms (with or without door) shall meet the post-detonation resistance value according to specified values, and shall have any cable openings so constructed that explosives (e.g. fuses or charges) cannot be introduced through such holes.

37_10.3.4 General Requirements

The standard specifies certain general requirements that must be met by all enclosures:

- **There can be no holes through the protection material other than for locks, cables or anchoring;**
- **Cable openings cannot exceed 100 mm^2. If they exist,**

they must be obstructed or plugged by the manufacturer through means that cannot be removed externally without leaving traces;

- **A free-standing safe with a mass less than 1,000 kg shall have at least one hole by which it can be anchored, and the anchoring assembly for each hole must be capable of sustaining the force specified elsewhere in the standard;**
- **Post-detonation resistance values are within a range of 6-68 for safes and 4-250 for strong rooms, depending upon the design of the enclosure.**

37_10.3.4.1 Requirements for Classification of Safes into Resistance Grades

Minimum requirements are specified for the classification of safes and strong rooms into resistance grades based upon several criteria:

- **Locks that are fitted;**
- **Level of access that is attained;**
- **Weight and mass of the enclosure;**
- **Tool attack testing criteria set forth in the standard;**
- **Use of explosives.**

37_10.3.4.2 Documentation Provided by Manufacturer

Extensive documentation regarding the enclosure must be provided to the testing laboratory relating to all technical issues, including:

- **Description of enclosure;**
- **Drawings and specifications with data regarding size, weight, dimensions, tolerances, and horizontal and vertical cross-sections;**
- **Manufacture;**
- **Installation and mounting data;**
- **Encasement material;**
- **Mechanical designs;**
- **Quantity, placement, and features of locks,**

boltwork, and relockers;

- **Specific data regarding bolts to include the quantity, pitch and position of door bolts, their dimensions (e.g., cross-section), throw and engagements, and their type (e.g., moving or fixed);**
- **Location and design parameters of local barrier materials;**
- **Elements relevant to physical security, including method of joinder, anchoring, and fastening of components, joints and connections, mounting of frames;**
- **Marking, position, and dimensions of any holes that pass through the barrier material, together with a detailed representation of specially protected areas;**
- **Optional security measures, such as time-delay locking systems;**
- **Listing of all compatible locks that may be fitted to the enclosure;**
- **Information regarding any materials or devices that are intended to generate gas, smoke, soot, or markers in the event of physical attack primarily by torch or high temperature or which could generate harmful substances during testing;**
- **Statements of the nature and position of any cables and/or facilities for penetration detection systems, for the mounting of electromechanical securing devices, and alarm devices;**
- **Full instructions for installation, including data regarding:**
  - **The method of anchoring free-standing safes with a mass less than 1,000 kg**
  - **Full details and specifications regarding the method of encasing built-in safes and the materials that must be utilized for doing so;**
  - **The method and techniques for the construction of monolithic cast in situ strong room, including full details regarding building materials, reinforcement, joinder, and the methods for assembling prefabricated strong room elements.**

37_10.3.5 Tool Attack Test

37_10.3.5.1 Introduction

The test serves to establish values for the complete access of a container and the partial-access minimum resistance values of a safe.

A testing team examines a test specimen together with the technical documentation, and devises a program of attack. The testing team attacks the test specimen. The time taken to gain partial or complete access, assessed by inserting a test block, is recorded and used to calculate a resistance value.

The tools and program of attack used during testing shall be those most likely, in the opinion of the testing team, to result in the lowest resistance values. Exploratory tests may be made.

37_10.3.5.2 Testing Team

The test team is comprised of a leader, timekeeper, and operatives to carry out the necessary attacks on the specimen. Tests are conducted according to the current state-of-the-art, and in compliance with **EN 45001**, to insure consistency of result.

37_10.3.5.3 Definition of Attack Tools

Any tool used for the testing shall be given a coefficient and basic value according to tables that are defined within the standard. Categories for the different types of attack tools are delineated.

37_10.3.5.4 Test Protocols

Test protocols are specified for:

- **Free-standing safes;**
- **Doors;**
- **Strong rooms.**

These define the required extent of entry that constitutes sufficient access to make a determination that the container or enclosure has been compromised.

37_10.3.5.4.1 Free-Standing Safe

The tests shall comprise at least one tool attack test for:

- **Partial access against the area of the body, wall, or the door of the test specimen;**
- **Complete access against the body or the door;**
- **Additional tool attack tests are required against wall, top, base or door if the test specimen has areas or zones of a different construction and for which the resistance value can be reasonably expected to be lower (e.g. in the area of preexisting holes).**

37_10.3.5.4.2 Built-in Safes

The test shall comprise at least one tool attack test for:

- **Partial access against the door or lid (including the frame and encasement, if appropriate);**
- **Complete access against the door and/or against the body to remove the built-in safe from its encasement;**
- **Additional tool attack tests are required if the test specimen has areas or zones of a different construction and for which the resistance value can be reasonably expected to be lower (e.g. in the area of preexisting holes).**

37_10.3.5.4.3 Strong room

The test shall comprise at least one tool attack test for complete access against the strong room wall and one tool attack test against the strong room door for complete access.

37_10.3.5.4.4 Strong room without Door

The test shall comprise at least one tool attack test for complete access. Additional tool attack tests for the complete access are required against walls, ceiling or base if the construction of the strong room has areas or zones of different construction and for which the resistance value can reasonably be expected to be lower (e.g., in the area of preexisting holes).

37_10.3.5.4.5 Strong room Door

The test shall comprise at least one tool attack test for complete access on the door (including frame and adjoining wall sections if necessary). Additional tool attack tests for complete access are required if the test specimen has areas or zones of different construction and for which the resistance value can reasonably be expected to be lower (e.g. in the area of preexisting holes).

37_10.3.5.4.6 Holes

Any holes (other than those through the base of a safe and which are provided for anchoring) which are present in the test specimen may be exploited in the testing.

37_10.3.6 Tool Categories that are acceptable for Testing

Specific Categories of Containers or enclosures:

- **Safes shall only be tested with tools of categories A, B. C and D;**
- **Strong rooms and strong room doors can be tested with tools of categories A, B. C, D and S.**

37_10.3.6.1 Special limitations for Tools

During any tool attack test, the following tools shall not be used simultaneously:

- **Two electric-powered tools (A.7, A.8, A.9 and A.10);**
- **Two thermal tools (A.11);**
- **Two hand-hammering tools (A.5);**
- **An electric-powered tool and a thermal tool;**
- **Hand-hammering tool and an electric-powered d tool;**
- **Hand-hammering tool and a thermal tool;**
- **Two specially made electric-powered tools (A.6);**
- **For hand-hammering tools used with both hands, the number of blows is limited to 250 per tool attack test;**
- **In any single tool attack test, only two operatives**

and the testing team leader are allowed to work on the test specimen. Only two persons are allowed to work on the test specimen at one time;

- **Dust cleaners and compressed air may be used for cleaning the test specimen;**
- **Testing shall only be done in areas or against features that have not been weakened by earlier tests.**

37_10.3.6.2 Procedure for Testing

A detailed protocol is established within the Standard to document the procedures employed during all phases of the test. All tools must be prepared for immediate use, once the test begins. Specific timing requirements and values are defined, and assignment of values are given to different aspects of the test, based upon the category and usage of tools. For example, tools of category "A" are allocated 1/60 minute per blow when the tool impacts directly against the test specimen. In this manner, precise timing of an attack can be ascertained.

37_10.3.6.3 Calculation of Resistance Values

For each tool attack test, the resistance values $\mathbf{V_R}$ is derived from the following formula and represents the resistance value in resistance units (**RU**) for that tool attack test:

$$\mathbf{V_R = (\Sigma \tau \times C) + \Sigma BV}$$

where:

Σt is the sum of all operating times in minutes

C is the highest tool coefficient of the used attack tools

ΣBV is the sum of the basic values for all attack tools used

37_10.3.6.4 Explosive Testing

The test is for determining the resistance against attacks with explosives. In practice, an explosive charge is detonated. A tool attack test is then made to measure the remaining resistance value. Upon completion of the tests, a calculation is made, based upon analysis of many factors contained within a comprehensive

formula, to determine the resistance value of the container or enclosure.

37_10.3.6.4.1 Explosives

The charge shall be of pentaerythritt trinitrate (PETN) with the following properties:

- **Density (1 500 ±50) kg/m3;**
- **Specific energy (5000 ±500) J/g;**
- **Detonation velocity (7000 ± 500) m/s.**

37_10.3.6.4.2 Determination of Explosive Charge Mass

The mass of the explosives charge is based upon the resistance grade and container and is defined within the standard.

37_10.3.6.4.3 Methods and Conditions for Explosive Attack

Specific protocols are set forth within this Standard for the methods to be employed in the utilization of explosives. This depends upon the type and design of the container or enclosure to be attacked.

37_10.3.6.4.3.1 Safes

The explosive charge is positioned in a compact shape at the geometric center of the storage volume of the safe. The door is closed and locked; the charge is then detonated. After detonation, the tool attack shall be continued until the complete access or the required post-detonation resistance value has been reached.

37_10.3.6.4.3.2 Strong room Doors and Strong rooms

Preparatory tool attacks may be undertaken and shall follow the tool attack test to create holes into which the explosive charge can be located. The charge is placed, stemmed, and detonated. After detonation, the tool attacks shall be continued until the complete access or the required post-detonation resistance value has been achieved.

37_10.3.6.5 Marking of Product

Any product that has been assigned a resistance grade within a classification must be marked. The marking shall be indelible and shall appear on a securely fixed metal plate on the inside face of the door, in the locking chamber, or on the face of the prefabricated elements for strong rooms. The marking shall comprise:

- **Manufacturer name or identification code;**
- **Standard designation and resistance grade;**
- **EX designation (if applicable);**
- **Year of manufacture;**
- **Type, model number and description or size of the product (optional);**
- **Serial number.**

37_10.3.6.6 Identification and Description of Attack Tools

The standard provides coefficient basic values for each tool and category that is allowed to be utilized in attack tests. In addition, the intended primary use of a tool is described. Each classification of tool is given a coefficient and resistance unit rating. If tools are utilized for different purposes, then the highest RU is assigned. The assignment of a basic value RU is dependent upon many factors, including the weight of the tool and its length.

37_10.3.6.6.1 Categories of Tools

Fourteen categories of tools, accessories, and supplementary implements are defined within the standard for use in forcible entry. The identification number has been included for reference. In Sections **A.1-A.6** tools are specified as **Manual use without External Power**. In Sections **A.7-A.10: External power supplies are required** (A.7, A.8, A.10 can be used with cutting and/or cooling fluids.

The classification of tools described within CEN 1143 should be considered as supplementary to the discussion in **Chapter 32**, wherein the different methods of application of energy for

forced-entry are examined.

(A.1) Manual Tools

These are handheld tools that are used for non-destructive assembling and disassembling of detachable elements, e.g., to detach screws, pins or bolts, spring clips. Tools included:

- **Screwdrivers;**
- **Fork/ring wrenches.**

(A.2) Hand Gripping Tools

These implements are employed for the gripping (lever transmission) of tools and materials, e.g., fixing/holding of chisel. Tools included:

- **Universal pliers;**
- **Wrenches;**
- **Chisel holder;**
- **Forge tongs.**

(A.3) Hand Levering Tools

These transmit physical force by a lever, e.g. pry-up a door, deform or fracture weak components. Tools included:

- **Screwdriver;**
- **Tire levers;**
- **Hand levers;**
- **Crowba**

rs.

(A.4) Hand Sawing, Milling, Cutting, and Drilling

These tools are used for manual grinding, cutting and detaching of various materials without additional electric means of propulsion, e.g., sawing steel sheets. Tools included:

- **Hand drill;**
- **Saw;**
- **File;**
- **Side cutter;**
- **Bolt cropper;**
- **Plate shears;**
- **Steel cutters.**

(A.5) Hand-Hammering Tools

These tools are used to break various materials and to propel different accessories such as chisels, drift punches and wedges. Tools included:

- **Hammers;**
- **Hand axes;**
- **Pickaxs.**

(A.6) Specially-made Tools

These are tools which are usually not commercially available but

are conceived or provided especially for certain purposes at the test. If appropriate, sources of electricity not exceeding the working voltage (max. 240 V) may be used for attacks dealt to electromechanical security devices.

(A.7) Electric Powered Tools, without Impact

These tools are used to drill or cut (without impacting option) and their working energy is supplied by a source of electricity. Tools included:

- **Drilling machines.**

(A.8) Electric-Powered Rotary Tools with Impact Option

These are electric drilling machines that can be used with or without impacting options. Tools included:

- **Hammer drills;**
- **Jackhammers;**
- **Concrete breakers.**

(A.9) Electric-Powered Impacting Machine Tools without Rotation

Tools that are used for hammering, breaking up or deforming materials are described within this category. Included tools:

- **Building hammers.**

(A.10) Electric Powered Grinding/Slitting Machine Tools

These tools are used for cutting or abrasion. Tools included:

- **Electric disc cutters;**
- **Diamond core drills.**

(A.11) Thermal Cutting/melting Tools

These thermal tools receive the necessary energy either by an exothermic chemical reaction (heating/cutting gas, solid material/cutting gas) or by arc cutting. Tools included:

- **Gas cutting and welding oxygen lance;**
- **Electric cutting and welding.**

(A.12 Accessories for Tools listed in A.1-A.11

These tools include drills, saw blades, abrasive discs, nozzles, and electrodes. They are consumable and/or replaceable and used together with the tools shown in Sections **A.1-A.11**. Accessories include:

- **HSS drill bits;**
- **Carbide-tipped drills;**
- **Saw blades;**
- **Chisels;**
- **Electrodes for lance;**
- **Wedges;**
- **Punches;**
- **Discs;**
- **Diamond core drills;**
- **Diamond discs.**

(A.13) Miscellaneous Tools

This group includes tools, special procedures and devices that must be taken into account. Their use is timed. Materials include:

- **Battery lamps;**
- **Cooling/cutting agents;**
- **Chemical;**
- **Hydraulic**

- **equipment;**
- **Fiber optics;**
- **Electronic devices;**
- **Hooks;**
- **Fishing devices.**

(A.14) Non-tools

These are implements to enhance testing work. Their use is not timed but represented only by a basic value. Materials include:

- **Torches;**
- **Fiber optics;**
- **Electronic devices.**

37_11.0 Japanese Industrial Standards

The JIS (Japanese Industrial Standard) was established in 1921 as the result of legislation enacted by the Japanese government. JIS performs equivalent functions to Underwriters Laboratories; it sets minimum testing standards for all products utilized in the private and government sectors.

37_12.0 Statutes, Precedent, and Legal Issues

There are a number of federal statutes relating to locks and keys with respect to duplication and distribution through channels of interstate commerce. The General Services Administration and Department of Defense have also promulgated federal regulations regarding the classification, acquisition, testing, maintenance, installation, and repair of security containers, locks and keys. These were summarized earlier in this chapter. Some states have also enacted legislation regarding licensure of locksmiths and the possession of burglary tools designed for covert or forced-entry by unauthorized persons.

There has been increasing concern by locksmiths and some litigation involving the reverse engineering, analyses, detection

and disclosure of defects in locks and security containers. Certain manufacturers have attempted to prevent the disclosure of defects and have filed civil lawsuits in an effort to insure that defendants do not make public such findings. Issues involving reverse engineering, free speech, and trade secrets have been argued by both locksmiths and manufacturers. There has also been increased awareness of potential liability issues on the part of locksmiths and security experts, partly as the result of media coverage of the compromise of master key systems. A comprehensive summary of liabiliity issues is provided as a guide to all locksmiths to reduce their potential exposure to litigation.

37_12.1 Federal Statutes

The United States criminal code, Title 18, and the Postal Code, Title 39, contain relevant statutes relating to locks and keys. The actual postal regulations are cited below, from **Publication 52**, issued in July, 1999.

47 Motor Vehicle Master Keys and Locksmithing Devices

471 Definitions

471.1 Motor Vehicle Master Keys

A key is any of the following:

a. Any key other than the key (or an exact duplicate) furnished with the
motor vehicle by the manufacturer.
b. The key (or an exact duplicate) furnished with a replacement lock.
c. Any key or manipulation device designed to operate two or more motor
vehicle ignition, door, or trunk locks of different combinations, including
any pattern, impression, or mold from which a master key or manipulation device can be made (18 U.S.C. 1716 and 39 U.S.C.3002).
July 1999

471.2 Locksmithing Devices

A device is any of the following:
a. A device or tool (other than a key) designed to manipulate the

tumblers
in a lock into the unlocked position through the keyway of such lock.
b. A device or tool (other than a key or a device or tool under 471.2a)
designed for bypassing a lock or similar security device, or for opening
it by a method normally not used by consumers to open such locks or
security devices.
c. A device or tool designed for making an impression of a key or similar
security device in order to duplicate such key or device.

472 Mailability. The following conditions apply:

a. Motor vehicle master keys, as defined in 471.1, are nonmailable unless sent to any of the following categories of addressees:
(1) Lock manufacturers.
(2) Professional locksmiths.
(3) Motor vehicle manufacturers or dealers.
(4) Federal, state, or local government agencies.

b. Locksmithing devices, as defined in 471.2, are nonmailable except when sent to any of the following categories of addressees:
(1) Lock manufacturers or distributors.
(2) Bona fide locksmiths.
(3) Bona fide repossessors.
(4) Motor vehicle manufacturers or dealers.
(5) Bona fide automotive repair shops or businesses.

Note: This statute appears to prohibits the sending, through interstate commerce, of locksmithing devices to any law enforcement agency.

473 Packaging and Marking

No marking of any kind that indicates the nature of the contents may be placed on the outer wrapper or packaging of any mailpiece containing motor vehicle master keys or locksmithing devices. Mailable matter must be properly and securely packaged within the general requirements in DMM C010.

474 Nonmailable Matter Found in the Mails

All nonmailable motor vehicle master keys and locksmithing devices discovered in the mailstream must be reported in accordance with POM 139.117.

§ 18 USC 1386 Keys and keyways used in security application by the Department of Defense.

(a)(1) Whoever steals, purloins, embezzles, or obtains by false pretense any lock or key to any lock, knowing that such lock or key has been adopted by any part of the Department of Defense, including all Department of Defense agencies, military departments, and agencies thereof, for use in protecting conventional arms, ammunition or explosives, special weapons, and classified information or classified equipment shall be punished as provided in subsection (b].

(2) Whoever—

(A) knowingly and unlawfully makes, forges, or counterfeits any key, knowing that such key has been adopted by any part of the Department of Defense, including all Department of Defense agencies, military departments, and agencies thereof, for use in protecting conventional arms, ammunition or explosives, special weapons, and classified information or classified equipment; or

(B) knowing that any lock or key has been adopted by any part of the Department of Defense, including all Department of Defense agencies, military departments, and agencies thereof, for use in protecting conventional arms, ammunition or explosives, special weapons, and classified information or classified equipment, possesses any such lock or key with the intent to unlawfully or improperly use, see, or otherwise dispose of such lock or key or cause the same to be unlawfully or improperly used, sold, or otherwise disposed of,

Shall be punished as provided in subsection (b).

(3) Whoever, being engaged as a contractor or otherwise in the manufacture of any lock or key knowing that such lock or key has been adopted by any part of the Department of Defense, including all Department of Defense agencies, military departments, and agencies thereof, for use in protecting conventional arms, ammunition or explosives, special weapons, and classified information or classified equipment, delivers any such finished or unfinished lock or any such key to any person not duly

authorized by the Secretary of Defense or his designated representative to receive the same, unless the person receiving it is the contractor for furnishing the same or engaged in the manufacture thereof in the manner authorized by the contract or the agent of such manufacturer shall be punished as provided in subsection (b).

(b) Whoever commits an offense under subsection (a) shall he fined under this title or imprisoned not more than 10 years, or both.

(c) As used in this section, the term "key" means any key, key blank, or keyway adopted by any part of the Department of Defense, including all Department of Defense agencies, military departments, and agencies thereof, for use in protecting conventional arms, ammunition or explosives, special weapons, and classified information or classified equipment.

18 USC §1704 Keys or locks stolen or reproduced.

Whoever steals, purloins, embezzles, or obtains by false pretense any key suited to any lock adopted by the Post Office Department or the Postal Service and in use on any of the mails or bags thereof, or any key to any lockbox, lock drawer, or other authorized receptacle for the deposit or delivery of mail matter; or

Whoever knowingly and unlawfully makes, forges, or counterfeits any such key, or possesses any such mail lock or key with the intent unlawfully or improperly to use, sell, or otherwise dispose of the same, or to cause the same to be unlawfully or improperly used, sold, or otherwise disposed of; or

Whoever, being engaged as a contractor or otherwise in the manufacture of any such mail lock or key, delivers any finished or unfinished lock or the interior part thereof, or key, used or designed for use by the department, to any person not duly authorized under the hand of the Postmaster General and the seal of the Post Office Department or the Postal Service, to receive the same, unless the person receiving it is the contractor for furnishing the same or engaged in the manufacture thereof in the manner authorized by the contract, or the agent of such manufacturer—

Shall be fined not more than $500 or imprisoned not more than ten years, or both.

18 USC §1716a Nonmailable locksmithing devices and motor vehicle master keys

(a) Whoever knowingly deposits for mailing or delivery, or knowingly causes to be delivered by mail according to the direction thereon, or at any place to which it is directed to be delivered by the person to whom it is addressed, any matter declared to be nonmailable by section 3002 of title 39, shall be fined under this title or imprisoned not more than one year, or both.

(b) Whoever knowingly deposits for mailing or delivery, causes to be delivered by mail, or causes to be delivered by any interstate mailing or delivery other than by the United States Postal Service, any matter declared to be nonmailable by section 3002a of title 39, shall be fined under this title, imprisoned not more than one year, or both.

Note: This statute applies to any interstate common carrier, such as Federal Express, UPS, or DHL. The federal criminal statute prohibits the mailing of items that are deemed non-mailable by the U.S. Postal Service.

§ 39 USC 3002 Non-mailable motor vehicle master keys, found in **39 CFR 111.1.**

§ **39 USC 3002a Non-mailability of locksmithing devices.**

(a) Any locksmithing device ***is*** non-mailable mail, and shall not be carried or delivered by mail, and shall be disposed of as the Postal Service directs, unless such device is mailed to:

(1) a lock manufacturer or distributor;
(2) a bona fide locksmith;
(3) a bona fide repossessor;
(4) a motor vehicle manufacturer or dealer.
(5) Bona fide automotive repair shops or businesses.

(b) For the purpose of this section, “locksmithing device" means--

(1) a device or tool (other than a key) designed to manipulate the tumblers in a lock into the unlocked position through the keyway of such lock;

(2) a device or tool (other than a key or a device or tool under paragraph (1) designed for the unauthorized opening or bypassing of a lock or similar security device; and

(3) a device or tool designed for making an impression of a key or similar security device to duplicate such key or device.

37_12.2 Case Law and Legal Precedent

37_12.2.1 Discovery and Disclosure of Proprietary Information about a Lock: Trade Secrets and Reverse Engineering

Can a locksmith or government agent disassemble a lock to determine potential design defects that allow bypass? Several manufacturers, including Chicago Lock and ElSafe (Norway), have attempted to prevent such practice and the disclosure of information obtained as the result of analyses and reverse engineering. The landmark case of **Chicago Lock Company v. Panberg(436)**, 676 F.2d. 400, 1982, was argued before the United States Court of Appeals for the Ninth Circuit in 1982 and involved the decoding of Chicago tubular locks and reprinting of key code lists by the Defendant in a trade publication.

In that case, the locksmith defendants compiled a list of key code-serial number correlation to create a book which could be sold to other locksmiths so that those locksmiths could make duplicate keys without having to pick the locks. To create the book, the defendants obtained the serial number-key code correlation from a 'comparatively small' number of locksmiths, who themselves had reverse-engineered the locks of their customers. Chicago alleged that the defendants' actions constituted a misappropriation of the manufacturer's trade secrets.

Chicago Lock brought suit against locksmiths and publishers of a specialized trade journal to enjoin unauthorized dissemination of key codes for one line of locks. The lower court held that the acquisition of the codes were trade secrets that were improperly obtained, and enjoined publication. The Court of Appeals reversed and found for the defendants.

Two critical questions were raised by this case: **Does a locksmith and lock owner owe a duty to the lock manufacturer not to disclose confidential or proprietary information about the lock?**

What does the trade secret doctrine provide with regard to reverse engineering and the method by which information is obtained about a lock?

A locksmith who obtains information by examining or working on a lock or safe is held not to have obtained it through improper means. The court stated "It is well recognized that a trade secret does not offer protection against discovery by fair and honest means such as independent invention, accidental disclosure or by so-called reverse engineering, that is, starting with the known product and working backward to divine the process." (at page 404).

The court further held that "the concept of 'improper means'…connotes the existence of a duty to the trade secret owner not to disclose the trade secret…."

"We find untenable the basis upon which the District Court concluded that the individual locksmith owes a duty of nondisclosure to the Company. The court predicated this implied duty upon a "chain" of duties: first, that the locksmiths are in such a fiduciary relationship with their customers as to give rise to a duty not to disclose their customer's key codes without permission, and second, that the lock owners are in turn under an 'implied obligation [to the company] to maintain inviolate' the serial number-key code correlation for their own locks."

"The Court's former conclusion is sound enough: in their fiduciary relationship with lock owners, individual locksmiths are reposed with a confidence and trust by their customers, of which disclosure of the customers' key codes would certainly be a breach. The duty, however, could give rise only to an action by 'injured' lock owners against the individual locksmiths, not by the Company against the locksmiths or against the Defendant."

"The court's latter conclusion that lock owners owe a duty to the Company, is contrary to law and to the Company's own admissions. A lock purchaser's own reverse engineering of his own lock, and subsequent publication of the serial number-key code correlation, is an example of independent invention and reverse engineering expressly allowed by trade secret doctrine."

The Chicago case is a well-recognized and respected authority. It was cited with approval by the United States Supreme Court in the landmark case of **Bonito Boats, Inc. v. Thunder Craft Boats, Inc.**, 489 U.S. 141, 160 (1989), and in M.F. Jaeger, Trade Secrets Law,

§**5.04[3][b] (1996).**

37_12.2.2 First Amendment Protection of Commercial Speech

Dissemination of information about a lock or safe constitutes commercial speech, which is protected by the First Amendment. The Supreme Court has recognized that "the free flow of commercial information is 'indispensable to the proper allocation of resources in a free enterprise system because it informs the numerous private decisions that drive the system." **Rubin v. Coors Brewing Co(437).**, 131 L. Ed. 2d. 532, 538 (1995), and **Virginia State Board of Pharmacy v. Virginia Citizens Consumer Council, Inc.**, 425 U.S. 744, 761 (1976).

A locksmith may disclose any defect that he discovers, so long as his statements are true. Truth is an absolute defense to libel and business defamation. A locksmith may have liability for failing to disclose a known defect or security risk in a product that he sells, recommends, or installs.

See **www.security.org** regarding information about the ElSafe lawsuit in Hawaii and the pleadings that were filed in that case in an attempt to prohibit a locksmith from making certain disclosures about defective products.

37_12.3 Issues of Liability for Locksmiths and Security Experts

Increased security concerns after 9/11 and the post Iraq war terrorism threat have lead to a heightened awareness of potential liability upon the part of locksmiths and security experts for negligent acts in the recommendation and installation of security hardware within the commercial and government sectors. Increasingly, locksmiths are taking on the role of, or representing themselves as security experts with respect to consulting with, recommending, designing, installing and maintaining security systems and related hardware. The complexity of the industry and the wide array of available components have required that the locksmith obtain special training and education for specific disciplines. The integration of electronics, microprocessors, emerging and mature access control technologies, and advances in mechanical locking systems have made the job of the security professional all the more demanding. A successful

locksmith in this environment cannot continue to do business as a general practitioner and yet hold himself out as a security expert without specialization and the requisite training and equipment.

Media attention with regard to vulnerability of commercial and public buildings, including the compromise of master key systems, has caught the attention of both security professionals and the legal community. Locksmiths, security consultants, and security management must understand their possible exposure to litigation and subsequent damages for their failure to act properly, or negligent actions that result in harm to people or property. Every locksmith and security consultant has a fiduciary duty to their clients with regard to certain issues outlined in this section. A breach of that duty can lead to serious consequences and can result in jury awards for actual and in some cases punitive damages, as well as potential criminal liability for certain acts. Damage to reputation and the ability to continue in business is also of paramount concern.

Some locksmiths impliedly or directly represent that they have the expertise to provide consulting services to their clients with regard to issues of security, master keying, alarm systems, or forensic investigations when in fact they do not. Unless they have the appropriate education (and continuing education), training, experience, and professional certifications from ALOA, ASIS, AFTE or other organizations, then the making of such representations can result in the potential for significant liability and resultant damages.

Whenever you meet with a client or prospective client, you must be certain not to overstate your knowledge or capabilities, either directly, or by implication. Recommendation of certain locks, safes, and security hardware implies that you have the requisite knowledge about the products and the environment and threat levels into which they will be installed or located. This is especially true in the arena of high security locks. You must be able to knowingly discuss potential security issues or vulnerabilities with regard to such hardware and systems. You have a duty to point out any known vulnerabilities that could make such installation unsuitable for the client. Remember, your opinion is being relied upon as that of an expert. Most often, the customer is not expected to have the necessary expertise to make independent evaluations as to suitability of the product for its intended purpose: you are. If you tell a customer that a lock will provide sufficient security for his application and it does

not, then you may be held liable if there was a known defect in its design, or it was installed improperly.

The critical issue is an understanding by the client of the risks associated with a specific component within a security system. They cannot be expected to make an intelligent assessment with regard to the risks if they do not fully understand them. Much of the controversy stemming from the New York Times article on master keying dealt with the issue of whether locksmiths were aware of the ability to decode master key system through the use of a change key. There is no question that locksmiths that routinely deal with master key systems were clearly aware of the potential to compromise the security of virtually any conventional master key system. The legal issue, however, is whether clients of the locksmith were aware of such risks. In many cases, they were not. The potential exposure for locksmiths is the failure to adequately discuss the security risks or any master key system with their customers, so that the customer can make the decision as to whether to implement a master key system, and how extensive that system should be.

The following summary provides an overview of liability issues, but may not be considered as exhaustive, given the inventiveness of plaintiff's attorneys, and the penchant of some juries for outlandish verdicts. These actions (or failure to act) could subject you and/or your business to significant liability.

Employee Guidelines and Procedures:

- Failure to establish operating procedure and guidelines for the protection of information and property of clients;
- Failure to properly vet employees with regard to background and experience, which leads to theft of property or compromise of customer data;
- Cutting of keys stamped DO NOT DUPLICATE or other indication that they should not be copied without specific permission of person in authority;
- Cutting of keys on restricted blanks without the proper authority;
- Cutting keys by code without full information about the customer or locks and customer's authority to have a code-cut key produced;

Failure to Maintain Adequate Security for Business Location of Locksmith:

- No alarm system to protect the premises;
- Insufficient level of data security: protection against fire, theft, employee compromise;
- Failure to protect mobile information in vans and other service vehicles and on laptop computers and PDAs;
- Allow network or Internet access to computer-stored customer records or databases containing such records;
- Failure to protect restricted key blanks;

Records:

- Failure to maintain confidential records in a secure manner;
- Failure to protect the following critical records:
    - TMK Register
    - End user register;
    - Progression and bitting list;
    - Authorization and inventory cards;
    - Parity records and registers;

- Violation of duty to maintain certain records as confidential;
- Use of analog cellular telephone or radio channels to discuss proprietary or confidential information regarding a client, and which is intercepted;
- Transmission by e-mail or facsimile of confidential information in a non-encrypted format, or to the incorrect recipient;
- Failure to maintain sufficient computer security where client records are stored;
- Loss or theft of a laptop containing confidential information and the failure to protect that laptop computer from compromise by a third party;
- Compromise of confidential information on a voice mail system regarding a client;
- Failure to maintain an adequate and timely backup of client data;
- Failure to properly and securely erase discarded hard drives that contain client information. This can be a problem when computers are thrown away, given away, or traded;
- Failure to provide for adequate physical security of records to protect against theft or destruction;
- Failure to establish and follow a records retention and destruction policy that meets the needs of customers and complies

with any statutory requirements;

- Failure to protect customer information within files against disclosure or compromise. This may be especially important for clients that secure medical records. A federal statute that became effective on April 14, 2003, known as the Health Insurance Portability and • Accountability Act (HIPAA) has stringent security requirements that could logically be extended to a locksmith in the event that the requisite security is not implemented;
- Failure to advise clients of a breach in security that could affect the security of his employees, facility, or property.

Compromise of Customer Confidential Information:

- Failure to protect, or disclosure of code lists, TMK registers, bitting lists, etc;
- Cut and distribute restricted keys to unauthorized individuals, or failure to follow established rules and guidelines with regard to the distribution of such keys;
- Failure to take proper measures to protect computer information from hacking;

Improper Installation, Maintenance, Repair, or System Design:

- Improper installation of hardware that is the proximate cause of a loss;
- Failure to properly maintain, program, or set codes, combinations, or time locks that result in a lockout condition;
- Failure to make proper repairs to safes and vaults after forced entry or drilling. Such failure may make the container more vulnerable to subsequent attack, reduce or eliminate insurance coverage, nullify UL classifications or ratings, cause subsequent malfunction or lockout, and also subject you to liability for destruction of the container;
- Defective repairs that reduce tolerances or reduce resistance to covert entry. This may include filing of pin tumblers or plugs, or adding unnecessary master pins;
- Improperly change or modify UL or other rating labels;
- Failure to change factory original combination or password upon installation;
- Failure to adhere to manufacturers recommended installation procedures;
- Use of old or worn pins or springs;

- Failure to utilize pins and springs in all chambers within a lock;
- Set combination in the forbidden zone which results in a mechanical malfunction;
- Violating MACS rules that results in mechanical malfunction;
- Erase audit trail within electronic memory, either intentionally or by mistake and which causes a loss;
- Failure to utilize balanced drivers, thereby allowing the lock to be covertly opened through "combing";
- Designing change keys, master keys, or TMKs that do not follow industry guidelines and that contribute to system bypass or circumvention;

Failure to Consider Inherent Dangers

- Opening a safe that contain explosive residue, tear gas, or drugs where harm is caused;
- Improper handling of heavy container that falls and damages other property or results in injury to persons;

- Failure to report property found in locked containers, such as explosives, drugs, child pornography or other contraband;

Damage to Property

- Property damaged within a container that is opened by force;
- Relockers triggered due to lack of experience; causing additional damage during the opening process;

Violation of Fiduciary Duty

- Disclosure of confidential information to law enforcement or others without authorization or court order;
- Non-disclosure of known security defects or potential for bypass in locks and hardware that is sold to, or utilized by a customer;
- Failure to be current with regard to literature and security advisories regarding products that are sold and represented as secure;
- Failure to maintain control of customer locks;
- Failure to maintain control of customer keys and key blanks;
- Use of customer information or key data for unauthorized

purposes;

- Theft from customer location by employees of locksmith, as a result of access to confidential information regarding the premises;
- Sale of restricted blanks to unauthorized individuals or entities;
- Unauthorized creation or milling of blanks to create restricted blanks that are utilized by customers of the locksmith or other locksmiths. There are two potential issues: violation of copyright or patent protection, and compromise of customer security.
- General breach of fiduciary duty owed to customer;

Documentation of Work Performed

- Failure to properly document installation, upgrade, or maintenance;

Performance of Work to Recognized Industry Standard:

- Failure to properly or adequately assess the security requirements of a customer location;
- Misrepresent the security of hardware or a system that is installed or implemented for a customer. There are two issues: making a representation regarding security that is not actually provided, and charging for something that was not received;
- Failure to utilize restricted blanks, if needed or sold as such;
- Improper pinning of Interchangeable core locks that allow for a change key or TMK to act as control key;
- Create key interchange between interchangeable core systems that creates an unknown or unauthorized control key and which leads to a loss;

Master Key Systems:

- Work performance that calls into question the training and competence of the locksmith;
- Improper system design that creates key interchange that results in a loss;
- Use of non-standard master key systems that result in loss of security;
- Improper system design that results in unintended cross-keying

and subsequent loss;

- Poor documentation that makes it difficult to expand, maintain, or evaluate a system;
- Repeat the TMK or system in the same geographic area for different customers;
- Mistakes made in defining the KBA that results in key interchange, cross-keying, or other errors;
- Use of master pins that are not required and which reduce the security of a lock, resulting in ease of picking or other covert means of entry;
- Release of master keys to the wrong individual, contrary to established guidelines;
- Cutting or duplicating sectional keys on the wrong blank that allows access to keyways for which the user does not have authority;
- Pinning certain cylinders that should not be on the master key system;
- Failure to follow the .023" rule that results in mechanical malfunction and inability to access critical areas;
- Failure to advise property owners in major housing or apartment construction projects that locks have been master keyed for construction personnel, and that such keying will remain after the project is completed;
- Utilizing pre-written master key systems that are published and are available to the general public;
- Utilization of the same master key programs for more than one customer;
- Use of the same bitting lists, keyways, and master key system architecture for multiple clients;
- Failure to warn and document such warning to customer regarding the risks associated with the use of master key systems;
- Failure to adequately warn customers of cross-keying issues and the reduced security that results from intentional cross-keying;
- Master keying all or several customer locations for the convenience of the locksmith without disclosing such fact to each client;
- Failure to conduct comprehensive site survey and keying conference with the client prior to performance of work;

Failure to Exercise Due Diligence and Follow Standard Procedures:

- Effecting entry into locked location for third party after failing to obtain sufficient identification which results in

theft, other loss, or burglary;

- Owner claims disappearance of goods from container or other area that was opened by locksmith, but to which there was no witness to document contents during the opening;

General Liability Issues:

- Represent to customer that locksmith has expertise in certain specialties that he does not have;
- Acting as an expert in forensics or security when you do not have the requisite expertise;
- Failure to maintain liability insurance;
- Failure to comply with licensing laws for specific jurisdiction;

CHAPTER THIRTY-EIGHT: SECURITY

Security: Analysis and Reduction of Risk

LSS202: Ross Anderson on security engineering

PART A: Burglary and Related Attacks

Burglary

The concept of security encompasses more than just locks, safes, and vaults. Rather, the elusive and imprecise term describes many factors that must all complement each other to achieve the desired result. Security can be likened to a formula, comprised of hardware, software, organizational measures and procedures, awareness, vigilance, monitoring, and commitment. No one component should ever be relied upon as an alternative option, sole measure, or solution.

The final three chapters of this book will provide a summary of

the primary components of what is referred to as "security." Many in-depth treatments have been written about the subject that examines in detail each aspect of the concept. There is no necessity to duplicate such works here. Rather, the materials that follow will provide a summary of issues that must be considered in the evaluation of any security program. The emphasis will be on loss prevention, concentrating on the analysis and reduction of risks for robbery and burglary associated with certain types of businesses. **Chapter 39** focuses on physical security measures. It provides a comprehensive catalog of generic security hardware, and the vulnerabilities of such devices to attack. An in-depth treatment of alarm systems is presented in the final chapter.

Throughout the book, we have concentrated on the development, operating theory, design, use, and bypass of locks and safes. It is therefore appropriate to focus on issues related to security hardware that augments, supports, or is reliant upon locks, safes, and vaults to insure physical integrity and protection. Our discussion will survey each physical security component that must be examined by those responsible for decision making. Construction practices, materials, subsystems such as alarms and ventilation, the location and placement of secure areas and containers, and the vulnerability of such components will be detailed.

Insurance companies throughout the world have become increasingly concerned about the problem of burglary and resultant losses, and for good reason. Claims have escalated, based upon trends in property crimes. Insurers have taken a proactive stance, concentrating on the analysis of crime and its prevention as relates to loss. In the end, it should not be the responsibility of the insurance company to cover losses, if they could have been prevented through adequate security measures.

Munich Reinsurance Company in Munich, Germany is one of the premier companies that are aggressively attempting to make it more difficult for the burglar or robber to achieve success. They provided invaluable assistance during the research phase of this book. Their extensive expertise and experience in loss prevention and analysis and testing of security hardware is known throughout the world. Many of the graphics in these last three chapters were provided by them and for which the author is most grateful. Additional information about the company is available at **munichre**.

38_1.0 Physical Security Measures and Procedures

38_1.1 Introduction: Security Engineering

LSS202: Ross Anderson on security engineering

The real mission of this book is to deal with the larger concept of "security engineering." That is, locks, safes, physical security issues and alarm systems are all components for providing defense in depth of an installation or facility and are all equally critical components. According to **Ross Anderson(438)**, security engineering deals with the interrelationship of security components and systems to protect against both expected and unexpected dangers. In our context, it relates to both forced and covert entry through a myriad of means that are described throughout this text. The concept takes into account those individuals who act with malicious intent, mischance, or error.

Throughout this text, we are concerned with procedures, hardware, software and methodology that are required and geared to implement security and to provide the means to determine that level of security that meets the perceived threats for which the system has been designed.

Security can involve many disciplines, including locks, safes, computer networks, access control, physics, chemistry, knowledge of methods of attack, psychology of the intruder, organizational methods, legal requirements, business processes and organizational requirements, and quality assurance standards. The failure to adequately engineer the security for a facility has broad ramifications, both to life and property. Failures can result in loss of critical assets, loss of information, loss of protection of critical materials, danger to the environment, loss of life, damage to economic infrastructure, loss of privacy, facilitate crime, present danger to a business model. There are potentially many other more subtle effects.

The purpose of security engineering is to protect against known risks and to prevent unknown or unperceived risks from occurring. Every system has its own security requirements. It is incumbent upon planners to insure that they are protecting against the right things and in the right way. Often, this is not the case.

Where do we start in the security engineering analysis? What is the threat. Where does it come from? Where would it be directed? Once the threat is identified, what is the defense? What irregularities in the process would result in a breach of security? Where would the attack come from? Outside or within? Are there loopholes in the current system? What procedures are in place to assure that a breach in security does not occur, and if it does, that it will be detected immediately?

What is the threat? This is perhaps the most difficult to evaluate because every business, every installation, every operation has its own set of unique dangers. The author has been involved in criminal and civil investigations for the past thirty years. There are as many types of threats to security as there are employees and different kinds of facilities. For example, look at banks. Probably the greatest threat within a bank is an dishonest employee, not the robber or the burglar. It is clearly internal theft. The robber presents a different kind of threat to the bank, but not as persistent.

Likewise, in commercial business such as restaurants, bars, hospitals, retail outlets, medical clinics, transportation and communications facilities, there are different kinds of threats. Virtually anywhere there is an item of value or an asset or tangible property, intellectual property, or something that someone needs, there is always one or more threats. Perhaps the most difficult part of the security engineer's job is to correctly analyze the threat, from where it comes from, and how to adequately deal with it through the implementation of tactical security measures and procedures. Three simple examples of threat analysis for different environments can illustrate the point that each has unique and varied security issues:

Banks:

Bookkeeping systems
Dual signature responsibility requirements
Authentication of transactions
Personal identification
Wire transfer procedures and encryption
Physical security of cash and document handling
Safes and strong rooms
Alarm systems
Monitoring systems
Cryptography for critical transfer of information, such as ATM networks and wire transfer network

Computer network security

Hospitals:

Safety procedures for staff, patients, visitors
Patient records and privacy
Theft prevention
Patient privacy
Protection of medical records
Electronic authentication and encryption tools to assure the integrity of records and data
Federal access requirements regarding patient records
Protection of critical materials, such as narcotics
Data backup procedures
Power failures
Communications failures
Computer networks
Fire control and prevention
Criminal activity
Kidnapping

Homes:

Physical security against burglary, robbery, and home invasion
Internet access
Wireless systems security
Alarm systems: burglary and fire
Environmental monitoring systems
Transponder systems that are used in vehicles
Cellular security
Cordless telephones
Babysitter monitoring
Satellite television
Copyright controls for copyrighted media (CD, DVD)
Prepayment meters for utilities

The primary goal of Locks, safes, and security is to provide the information necessary to understand different types of physical security systems involving locks and safes and allied hardware in order to evaluate and design the requisite level of protection into any facility and to correctly assess vulnerabilities.

Certain physical procedures can be implemented to improve security and reduce the risk of loss. Their extent and comprehensiveness must be based upon an analysis of the property to be protected and the facility that must afford primary

security. Fundamental issues to consider will include:

- **The specific property to be protected;**
- **Exposure to loss;**
- **Value (both material and sentimental);**
- **Ability of goods to be resold or fenced;**
- **Ease of transport of the property from the premises;**
- **Quantity of property available for theft;**

With respect to the premises and implementation of security measures, consider the following:

- **Existence of electronic security systems for burglary, fire, and other forms of electronic monitoring;**
- **Occupants of the premises and their ability to provide watch;**
- **Security staff;**
- **Construction of facilities and burglary resistance or rating;**
- **Access and openings to facilities;**
- **Methods of access;**
- **Methods of escape;**
- **Methods of transport of goods.**

38_1.2 Risk Survey

A risk analysis should be considered as a starting point for the development and implementation of a security program. The following survey presents the primary issues to be evaluated in order to reduce the potential for loss through burglary and robbery. It is intended for both simple and complex businesses.

The assessment of risk must encompass both **physical hazards** and **moral risk.** This means that a thorough investigation must be made and knowledge acquired with regard to the following issues:

- **Premises to be protected;**
- **Neighborhood;**
- **Police information, trends, and statistics on crime in the area;**
- **Loss prevention techniques;**

- **Security guidelines, regulations, and standards.**

The survey addresses four primary levels of risk:

- **Simple as well as highly exposed businesses;**
- **Safes and strong rooms;**
- **Robbery on the premises;**
- **Robbery of cash or valuables in transit.**

The purpose of a risk survey is to develop detailed, accurate, and comprehensive information so that decisions can be made as to how to reduce risks of loss. The implementation of physical hardware and organizational procedures resulting from such surveys must always meet the following criteria for reasonableness:

- **Proposed measures must correspond to the actual risk;**
- **All factors must be considered that can either increase or reduce such risk;**
- **Proposed action must be economical and reasonable: they must maximize their effect at a minimum expense;**
- **The security measures must be comprehensive in scope and affect all aspects of the problem or potential risk;**
- **Partial solutions cannot be an acceptable alternative.**

38_1.2.1 Nature of Risk: General Issues

The nature of the risk takes into account those issues that may be considered by burglars or robbers to determine the desirability for them to target a specific business, location, or goods. Relevant criteria include:

- **Security awareness of owner and employees;**
- **Does the business appear to be well organized;**
- **Previous burglaries, robberies, losses, or attempts. Burglars often return to the scene if it is an easy target. If there were**

previous attacks, the following information should be evaluated:

- **Date of loss;**
- **Extent of loss;**
- **Method of entry;**
- **Added security measures that were implemented to correct for earlier risks;**
- **Many false alarms. This may indicate that a criminal is attempting to undermine the reliability of monitoring systems;**
- **Type and nature of business;**
- **Type and value of goods or commodities;**
- **Exposure of business;**
- **Are high-value items concentrated in small areas;**
- **What is the size of individual items of value;**
- **Can the goods be disassociated, taken apart, or reconstructed so as to make identification impossible;**
- **Can the goods be sold in divergent geographic areas to make tracing difficult or impossible;**
- **Is there anything unique about the goods;**
- **Is there a large amount of cash and/or goods available for theft;**
- **Can the establishment be easily cased;**
- **Can target goods be "preselected" for theft;**
- **Ability to sell, fence, or use such goods;**
- **Demand for such goods;**
- **Location of storage of goods within the building;**
- **Design of storage areas;**
- **Type of containers, if valuables are stored within enclosures;**
- **Use of safes, vaults, and strong rooms;**
- **Weight of safes;**
- **Security rating of safes and vaults;**
- **Local incidence of burglaries and robberies;**
- **Difficulty in transport of goods from the premises and to hidden distribution locations by burglars;**
- **Local vehicle and pedestrian traffic;**
- **Illumination and visibility of premises;**

- **Perimeter protection;**
- **Enclosure of premises;**
- **Access and transport routes to and from the premises;**
- **Perceived risk of detection within the premises;**
- **Adjacent rooms belonging to or used by other persons such as lessees and subtenants;**
- **Whether adjacent rooms, cellars, attics, basements, garages, or other areas are secured;**
- **What use is made of adjacent rooms, and can burglars enter the premises through such rooms;**
- **What is the construction of the walls of adjacent areas;**
- **Would it be possible to cut through adjacent barriers without notice;**
- **Reliability and rating of physical security hardware, including doors, door frames, locks, hinges, and bolts;**
- **Maintenance staff and work schedules;**
- **Emergency power supplies and generators;**
- **Protection against sabotage;**
- **Electronic surveillance;**
- **Blind spots in monitoring systems;**
- **Design of interior rooms containing high-value items, and whether they are protected by an outer shell that is alarmed;**
- **Alarm systems: silent or local;**
- **Holdup systems that are in place;**
- **Central station direct wire or dial-up alarm;**
- **Personal wireless panic alarms;**
- **Employment of security company or patrol;**
- **Secure internal wiring;**
- **Secure underground telephone cabling;**
- **Burglary insurance;**
- **Financial condition of the company;**
- **Competitive position of company;**
- **Likelihood that a theft would be disclosed to authorities;**
- **What is the interaction between staff and potential**

robbers or burglars;

- Is there a physical division or barrier between the merchandise and the would-be criminal;
- What is the layout of areas where high-value items are kept;
- Can potential criminals be closely observed while they are in the premises;
- Would customers recognize that a robbery was in progress;
- Visibility of safes from outside of premises;
- Would personnel be in a position to sound an alarm in time to summon assistance;
- Are current records of inventories maintained, including valuation and description of goods;
- Special identifying marks on goods;
- Can stolen goods be easily traced;
- Types of safes and vaults on the premises:
  Design, manufacturer, model, and classification;
    - Size and weight;
    - Value of goods stored within such containers;
    - Type of locking system;
    - Type of alarm system;
  - Persons who have keys or combination.
- Storage of tools in close proximity to targets;
- Information regarding frequent visitors to premises;
- Information regarding guard dogs on the premises.

38_1.2.1.1 Management Attitudes Towards Security Measures, and Insurance

- Management procedures with regard to reporting losses;
- Reliance upon insurance as the primary means of loss prevention;
- Age and condition of the premises;
- Commercial risks: how long has the business been in existence and its financial condition;
- Staff input regarding security and risks;
- Working hours;
- Overall cleanliness of the facility;

- **Previous experience with loss, and result (increased security measures implemented).**

38_1.2.2 Issues Relating to Burglary

38_1.2.2.1 Building Construction, Location, and Access

- **Adjacent buildings;**
- **Age of building;**
- **Type of construction: exterior walls made of masonry, reinforced concrete, wood, glass, metal;**
- **Wall thickness: exterior and interior;**
- **Type of building;**
- **Character of building: shops, office, dwellings, mixed usage;**
- **Number of stories, basement, attic;**
- **Use of areas adjacent to premises;**
- **Adjacent buildings or rooms;**
- **Unoccupied rooms adjacent to premises;**
- **Connection between adjacent buildings;**
- **On which floors are the target premises operating;**
- **Access between stories: stairs, elevators, escalators, and whether they are open or enclosed;**
- **Fire escape;**
- **Elevators;**
- **Ventilation or air conditioning ducts;**
- **Dome lights or skylights;**
- **Glass roof;**
- **Balconies;**
- **Trellises, sills, or cornices;**
- **Façade elements that can be used for climbing;**
- **Cellars, and connection to other areas.**

38_1.2.2.2 Geographic and Demographic Information

It is axiomatic that the risk of burglary is inversely

proportional to the risk of discovery during the crime. Thus, geographic and demographic information is important to any survey.

- **Nature of area: isolated, rural, urban, metropolitan;**
- **Geographic location: commercial, industrial, residential;**
- **Geographic proximity: within city limits, outside city limits;**
- **Geographic characteristics near premises: parks, forests, open areas, lakes;**
- **Potential response time of law enforcement;**
- **Is the neighborhood of such a nature that burglars can easily conceal themselves without detection or disturbance;**
- **Can burglars easily case the target;**
- **Are there unoccupied buildings, industrial plants, parks, or other places for cover;**
- **Will crowds allow escape without attention;**
- **Type of business: manufacturer, wholesale, retail;**
- **Relationship between business and valuables stored within the premises;**
- **Total space occupied by the business;**
- **Traffic: normal, heavy, continuous, isolated;**
- **Distance from closest police station;**
- **Distance from nearest occupied dwelling;**
- **Public access: major artery, street, side street, motorway;**
- **Neighborhood: residential, commercial, restaurants, shopping, unoccupied buildings, abandoned buildings;**
- **Economic quality of neighborhood;**
- **Sound levels: is the premises near installations or facilities that continuously or sporadically produce noise that can provide a cover for burglars;**
- **Anonymity of residents, making it easier for strangers to enter the premises and move about without being detected.**

38_1.2.2.3 Lighting

- **Night lighting;**
- **Interior lighting: rooms, windows, display cases;**
- **Exterior lighting: grounds, building;**
- **Type of illumination, brilliance, and sufficiency;**
- **Dark or shadow areas;**
- **Protection of lights against vandalism or damage;**
- **Can lighting be switched off by burglars;**
- **Are photoelectric cells utilized to sense lack of illumination.**

38_1.2.2.4 Security Devices and Hardware

38_1.2.2.4.1 Doors

- **Inspection of all doors, including infrequently used entrances such as emergency exits and cellars;**
- **Materials used for door leaves and frames;**
- **Type and quality of the door leaf:**
  - **Weight;**
  - **Resistance to displacement;**
  - **Sound patterns when tapped, indicating construction;**
  - **Removal of mortise lock to view interior construction;**
- **Mounting of door frame:**
  - **Weak points in door frames made of laminated wood or plastic;**
  - **How are they affixed to surrounding elements;**
- **Single leaf, double leaf;**
- **Wood panel, glass panel;**
- **Thickness;**
- **Hinge type;**
- **Hinge bolts;**
- **General condition of doors;**
- **Cracks or a loosening of the door frame from the surrounding construction;**
- **Gaps between the door leaf and frame;**
- **Gaps between the door leaf and floor.**

38_1.2.2.4.2 Locks

- **Type of mechanism: warded, lever, wafer, pin tumbler, combination, electronic;**
- **Security rating;**
- **Mortise Cylinder:**
    - **Rim Cylinder;**
    - **Deadlocking;**
  - **Strike plates;**
- **Proper mounting of security hardware, including striking plates and hinge bolts;**
- **Use of proper mounting screws and their thickness;**
- **Secure and proper mounting of locks, strike plates and hinges on the door**

leaf or frame;
- **Security rating of locks;**
- **Do all locks function properly;**
- **Key control procedures;**
- **Inventory of keys;**
- **Can keys remain in the possession of unauthorized persons;**
- **When was the last time the locks were changed.**

38_1.2.2.4.3 Windows

- **Type of window: fixed glazing, bottom-hinged, sliding sash, center-hung sash, swinging, casement, swinging bottom-hinged;**
- **Glass: Fixed glazing, ordinary glass, insulating glass, wired glass, toughened safety glass, laminated glass, polycarbonate;**
- **Thickness of glass and description of layers (materials and thickness);**
- **Glass mounting: screws, clamps, no mounting (putty or rubber restraining rims), lockable mountings, permanent;**
- **Aluminum, plastic, steel reinforcement;**
- **Grill: distance from bars, roller grating, roller shutters, reinforced;**
- **Grill materials: wood, plastic, steel, aluminum;**

- **Frames: wood, steel;**
- **Glass bricks: thickness, size, reinforcement;**
- **Skylights and dome lights should be considered as windows.**

38_1.2.2.4.3.1 Display Windows and Showcases

- **Type of glass;**
- **Mountings.**

38_1.2.2.4.4 Alarm System

- **Type, make, model;**
- **System inspected and tested regularly;**
- **Date of installation;**
- **Installer;**
- **Maintenance contract;**
- **UL approved;**
- **Insurance approved;**
- **Method of reporting: direct wire, dial-up, local, RF, packet, satellite, network;**
- **If local alarm:**
    - **Number of sounders or lights;**
    - **Location;**
    - **DB level output;**
  - **Visibility (lights);**
- **Number of telephone circuits;**
- **Emergency power: duty cycle;**
- **Type of control panel;**
- **Audit trail;**
- **What is protected by the alarm system:**
    - **Individual objects, rooms, areas, perimeter, safes and vaults;**
- **Individual authorization codes for each employee.**

38_1.2.2.4.5 Electronic Surveillance

- **Openings: doors, windows, skylights, air shafts**
- **Potential access points: walls, floors, ceilings**
- **Alarm trips and traps:**
  - **Magnetic contacts, glass-breakage detectors, alarm glass, films, trip wires, bolt-contacts, seismic, video, capacitance, volumetric monitoring (with microwave, infrared, ultrasonic), radio, photographic (film, video, time lapse);**
  - **Holdup alarms;**
  - **Other surveillance devices.**

38_1.2.2.4.5.1 How is Alarm System Activated:

- **Switch lock;**
- **Control panel or keypad;**
- **ID card reader;**
- **Is alarm active at all times;**
- **24-hour trips;**
- **Guard company for protection after business hours.**

38_1.2.2.4.6 Equipment Storage

Do not store equipment in places that can be accessed and used by burglars. Such items would include:

- **Vehicles;**
- **Forklift trucks;**
- **Ladders;**
- **Power plants;**
- **Welders;**
- **Hydraulic equipment;**
- **Tools;**
- **Drills;**
- **Dumpsters that could be used for hiding equipment should be locked.**

If outside storage is required, then all items must be secured with chains, locks, blocking devices or alarms.

38_2.0 The Psychology of Burglars and the Risks of Burglary

Through exhaustive analysis of thousands of burglaries by law enforcement agencies and insurance companies, a psychological profile of both the acts of burglary and the burglar can be accurately provided. The following summary attempts to offer the required link between the mind of the "typical" burglar, actions that may be expected during the commission of the crime, and the physical measures that may prevent or deter the criminal conduct.

38_2.1 Preliminary Considerations

The value of goods is only one factor and may not be particularly relevant in assessing whether they will be stolen. Considerations that might be more important include:

- **Access;**
- **Quantity of goods that are subject to theft;**
- **Value of goods;**
- **Danger inherent in their taking;**
- **Ease in removal;**
- **Storage requirements after the theft;**
- **Investment by the criminal in tools, equipment, and other expenses that must be made to facilitate the crime.**

38_2.2 Risk Assessment Considerations

The following assessments will usually be made by a burglar with respect to the theft of goods.

38_2.2.1 Access to Crime Scene

Access is of critical importance to most burglars because no **physical property crime** (other than one that involves the manipulation of an order or delivery process) can be committed without actually getting to the goods to be stolen. The following issues may be considered during the evaluation of the feasibility of burglary.

- **Do conditions appear favorable for the commission of the crime;**
- **Ease with which the target area can be cased or observed;**
- **Potential to compromise one or more staff members, with or without their knowledge;**
- **Ingress and egress to a crime scene;**
- **Method of entry and difficulty;**
- **Chances of interruption;**
- **Likelihood of being caught;**
- **Possible delays that may be encountered during commission of the crime;**
- **Impediments to access;**
- **Tools required to complete the crime;**
- **Tools required for access;**
- **Apparent security systems or security hardware in place;**
- **Likelihood of observation during commission of crime, evidenced by the presence of employees, alarm systems, watchmen, or lighting;**
- **Local alarm devices that provide optical or acoustic indication of intrusion;**
- **Perimeter protection;**
- **Alarms or electronic monitoring of objects of attack;**
- **Will apparent security measures complicate ingress or egress;**
- **Factors of uncertainty that may be encountered;**
- **Are there outer perimeter walls, roofs, skylights and areas within the building that are specially protected by electronic monitoring;**
- **What is the likelihood that there are unknown obstacles to entry of a target facility;**
- **How sophisticated or reliable are known electronic monitoring systems, and how difficult will they be to overcome;**
- **How many different alarm or monitoring systems must be bypassed;**
- **What is the likelihood that criminals can work**

undisturbed throughout the course of the burglary;
- **Is there a place of concealment for the burglar if intrusion is detected;**
- **Is the escape route protected or concealed;**
- **Are there any obstructions in the egress route, with respect to the type of property being removed;**
- **Difficulty of removal of goods from the premises;**
- **Are perimeter protection systems in place;**
- **Are protective devices recognizable from the outside;**
- **Will protective devices prevent damage to display windows;**
- **Will protective devices make the theft of goods more difficult;**
- **Are high-value goods concentrated in small places;**
- **Will a display window have to be entirely shattered to retrieve goods;**
- **Are goods that are visible behind a display window difficult to reach from the outside;**
- **Does it appear that "dummy goods" are shown in displays.**

38_2.2.1.1 Specific Construction Considerations Regarding Ingress

- **Roof and skylight construction;**
- **Ease of penetration;**
- **Rigid roof, made of reinforced concrete, gas concrete, or foamed concrete elements. Roofs may also be made of tile, clay, or concrete bricks placed between girders of steel;**
- **Non-rigid roofs, made of wooden or steel framing, covered with materials only partially secured, such as shingles or tiles;**
- **Windows and frames: construction and material;**
- **Building construction;**
- **Access through other than doors, such as ventilation shafts, dome lights, skylights;**
- **Access to setscrews that retain cylinder locks;**
- **Open ceiling access between offices or areas;**

- **Access to balcony;**
- **Electronic access, such as RF transmitter;**
- **Electronic bypass of access control;**
- **Strike plate access and replacement to bypass secondary bolt mechanisms;**
- **Which rooms are most vulnerable in terms of lightweight walls, numerous openings, or weak doors;**
- **Have access routes, including cellars, fire escapes, lifts, ventilation shafts, air conditioning ducts, skylights and dome lights been alarmed;**
- **Is it possible for burglars to move throughout a building without impediment;**
- **Is there a concentration of valuables in a small area, making their collection easier for burglars.**

38_2.2.1.2 Time

- **Elapsed time required for ingress to the target property;**
- **Time required for collection of goods;**
- **Egress or escape time that is computed from the moment the burglar has left the crime scene;**
- **Speed of ingress and egress;**
- **Estimate of overall time required to complete the theft;**
- **How much time will be needed to overcome each known obstacle;**
- **What is the probable response time of security staff or law enforcement in the event of detection;**
- **What is the fastest method of entry that will provide access to the target area of property;**
- **What is the time required to gather or collect the target property and remove it from the location;**
- **What are the weight and volume of the property to be stolen and the correlation of that information to collection and egress times.**

38_3.0 Organizational Procedures and Actions to Reduce Risks

Actions and measures taken by an organization can dramatically reduce the potential for loss from burglary. Such measures include:

- **Effective use of technical security systems;**
- **Background clearance of all staff through personal interview of references;**
- **Maintenance of internal security with regard to the value of goods and details of security systems;**
- **Competence of staff to supervise security systems and measures;**
- **Staff responsibilities with regard to security measures;**
- **Locking or securing of access points to facility:**
    - **Doors;**
    - **Windows;**
  - **Ventilation covers;**
- **Lighting turned on;**
- **Keys kept in secure area;**
- **Alarm documentation;**
- **Physical check of internal facilities such as washrooms, for hidden intruders;**
- **Physical checks of areas where objects of value are stored;**
- **Cash registers emptied;**
- **Safes and strong rooms;**
- **Alarm system turned on, and trips routinely checked for proper operation.**

38_3.1 Watchmen and Security Patrols

Watchmen can reduce the risk of loss but are expensive to maintain. For that reason, they are only utilized in large facilities or in instances where high-value items must be protected. In many installations, watchmen or security patrols are a necessary component of overall system security. Their principal value lies in the detection of open doors or windows, failure to properly set alarm devices, or in discovering breaches of security. At least two watchmen should be available to insure that one can act as a backup. Many tasks should be provided to break the monotony and routine of the job.

38_3.1.1 Watch Patrols

The watch patrol should be planned for maximum effectiveness, but not follow any fixed routine. It is important that all high-risk locations, such as safes and cash areas, be checked frequently. Obligatory reporting of status will improve security. Failure to report on a timely basis must trigger immediate investigative action. The effectiveness of watch patrols can be enhanced through the following hardware and security measures:

- **Comprehensive two-way communications system;**
- **Interagency communications capability for immediate assistance;**
- **Internal call boxes conveniently placed;**
- **All security staff must be able to communicate by radio and/or telephone;**
- **One watchman should always be located within a secure area;**
- **Varying the routine at least once per week, so that no meaningful intelligence can be gathered during casing;**
- **Use of time clocks that must be activated at periodic intervals;**
- **Use of alarm systems;**
- **Closed-circuit video and audio, including infrared cameras;**
- **Use of night vision equipment, where applicable;**
- **Capabilities to summon help or trigger an alarm from any point in the facility. This will include the ability to signal an emergency status from two-way radios or personal alerting devices;**
- **Use of guard dogs, where appropriate.**

38_3.2 Key Control

Key control has been discussed elsewhere in this text. The security of a lock or safe is dependent upon how the keys or combination is maintained. Therefore, it is vitally important that effective controls be put in place to insure that unauthorized persons can never obtain unauthorized access. The following procedures can help to assure effective key control:

- **Duplicate keys and the combinations to critical areas, computer rooms, alarm panels, electrical panels, and telephone switching facilities should not be kept on the premises;**
- **A record of key codes, safe and vault combinations, passwords, encryption algorithms, master keying schemes and other critical information should be maintained in a safe-depository or specially designated and closely controlled vault located on the premises. The keys or combination to this vault should be varied from time to time, or after there has been a change in staff or a security compromise;**
- **Only supervisory staff should have access to and responsibility for master keys and locks that protect key depositories;**
- **Keys for emergency exits must be protected to insure that they are not removed without permission or knowledge;**
- **Keys should not be capable of being copied when stored in elevator or emergency exit containers. Usually, these key-cabinets have a glass front and will allow an unrestricted view of the keys contained therein;**
- **Combination locks with dual control or time locks may be required for high-security areas.**

38_3.3 Background Investigation of Staff

Staff that has access to any secure area must be vetted. This includes maintenance and cleaning personnel. Background investigations must not simply be routine but should seek to determine any problems relating to honesty and integrity that have surfaced on prior occasions. Previous employers should be personally contacted, preferably through direct interviews. Polygraph may also be utilized to verify background.

38_3.4 Lighting

Illumination and visibility of the object and area to be secured is an inexpensive measure to reduce exposure to risk. The following issues should be considered with regard to lighting:

- **Leave lights on at all times;**
- **Visibility (from other offices or the street) of property or rooms that contain property;**
- **Do not use blocking screens that obstruct views into storefronts;**
- **Open curtains at night to allow full view of interior;**
- **Provide lighting to those areas most vulnerable to entry attempts;**
- **Illuminate all exterior areas of a building that provide access for entry;**
- **Provide Lexan or other shatter-resistant covers for all outside lighting;**
- **Use building materials that promote visibility, such as glass bricks;**
- **Mount all lighting so that it is out of reach;**
- **Utilize automatic control for turning lights on and off;**
- **Install interior and external floodlights that are triggered by alarm, unless a silent system is employed;**
- **Utilize flashing strobes or brilliant halogen floods to startle intruders if the primary goal is to protect display windows from damage;**
- **Provide for the remote control of outside power sources to prevent their use by burglars:**
    - **Be certain that the system cannot be manipulated in order to cause short circuits, thereby defeating illumination;**
    - **Use of power tools for break-in.**

38_3.5 Tools Used in the Commission of a Crime

Burglars should be forced to utilize specialized tools to gain entry. The process must be made as difficult as possible for the criminal.

38_3.6 Vehicles

All vehicles should be kept within alarmed buildings. Keys should never be accessible to intruders.

38_3.7 Storage of Goods with High Risk of Theft

The choice of a storage location for high-risk goods should not be based solely on economics or convenience. Issues of security must always be considered, including the following:

- **Assessment of the likelihood of theft for each type or classification of property;**
- **What objects or items are subject to the most significant threat;**
- **What is the acceptable threshold of risk for which no extraordinary measures will be taken to protect goods or property;**
- **Can high-risk items be concentrated or stored in just a few protected areas that can be adequately secured;**
- **Which rooms, areas, or buildings afford the highest security, based upon construction and monitoring capabilities described elsewhere in this chapter;**
- **Which areas can best be protected by electronic alarms;**
- **Can access routes be properly and adequately protected by alarms;**
- **Which areas can afford the best capability of observation and monitoring from the exterior. It is often wise to place valuable goods, as well as safes, in an area that can be watched by security staff or passers-by;**
- **Can the removal of goods be made more complicated and difficult during the course of a burglary;**
- **Can goods be affixed to walls, floors, or display surfaces to make their removal more difficult. This is especially critical in the case of storefront display windows that are subject to smash-and-grab attacks.**

38_3.8 Perimeter Protection

The necessity of perimeter protection must be evaluated on a case-by-case basis. Some systems provide almost no measure of security; others are quite effective. However, the risk of

burglary may be dramatically increased if no safeguards are implemented. As a rule, any perimeter security program must be backed up by other systems. The result to be accomplished by any program must be defined. Essentially, perimeter protection envisages achievement of two distinct goals: **physical deterrent** to entry through barriers and **early detection.**

In assessing the need to implement a security protection program, a number of arguments can be made in favor of such measures. Proponents usually urge that:

- **A system can complicate intrusion with physical barriers and time delays;**
- **Systems will allow for a faster detection time and subsequent response;**
- **Movement of stolen property becomes more difficult;**
- **Casing of the premises takes on more risk.**

38_3.8.1 Physical Barriers to Entry

Measures may be adopted to protect the boundaries of the premises. Barriers can be constructed to act as a deterrent to penetration. They can protect both the outer perimeter and buildings located on the property by making it more difficult to enter, but also increasing the chances of being observed or heard.

38_3.8.2 Perimeter Boundaries

Perimeter boundaries encompass walls, fences, gates, and access route restrictions.

38_3.8.2.1 Walls and Solid Wooden Fences

- **Makes entry more difficult;**
- **Makes movement of stolen goods more complicated;**
- **Provides cover for the intruder.**

38_3.8.2.2 Iron-Barred Gates

- **Allows unobstructed view of the premises and intruders;**
- **Must be designed to be secure;**

- **Hinges should be incapable of removal or disassembly;**
- **Additional locking bars enhance security.**

38_3.8.2.3 Netting Wire or Chain-Link Fences

- **Must be topped with barbed wire or razor wire to prevent climbing;**
- **Must be in good repair.**

38_3.8.2.4 Access Route Restrictions

- **Hydraulic barriers sunk into the ground to protect driveways.**

38_3.8.2.5 Enhancements to Perimeter Barriers

- **Lighting and automatic control;**
- **Alarms;**
- **Watchmen;**
- **Video systems;**
- **Audio systems.**

38_3.9 Planning for Protection of Buildings

Security is often a low priority in construction planning. Current building methods favor lightweight materials with many openings. Construction plans are usually developed with the priorities of finance, function, esthetics, and environmental, with little attention paid to crime prevention and reduction of risk. Such policies can be extremely costly to remedy after the fact.

Risks of penetration are increased in the following areas:

- **Back doors;**
- **Dome lights;**
- **Doors below floor level;**
- **Ground floor windows;**
- **Locations within a building with poor visibility or lighting;**

- **Roofs;**
- **Skylights;**
- **Walls to adjacent buildings or rooms containing high-value goods;**
- **Windows on upper levels, if they can be accessed with ladders, gutters, or fences.**

Enhanced protection should be implemented in many different areas that encompass doors, special entrances, ventilation openings, walls, windows, and access routes.

38_3.9.1 Doors

Doors present a high-security risk for many reasons:

- **They are a target location for break-in;**
- **Entry will not attract as much attention as windows or other areas;**
- **Forced-entry of a lock is less noticeable than of a window or door;**
- **It is usually simpler to remove booty through a door;**
- **Attacks upon doors usually take one of three forms. See Chapter 32 for a description of specialized tools used for this purpose.**

Forced-entry methods include:

- **Forced removal or alteration of locks, bolts, or hinges;**
- **Force applied to the door or its frame;**
- **Smashing doors open;**
- **Shattering glass inserts;**
- **Removing the lock from its housing;**
- **Bypassing the lock.**

38_3.9.1.1 Security Measures for Protecting Doors and Adjacent Areas

The following measures may be implemented to increase security for doors and nearby areas:

- **Added protection to doors that provide access to adjacent areas;**
- **Doors should be bolted from the inside;**
- **Double-doors should not be used for exit;**
- **Enhancement of any rear door that has a higher risk of attack;**
- **Exit doors should be readily observable from the street or by security staff;**
- **Exit doors should be well illuminated;**
- **Heavy strike plate;**
- **High-quality locks and strong bolts;**
- **Metal screws properly anchored for locks and bolts;**
- **Properly protected hinges and which are mounted on the inside;**
- **Hinges restricted from inside opening;**
- **Number and dimensions of hinges;**
- **Location of hinge mounting pins;**
- **Can hinges be pried loose with relative ease;**
- **How are hinge bolts mounted to door leaf and frame;**
- **Use of locking chains, bolts, and devices that prevent the key from being pushed out of the keyhole.**

38_3.9.2 Non-functional Entrances and Openings, including Windows, Doors, Cellar Shafts or Skylights

- **Permanently secure with brick, cinder-block, or cement.**

38_3.9.3 Ventilation Openings

Air conditioning and air-intake systems can pose a special threat because even as small an opening as 30 x 30 cm is large enough for one person to fit through. Heavy perforated plates of at least 5 mm, with holes less than 8 mm or protective bars must be utilized.

38_3.9.4 Walls

Walls and ceilings should be constructed of high-grade reinforced concrete at least 20 cm thick or a comparable material.

38_3.9.5 Windows

Many recommendations can be made to architects and building contractors regarding issues of security relating to windows. These include:

- **Minimize the number of ground floor windows;**
- **Keep accessibility to the premises through windows to a minimum;**
- **High windows should be utilized in storage areas and adjacent buildings, making them difficult to reach from the outside;**
- **Use of bars and horizontal metal strips can prevent anyone from fitting through open spaces;**
- **Glass bricks and honeycombed concrete should be used at vulnerable points.**

38_3.9.6 Other Openings in a Building

Many openings other than windows and doors can present an opportunity for entry. These include:

- **Skylights;**
- **Light wells;**
- **Basement windows;**
- **Steel-atticed windows;**
- **Ventilation openings;**
- **Dome lights;**
- **Lift shafts;**
- **Coal chutes;**
- **Goods lift shafts;**
- **Other areas.**

Any orifice that is larger than 5” square and can be reached from

the ground or other areas should be protected. Protective hardware to safeguard potential secondary access points include:

- **Iron grates;**
- **Bars fixed in cement within the walls;**
- **Glass bricks placed in reinforced concrete;**
- **Steel-latticed windows, with a padlock for the inside lever;**
- **Bolts and bars, especially for double doors used in coal chutes;**
- **Steel meshing fastened securely to walls and inaccessible from the outside;**
- **Screw fasteners or anchors.**

38_3.9.7 Secondary Protection

Physical protection of an asset and of locations that can provide access to property must be secured both directly and indirectly. Measures and techniques can be varied, and have many options.

38_3.9.7.1 Access Routes

If access to valuable property or other targets of burglars is limited to one route such as a corridor, stairs, tunnel, or a door, then they can be protected by alarm trips. It is essential that reliable devices be installed and secreted, especially if perimeter alarm traps would have been defeated.

Electronic protection of doors and alternate primary routes will prevent access to other parts of a building. A variety of sensors may be employed, including magnetic trips, pressure sensitive floor mats, microwave, passive infrared, ultrasonic, and proximity detectors.

38_3.9.7.2 Other Protective Measures

Secondary protective measures of special areas and equipment used in jewelry stores and related businesses are essential. These include:

- **All display items should be fastened or connected to the display windows;**
- **Items of value should not be displayed as a single piece;**

- **Jewelry should be permanently affixed or anchored, using locks or other devices;**
- **Distribute valuable items throughout display windows so that they are not concentrated, making it more difficult to steal all goods at once;**
- **Showcases and night displays should not contain any valuables, or the merchandise should be obvious dummies representing valuable goods;**
- **Limit the size of the display window surface, making it more difficult to break, extract, or gather items;**
- **Place permanent partitions within a display window to limit access to goods;**
- **Armed guards may be utilized for areas that cannot be adequately protected by other means;**
- **Utilize watchmen services to check all access points to the building on a non-scheduled, regular basis.**

38_4.0 Burglary Risks for Specific Businesses

There are higher risks of burglary for specific types of business activities. These risks are based upon many criteria, the most obvious of which is **value of target goods.**

The following high-risk businesses are most susceptible to burglary. These include banks, jewelry establishments and gas stations/convenience stores. In the materials that follow, protective measures applicable to each will be explored.

38_4.1 Banks

A bank is a logical target of professional burglars, so long as the thieves possess the requisite experience and tools. For that reason, extraordinary security measures are adopted. Certain specific areas present the greatest risk of attack. These include strong rooms, ATMs, and night depositories. Appropriate precautions must be taken to insure that these areas are secure.

38_4.2 Businesses Dealing in Precious Metals, Gems, and Jewelry

These classes of businesses are always a target of burglars for obvious reasons. Smash-and-grab burglaries, as well as the more traditional covert entries, are now common throughout the world. The reduction of risks associated with property crimes involving high-value gems and metals require consideration of many issues and procedures. These must not only include analysis of physical security measures but also of an overall program of protection. Special attention must be given to the following issues:

- **Construction of perimeter barriers must offer a high resistance to forced-entry;**
- **Display windows constitute perhaps the greatest threat. Special glass, bars, grating, or other devices must be employed. Wired glass should be placed in front of other physical barriers to signal an alarm at the earliest possible time;**
- **All windows should be mounted from the inside, so that all frames are protected;**
- **Massive bars that are securely anchored in exterior walls provide significant protection to windows;**
- **Recessed entrances with a rolling grill can provide protection to interior windows;**
- **Burglar-resistant doors, leaves, and frames should be utilized. Steel sheets at least 2 mm thick can be used for reinforcement. Any supplemental protection should be secured from tampering. If there are glass panels within perimeter doors, they should be electronically monitored and properly mounted;**
- **Only entry and exit doors should have locks that can be activated from the outside. All others should be bolted from the inside with iron crossbars. Brackets and strikes must be securely anchored to walls;**
- **Alarm systems must provide an indication when any door, window or other opening is not secured;**
- **High-security cylinder locks must be utilized in mortise configurations, with extending dead bolts;**
- **Hinges must be properly secured, sufficiently heavy, and preferably not accessible from the outside. Bypass through removal of hinge pins must not be possible.**

38_4.3 Safes and Strong rooms

The security ratings for bank safes, vaults, and strong rooms are equally applicable to businesses dealings in precious metals and gems. Ratings based on the value of stored goods should not be exceeded by more than fifty percent. Special alarm systems for security containers should be fully integrated into the master system. These are more fully discussed in **Chapter 40.**

Unfortunately, there are inherent conflicts between robbery and burglary protection as involves safes and vaults. On the one hand, prevention of robbery demands that the repository not be visible to the customer. However, good burglary prevention requires that the same container is visible from the street. A possible solution: use a video camera and place a monitor in the window. A motion analyzer should trigger an alarm for any movement within the area of the safe.

PART B: Taking by Force

Robbery

38_5.0 Protection against Robbery and Holdup

Worldwide, the incidence of robbery is on the increase as protective measures against burglary become more effective. The prime motivation for robbery is currency, other negotiable instruments, or small, high-value items such as jewelry. Statistics indicate that robbers will take risks based on the nature and value of their targets. They will resort to violence to obtain their loot or to insure escape.

One of the difficulties in robbery prevention is the conflicting goals of security and the safety of innocent victims. As the risk of apprehension through protective measures and procedures increases, so does the danger to human life.

38_5.1 The Psychology of Robbers and the Risks of Robbery

Just as in our earlier discussion of burglary, we must begin by an analysis of those factors that we know are considered by

robbers in planning their crimes. An insight into the issues that criminals consider important, as a deterrent and benefit, will provide the starting point for any viable security program.

The critical threshold question for any security planner becomes "how do we prevent a robbery from occurring?" In our discussion of the psychology of burglars, a number of issues were raised for consideration. Many of those same issues are relevant in the context of a robbery. However, additional considerations for the robber and security manager pertain specifically to the taking of property by force.

38_5.2 Primary Considerations and Questions by Robbers

The following issues should be examined from the perspective of the robber:

- **The robber need not have any level of sophistication, intelligence, or cleverness, unlike his burglar counterpart;**
- **Robbery provides the amateur criminal the possibility of instant wealth;**
- **Targets of robbery are accessible to everyone;**
- **Targets are often not protected;**
- **Hidden cameras are to be feared by the robber and, for this reason, can be extremely effective;**
- **Many robbers are photographed on video or film that results in later apprehension;**
- **Planning and preparation of the robbery is often straightforward and non-problematical;**
- **Menacing behavior, display of weapons, and speed are often sufficient to intimidate victims of a robbery into compliance and submission;**
- **The relationship of risk to reward is generally favorable;**
- **No fence or receiver is generally required;**
- **Protective measures that are not apparent prior to a robbery may be of secondary importance as a deterrent;**
- **Non-obvious protective measures may cause unpredictable reactions by the robber that can**

create hazards to life;

- **Is access to exposed objects restricted or too risky;**
- **Is the physical removal of the targets of a robbery difficult and thereby risky;**
- **Has the target object been removed from the premises, thereby eliminating the desirability and profit motive of the crime;**
- **Are target goods stored in secure areas or containers that will make robbery more difficult or risky;**
- **Are time locks or other devices employed that will limit the ability of employees to comply with demands;**
- **Are alarm systems reliable and active;**
- **Will identification systems make apprehension more likely;**
- **What is the potential for taking hostages to obtain a desired result;**
- **Will employees likely do what they are told by robbers;**
- **Is the value of target goods limited and thus the risk/reward ratio diminished;**
- **Is there less incentive to commit a robbery due to the likelihood of a small haul (and a concomitant lower risk of loss by the business);**
- **Does the business characteristically have large amounts of cash on hand;**
- **Is most of the cash deposited or transported by armored courier prior to closing;**
- **Is cash transported to or from the facility;**
- **Are any breaches in security possible and observable during cash or valuable transport that can later be exploited;**
- **What specific security measures are taken during the loading and unloading of cash or valuables;**
- **Is a routine established for the transport of valuables;**
- **Are there multiple cash drops throughout the day, reducing the likelihood of a large haul;**
- **Are there certain periods where the risk of robbery**

is increased, such as pay days;

- **Are high-risk events, such as cash receipt and deposits, well known or secret;**
- **Is cash or valuables kept in a safe or strong room;**
- **Is access to a safe or strong room complicated or made difficult through the use of electric controlled doors, delayed action time locks, or guards;**
- **If access to large amounts of cash is complicated, will resulting delays be hazardous;**
- **Are floor safes utilized for immediate deposit through a slit. This practice is especially prevalent and effective in gas stations and convenience stores;**
- **Are keys to safes kept on the premises, allowing compromise by robbers;**
- **Are sinkable cash desks, locked showcases, or remote-controlled containers utilized for storing valuables, that can cause delays in access;**
- **What is the ease, speed, and unobtrusiveness of access to target goods;**
- **Is there a clear escape route that is not complicated, or one that is fraught with uncertainty;**
- **Is the target location close to the perimeter of the building;**
- **How many barriers exist between the outside of the building and the target;**
- **How many people have direct access to the target goods;**
- **Do barriers separate target goods from the robber. These include bullet-resistant glass, intermediate doors, or revolving doors. Are such devices equipped with security equipment;**
- **Is there bullet-resistant glass on all ground floor windows;**
- **Are safety desks employed that after an alarm has been triggered will cause an armored wall to rise. These barriers, consisting of bulletproof opaque elements, can block access from the customer area within one second;**

- **Are internal cash rooms connected to tellers by pneumatic tubes or posts, thereby removing access to valuables to the interior of the building;**
- **Can unauthorized personnel be immediately recognized;**
- **Is the main security emphasis placed upon an alarm system with an inadequate response time;**
- **Are holdup alarms in place, and are they silent or local;**
- **How many unknown security factors appear to complicate a robbery;**
- **Are holdup trips placed at strategic locations that would not provide an indication to the robber of activation;**
- **Is there automatic locking of cash desks, sinkable showcases, exploding bait money with dye, or other alarm-triggered devices;**
- **What is the chance of identification and apprehension resulting from the use and placement of video or still cameras;**
- **Are there dead-spots in photographic coverage within the premises;**
- **What is the quality of photographs or video;**
- **Is real motion or time-lapse video in use;**
- **Are photographs rapidly available in case of robbery;**
- **Are cameras operating all the time, or only upon command;**
- **Can height, weight, and movement be determined from photographs based upon the placement of cameras, even if robbers wear masks;**
- **Are cameras housed in protective enclosures;**
- **Are video recorders placed in secure areas, so that the tape cannot be easily accessed by robbers;**
- **If observed by criminals, do guard staff appear alert to the threat of robbery;**
- **Is it possible to kidnap key personnel or their families, and gain immediate access to cash or other valuables;**
- **Robbers consider the construction and security of entrances, including emergency exits, personnel**

entrances, and secondary points. They prefer such points of entry and exit. Emergency exits are usually easy to circumvent, and thus they are likely targets for unnoticed ingress and egress. The robber can often gain an element of surprise and leave in the same manner; their escape is often hidden and cannot be readily noticed from the outside;

- **The method in which valuables are protected will influence the desirability of the target. If goods are not accessible to customers, they will not be as enticing;**
- **What is the value of the goods on hand and the breakdown as to type of commodity;**
- **Method of access into the premises;**
- **Location of windows;**
- **Construction of doors;**
- **How are goods protected;**
- **Description of work areas;**
- **Can work areas be entered by unauthorized persons;**
- **Number of employees;**
- **What is the least number of employees on the premises during the workday;**
- **Opening and closing procedures for the business;**
- **Robbers often prefer closing time because there are normally few customers present and there is the most amount of money on hand;**
- **Do employees wait outside to observe the exit of other employees, thus to be in a position to sound an alarm in case of robbery;**
- **Is there freedom of movement of customers while on premises;**
- **Is the customer ever left alone with valuable goods;**
- **Are cash control desks always occupied;**
- **Do cashiers always remain in contact with other employees;**
- **Have cash-handling personnel received special training;**
- **Where is cash stored on a temporary basis;**
- **Procedure for the transport of cash and other valuables within the premises and location of**

personnel;
    - **Where are they stationed;**
    - **What equipment do they utilize;**
  - **Do guards remain in a bullet-resistant enclosure;**
- **Does the amount of money vary by time of day, day of week or season, making certain times more advantageous for robbery;**
- **Is it possible to detain a robber until assistance arrives;**
- **Do access locks prevent unauthorized entry, using bullet-resistant glass and electromechanical locking devices;**
- **Can holdup alarms be easily activated;**
- **Are day-tills utilized with time locks;**
- **Is the cash-handling room separated from customer areas. In this regard, two methods have been found to deter robberies. A separate room, into which the customer can see but that is protected with bullet-resistant glass and special access door is effective. A separate cash room located within a strong room, isolated from the customers, and connected through a remote conveyance system, provides the best security. Robbers know that such an arrangement can allow the activation of an alarm and can limit the amount of cash that can be taken;**
- **Is the amount of cash on hand limited, thus requiring the customer to call in advance for large withdrawals;**
- **Robbers target locations where money or high-value goods are transported during business hours;**
- **Are armed guards present at the premises. This may reduce the risk of robbery but also increase the risk to patrons in the event that an attack does occur due to the likelihood of use of firearms.**

38_5.3 Organizational Security Measures

Four organizational measures will help to insure the security of cash or shipment of valuables: **secrecy, staff selection, transport logistics**, and **technical aids.**

38_5.3.1 Secrecy

Robbery of high-value targets is always facilitated by knowledge. Therefore, secrecy is essential with regard to details of transport, including:

- **Method of transport;**
- **Amount of goods or value;**
- **Time of transport;**
- **Route.**

Employees can become willing or unwitting accomplices, hostages, or subjects of blackmail through the acquisition of this knowledge. Therefore, information as to value, routes, or time should not be provided to anyone until necessary.

38_5.3.2 Staff

Positive vetting should be required of all employees charged with the transport and protection of high-value items. Vetting should include the following areas of background investigation:

- **Age;**
- **Sex;**
- **Employment history;**
- **Criminal record;**
- **Civil record;**
- **Credit history;**
- **Physical suitability;**
- **Mental suitability;**
- **Previous law enforcement experience;**
- **Weapons experience;**
- **Previous training and experience;**
- **Previous responsibility.**

38_5.3.3 Transport Logistics

Transport logistics relate to issues involved in the conveyance of valuable goods from one point to another. The time, means of transport, methods of loading and unloading, and routes all have significant impact upon security. Issues to consider include:

- **Amount of exposure of valuables in transit;**

- **Amount of valuables in any one transport;**
- **Security measures that would be recognizable to a robber;**
- **Establishment of a routine that is predictable or observable;**
- **Variation of times, routes, vehicles, and personnel;**
- **Detours or delays;**
- **Distractions of staff;**
- **Number of employees accompanying the transport;**
- **Protective equipment carried by staff;**
- **Amount of valuables guarded by only one employee;**
- **Number of transports in relation to the amount of valuables;**
- **Turnover of employees;**
- **Ability to utilize alarm systems while in transit;**
- **Two-way communications;**
- **Response time for assistance in case of robbery;**
- **Use of second vehicle;**
- **Building construction for location of loading and unloading valuables;**
- **Security within cash or valuables transfer area;**
- **Traffic patterns at time of loading and unloading valuables;**
- **Use of weapons;**
- **Visibility of weapons for deterrent value;**
- **Use of hands for carrying valuables, and inability to utilize weapons because both hands are busy;**
- **Use of professional couriers.**

38_5.3.3.1 Armored Car Services

Professional courier services are preferred as a means of secure transport. The many advantages of using qualified companies are well known. However, vendors must be closely screened with regard to issues of personnel, liquidity, security, internal security measures against espionage and sabotage, and sophistication and maintenance of equipment. So long as qualified and responsible services are utilized, the security and efficiency of transport may be enhanced. Benefits of employing third-party contractors for high-value transport include:

- **Increased security;**
- **Professional staff training;**
- **Proper equipment;**
- **Reduction in cost of transport;**
- **Simplified administrative procedures;**
- **Lower insurance costs;**
- **Lower risk of loss;**
- **Simplified administration;**
- **Reduction in liability;**
- **Elimination of human resource issues;**
- **Reduction in scheduling conflicts;**
- **No moral responsibility for injury to bystanders if a robbery occurs;**
- **No legal issues relating to weapons training and handling;**

38_5.3.4 Technical Aids

Certain technical aids can act as a deterrent, making robbery more risky or impossible. Such aids include:

- **Method of storing cash: safe or vault;**
- **Construction of safe or vault;**
- **Use of time-delay locks or time locks (discussed in Chapter 33);**
- **Design of transport vehicle and incorporated physical security measures;**
- **Use of armored cars.**

38_6.0 Robbery Risks for Specific Businesses

As with burglary, there are higher risks of robbery in certain classifications of businesses. Such assessments are based upon many criteria, perhaps the most important of which is the value of target goods. The same high-risk businesses that were identified in the previous discussion about burglary are most susceptible to losses through robbery.

A risk survey for different types of businesses is presented for assistance in analyzing potential for losses primarily due to

robbery. Many of the same considerations apply to burglary. The survey is intended to provide those charged with the responsibility of protecting persons and property with a comprehensive checklist. Many of these issues correlate with our earlier discussion of physical security measures.

38_6.1 Nature of Risk: Specific Issues for Banks

Bank robberies present extreme risk of violence to staff, customers, and third parties. Security is based upon an approach that encompasses many techniques, with the ultimate goal of protecting human life. Measures that are adopted will in large part be based upon the organization of each bank and associated costs of implementation.

Any security measure must attempt to prevent the possibility of hostage-taking and unpredictable reactions on the part of the robbers. Thus, the practice of blocking exit doors, for example, is extremely dangerous. There are two basic methods to deter robbers and lessen the likelihood of an armed robbery: **increase the risk**, and **reduce the reward**.

38_6.1.1 Increasing the Risk of Bank Robbery

There are several risk factors considered by the robber:

- **Difficulties or complexities;**
- **Delays in execution;**
- **Increased risk of apprehension;**
- **Armed guards, both within the bank and outside;**
- **Bullet-resistant barriers;**
- **Remote video monitoring;**
- **Activation of silent alarms in an unobtrusive manner;**
- **Escape routes;**
- **Direct-wire alarm system to police;**
- **Reliability of alarm system;**
- **Protection of staff, using bullet-resistant barriers;**
- **Use of safety counters that create an instant separation between staff and customers upon activation. Raised panels can form an opaque barrier that can isolate robbers;**

- **Removal of direct contact with the cashier;**
- **Staff training in robbery prevention;**
- **Video or time-lapse cameras;**
- **Bait money, marked notes, recorded serial numbers;**
- **Cash bundles containing exploding dye or smoke, triggered upon leaving the bank, that makes use of the money impossible;**
- **Sophisticated holdup alarms with silent hostage notification;**
- **Time locks, notice of which is prominently displayed;**
- **Use of remote service centers and video terminals to handle customer transactions.**

38_6.1.2 Reducing the Reward

If cash or other valuables cannot be obtained by the robber, then there is no reason to commit the crime. Any physical security precaution or procedure that reduces the availability or access to valuables will have a tendency to thwart robbery attempts and ultimately reduce losses. The following procedures can be implemented to reduce the haul from a robbery:

- **The amount of cash at any teller cage can be reduced;**
- **Delayed cash withdrawal;**
- **Storing cash in a container with a time lock;**
- **Centralized cash storage with pneumatic tube transport. The cash-storage area must be totally inaccessible to robbers.**

38_6.1.3 Reducing the Overall Risk

The following steps may be taken to reduce the risk and attendant losses from robbery:

- **Surveillance, using film and video;**
- **Protection of cash on premises;**
- **Reduction of cash on premises;**
- **Use of special storage vaults with armored slots that do not require opening of the safe;**
- **Use of time locks;**

- **Varying of means of transport to bank;**
- **Varying of times of transport;**
- **Precautionary steps when entering or leaving premises with high-value items;**
- **Avoidance of use of entrances which are not visible or protected;**
- **Policy of not allowing persons to enter business prior to or after normal hours;**
- **Daily counts of cash and goods should be done only after the premises is locked.**

38_6.1.4 Organizational Procedures

- **Controlled access and authorization hierarchy;**
- **Key control and security;**
- **Personnel policies regarding remaining in secure areas and guarding assets;**
- **Periodic testing of security systems.**

38_6.2 Nature of Risk: Specific Issues for Businesses Dealing in Precious Metals, Gems, and Jewelry

Businesses dealing in jewelry, gemstones, and precious metals are especially vulnerable to robbery and burglary. They are a prime target due to the nature of the goods they sell, their portability, and ability to be easily fenced. Jewelers and gem dealers are high-risk businesses because they are not able or not willing to implement comprehensive security measures to prevent crimes against property. They, or their insurers, simply accept the added risk. Measures to reduce the potential for robbery must be adopted that will be effective, yet not obtrusive. The following issues are particularly relevant in evaluating and formulating an overall security program:

- **Staff training regarding robbery techniques and response procedures;**
- **Holdup alarms strategically placed within the store and at the entrance if manned by a staff member. Silent alarms should be disguised and readily available to staff. Regulations may require that there is a visible change in the status of the alarm**

when activated;

- **At least one staff member should be isolated from the main customer area. This individual should have an unobstructed view of the store and be able to activate an alarm without interruption;**
- **Do not leave customers alone once they enter the store;**
- **Observe all visitors to the store for suspicious movement or actions;**
- **Remote-controlled entry door locks that will admit only one person at a time;**
- **Bullet-resistant panels on front doors, windows, and showcases;**
- **Unobstructed view of the interior from the outside;**
- **Position staff members throughout the active area of the store in order that each can be observed by another employee, and it is impossible for a robber to capture all employees at one time, thereby preventing an alarm;**
- **Maintain valuable items in a protected area at all times;**
- **Keep less valuable items in controlled areas such as locked showcases, cabinets, or drawers that require keys or entry codes;**
- **Design showcases so that only one drawer at a time can be accessed;**
- **If high-value items cannot be kept in secure containers, then they should be displayed in a dispersed manner so that it is impossible for a robber to gather such items quickly;**
- **Remove high-value items from showcases during business hours only when showing to a prospective customer;**
- **Do not change display stock during normal hours;**
- **Show a customer only one item at a time;**
- **Utilize safes or vaults with storage areas that can be individually secured. Many small compartments should be available. A central locking device should block all but one compartment from access at any time;**
- **Keys for safes, vaults, and strong rooms should be**

located in secure areas that cannot be seen by customers. All key containers should be protected by time lock, and such fact should be visible to all customers;

- **Consider implementing a separate, secure sales area for special customers and high-value items. This room should have a separate security and access system as well as its own vault;**
- **Secure inside access to goods that are stored within display windows. Utilize locked wood, glass, or metal partitions.**

38_6.3 Nature of Risk: Specific Issues for Gas Stations

Gas stations and particularly 24-hour truck stops have always experienced a high risk of robbery, regardless of the location. Their vulnerability is comparable in many respects to banks and jewelry stores. The risk is based upon the following factors:

- **The type of service station: self-service or full service. In the latter, there is a higher risk;**
- **Early and late night operation;**
- **Large amounts of cash;**
- **Easy to case and observe;**
- **They do not attract much attention, even with loud noises;**
- **Rapid ingress and egress from the location;**
- **Small staff;**
- **Poor or inadequate security measures.**

The most common holdup techniques will usually involve one or more of the following scenarios:

- **Taking money directly from the attendant while outside at the service area;**
- **Taking money inside the station;**
- **Taking money from the owner, manager, or employee after business hours as they are leaving the premises.**

38_6.3.1 Reducing the Risk of Robbery

Certain steps can be taken to reduce the potential risk of robbery to gas station employees. These include:

- **Never handle cash in an unprotected area, i.e. outside the office;**
- **Cash should never be visible from the outside;**
- **Outside tills must be automatically locked and alarmed for tampering;**
- **Insure proper lighting of all areas, both inside and out;**
- **Protect all lighting fixtures from breakage;**
- **Provide an unobstructed view of all areas, both inside and out, by staff;**
- **Be certain that customers can look into all areas of the station;**
- **Telephones must be available to staff in a protected area;**
- **Provide separate telephone facilities for customers;**
- **Install local and silent-alarm systems with direct connection to the police for immediate response;**
- **Cash drops must be made throughout the day;**
- **Deposits must be made during business hours;**
- **Utilize safes with deposit slits;**
- **All safes must be encased in concrete;**
- **Keep all extra cash in the safe;**
- **No keys for the safe should be kept on the premises;**
- **Time-delay locks must be installed on all safes;**
- **Post a notice that safes cannot be opened by staff;**
- **Insure that shift-change procedures do not allow large amounts of cash to remain unprotected;**
- **All tills should be automatic locking;**
- **Separating walls of bullet-resistant glass should be provided between the cash desk and merchandise areas, thereby blocking access by customers to the cashier;**
- **Doors to the cashier area must automatically close and lock. A key must be required for entry;**
- **High-security locks should be used on all doors leading to cash-handling areas;**

- **Use sliding, rotating, or payment trays for cash transport between the cashier and customer.**

38_6.4 Nature of Risk: Specific Issues for Safes and Strong rooms

The following issues must be analyzed to determine potential risk of loss with respect to valuables stored in safes, vaults, and strong rooms:

- **Value and type of goods stored:**
  - **Cash;**
  - **Precious metals;**
  - **Gems;**
  - **Type of documents.**
- **Classification and type of container:**
  - **Make, model, serial number, year of production;**
  - **Security devices that have been installed;**
  - **Inspection and certification by testing institute;**
  - **Has the certification label been attached to the safe by other than the manufacturer or in an unauthorized manner.**
- **Mounting of repository:**
  - **Embedded in wall;**
  - **Thickness of wall;**
  - **Description of walls, ceiling, and floor material, thickness, structure);**
  - **Method of anchoring to wall;**
  - **Embedded in concrete;**
  - **Dimensions, height, weight;**
  - **If a safe, is it on casters;**
- **Dimensions of strong room;**
- **Type of alarm system and sensors;**
- **Use of time lock;**
- **Location of repository within the premises;**
- **Number of issued keys that can provide access to strong room or vault;**

- **Number of persons required to activate locking system;**
- **How many persons know the combination;**
- **Persons authorized to operate the locking system;**
- **Procedure for opening and securing the repository;**
- **Measures to protect against holdup;**
- **Can the repository be seen from the outside;**
- **Is there illumination on the entry to the safe or vault;**
- **What is the likelihood that noise will be heard from the outside in the event of a break-in;**
- **Have all prior attempts at burglary or robbery been evaluated for weaknesses in security.**

38_6.5 Nature of Risk: Specific Issues for Cash in Transit

There are certain specific risks associated with transporting cash and other high-value items. Factors that must be considered in determining appropriate security measures include:

- **Number of intermediate pickup points;**
- **Is the transport direct from the pickup to delivery point;**
- **Are there several transports at a regular interval from the same pickup to the same delivery point;**
- **Times of transport;**
- **If night transport, what is the lighting at the destination;**
- **What is the time required for each transport;**
- **What is the length of the transport route;**
- **Description of the transport route;**
- **Can streets with little traffic be controlled by robbers;**
- **Longer routes on high-traffic streets provide more security than secluded streets;**
- **Procedures in the event of roadblocks, accidents, or breakdown of transport vehicle;**
- **Coverage of two-way radio systems used by transport personnel;**

- **Intermediate storage of high-value goods while in transit;**
- **Is the location of pickup and delivery points varied;**
- **What goods are transported:**
  - **Value of goods for each transport;**
- **Highest value of goods transported;**
- **Description of transport destination:**
  - **Location of building;**
  - **Distance from nearest police station;**
  - **Description of the area: rural, residential, commercial, industrial, isolated;**
    - **Traffic patterns at transport destination:**
      - **Isolated and little traffic;**
      - **Normal traffic;**
  - **Continuous and heavy traffic.**
- **Are company employees or commercial carrier utilized for transport:**
  - **How many employees on the transport;**
  - **Experience and training;**
  - **Age;**
  - **Are employees security vetted.**

Transport personnel are often involved in thefts, either directly or as informants. Careful selection, vetting, and supervision is imperative. Periodic background investigations should be conducted that include credit history analysis. Changes in circumstances, behavior, and temperament of employees should be carefully monitored.

Rotation of transport personnel at short notice can reduce the risk of robbery and holdup. High-value transports should not be carried out by a single employee. If an escort is provided, a safe distance should be maintained from the transport to prevent interception by robbers. Issues for consideration include:

- **Is transport in a vehicle or on foot:**
  - **If a vehicle is utilized for transport, is it specially equipped;**
  - **Protection against robbery and burglary;**
  - **Equipment, weapons, and security measures for**

transport personnel;
  - **Escorts from police, military, or private guards;**
  - **Radio communications;**
- **Type of container used for transport:**
  - **Clothing, wallet, money belt, money bag, safe;**
  - **Simple transport container, such as a bag;**
  - **Cash-carrying case;**
  - **Repository.**

Non-secured methods of transport, such as in unprotected enclosures, are not recommended. The thought that inconspicuous transports are somehow more secure is inaccurate. Robbers will usually follow the transport from pickup point and wait for the most opportune moment. Issues to evaluate include:

- **Departure procedures from pickup point;**
- **Delivery procedures;**
- **Loading and unloading procedures. The risks associated with loading and unloading of high-value items can be reduced through organizational, technical and construction measures;**
  - **Organizational: additional specially trained and equipped security staff;**
  - **Technical: security containers;**
  - **Construction: entry and exit points that cannot be observed or penetrated by unauthorized persons;**
- **Limitation on the value of goods transported in any one shipment;**
- **Change in procedures to eliminate casing;**
- **Changes in passwords, codes, routes, and schedules.**

38_7.0 Master Key Systems

Master keying systems generally reduces security unless hybrid locks are utilized. See **Chapters 11** and **17** for a full discussion of locks and keying techniques. Almost all conventional master key systems can be compromised through a process of extrapolation, described in **chapter 31**. Issues to consider in evaluating the security of any keying system will include:

- **Levels of master keying, actual and required;**
- **Group master keying levels;**
- **Who should and should not have access to each specific area;**
- **Cross-keying potential;**
- **Use of restricted or different keyways;**
- **Time of day restrictions;**
- **Delay upon entry;**
- **Lockout capability;**
- **One-way entry restrictions;**
- **Audit functions;**
- **Number of keys in the system.**

Security can be enhanced by implementation of the following procedures:

- **Maintain a complete listing of all locks that are master keyed and the location where installed;**
- **Maintain a complete register of key issuance;**
- **Minimize the number of master keys released in the system;**
- **Do not allow unauthorized persons to have keys in their custody, use, or view;**
- **Maintain all spare master keys in a locked, controlled access cabinet;**
- **Conduct routine key audits of master keys;**
- **Do not let unauthorized persons make copies of keys;**
- **Know your locksmith or person/organization responsible for changing, repairing, or rekeying locks;**
- **Establish a procedure for providing access to maintenance personnel and other outside workers. Do not loan keys to such individuals without a proper policy of identification and background checks;**
- **Removable-core or construction locks should be employed in new facilities so that keys may be changed prior to utilization of the building;**
- **Select locks employing restricted keyways.**

CHAPTER THIRTY-NINE:

Security: Physical Protective Measures

Master Exhibit Summary

Hinges and forensic evidence. Courtesy Don Shiles.

Case example: removal of sliding glass door. Courtesy of Don Shiles.

LSS202: Ross Anderson on biometrics

39_1.0 Introduction

This chapter presents detailed information about physical security devices and technologies, encompassing hardware and structural components. An examination of the proper application of security hardware, together with common methods of bypass and forced-entry, is intended to complement the information presented in **Chapter 38.** Organizational measures, where relevant, are suggested with respect to the implementation and use of security devices.

Physical security measures can be organized within two primary classifications: external access protection, and internal protection of specific assets or areas. Within each primary category, the principal devices, technologies, materials, and construction techniques have been described. Alarm systems are treated as a separate topic in **Chapter 40. Munich** Reinsurance Company, Munich, provided much of the information and graphics for this chapter. Appreciation is expressed to them for their assistance.

PART C: Perimeter Protection

External Access Protection

The following discussion shall examine the components that are

involved in the external or perimeter protection of property. Included in the materials shall be the hardware, barriers, safeguards, and procedures that prevent an intruder from gaining access to a building or other secure area.

39_2.1 Glass

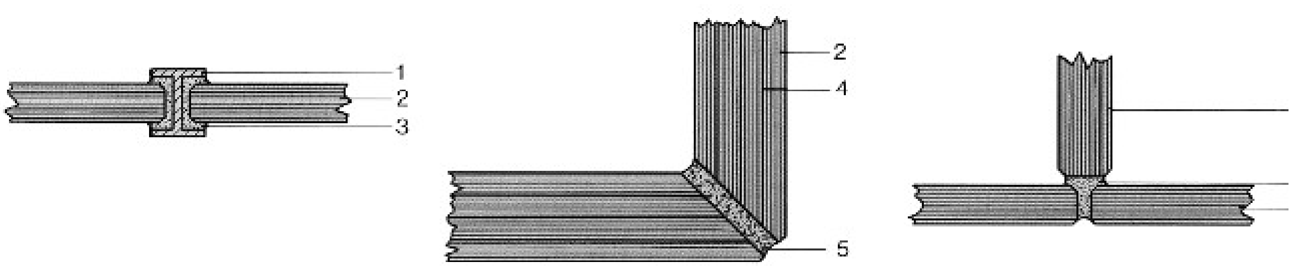
Glass is used extensively in commercial locations. It provides an attractive method of entry, due to its characteristics of brittleness and ease of destruction. Although the shattering of glass can generate noise and create a risk of injury, it is still a favored target for burglars. There are many different types of glass, depending upon the intended use. Characteristics that differentiate each primary category include:

- **Thickness;**
- **Tensile strength;**
- **Thermal transfer specifications;**
- **Noise conductivity;**
- **Mounting.**

39_2.1.1 Ordinary Glass

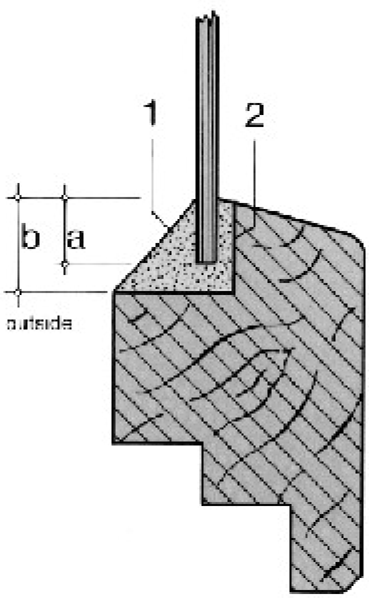
Ordinary glass should not be used in any location where burglars may effect entry by smashing it. Regardless of thickness, it will provide no security. Standard glass should always be protected with alarms and mounted bars to reduce the risk of smash-and-grab attacks.

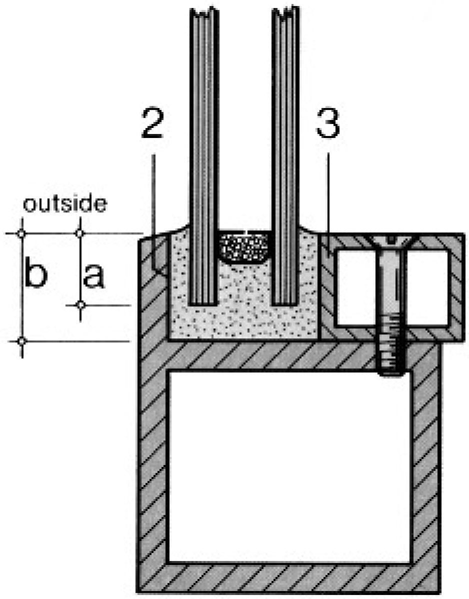
39_2.1.1.1 Installation of Ordinary Glass



The following guidelines apply to the installation of high-quality glass panes and construction of window frames and joints:

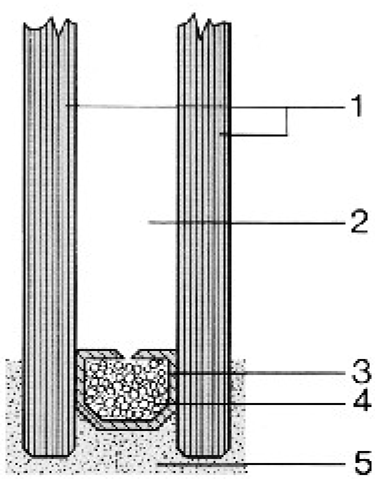
- **Compliance with installation instructions from the manufacturer;**
- **Glass installed with unprotected elastic sealant can be easily removed once the putty has been destroyed. Glass should always be mounted from the inside;**
- **Rebate grooves and mountings must be designed to resist external attack;**
- **Glass rebate depths must take into account the elasticity of glazing when plastic is utilized to maintain the position of panes;**
- **Joints must be protected from attack. Elastic sealant should only be used with such protection.**





39_2.1.2 Insulating Glass

Two or more panes of standard glass, separated by a gap of dry air or gas, are utilized where thermal transfer and sound absorption is desired. Contrary to popular opinion, a vacuum does not exist between the panes.



39_2.1.2.1 Two-Ply Insulating Glass

Insulating glass is comprised of panes separated by air gaps, spacers, dehydrating agents, and elastic sealant.
Burglary-resistance ratings are based upon the specifications for

individual panes: if ordinary glass is utilized, it has no special properties.

39_2.1.3 Wired Glass

Ordinary glass may have netting, braiding, or a wire lattice embedded during production for protection against fire and injury. The glass has no special burglary resisting properties and can easily be shattered. The purpose of the wire is to maintain a bond between glass fragments once the pane is broken.

39_2.1.4 Alarm Glass

Multilaminated glass panes are inset with fine silver wires, and are integrated within an alarm system to sense penetration. Wires are configured in a continuous loop to maintain electrical continuity. When the glass is broken, the series circuit is interrupted.

Alarm glass consists of silicate panes, bonded with intermediate plastic layers with embedded wires, terminated at connecting points. Wires can be run horizontally or vertically with spacing of 20-35 mm. This is not the multilaminated wired glass that is discussed in **2.1.3** above. The difference is in the termination of the wires, which in the former case are laid in parallel and cut off at the edge of the pane. Alarm glass provides a higher level of resistance to smash-and-grab burglaries.

39_2.1.5 Security Alarm Glass

Security alarm glass provides more protection against forced-entry than alarm glass with a wire inset described above. A loop of alarm foil measuring approximately 7 x 5 cm is burnt into a pane of toughened prestressed glass. When the glass shatters, it breaks into very small fragments, causing a loss of electrical continuity. Security glass must be used with other translucent materials to prevent smash-and-grab attacks. The foil loop should be located on the inner face of the outer pane on the attack side. This will insure the earliest possible initiation of an alarm.

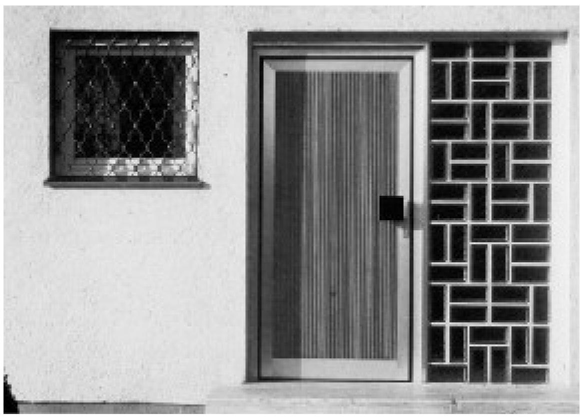
39_2.1.6 Toughened Safety Glass

This type of glass, known in Europe by the brand name Sekurit, is used in automobiles, doors, and gymnasiums. The silicon is prestressed by heating and air cooling during production. It can

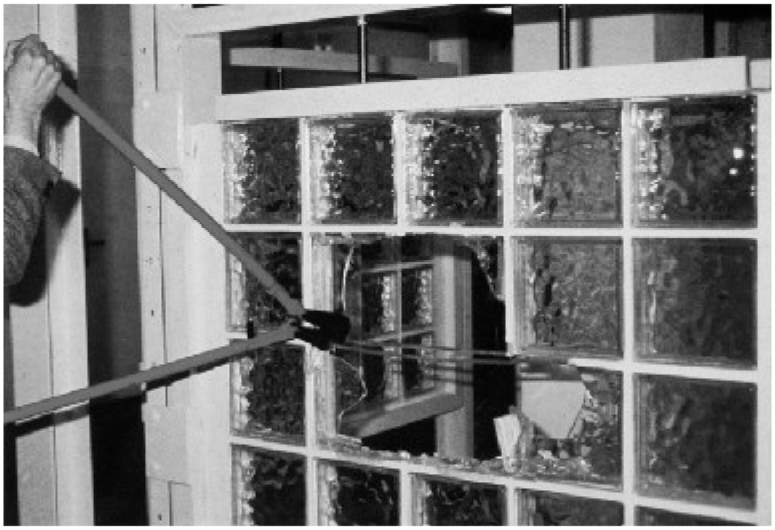
be up to six times more elastic than ordinary panes and can withstand increased pressure from blunt objects. The material is sensitive to striking by pointed instruments and in such cases will shatter into small granular pieces.

39_2.1.7 Glass Bricks

Glass bricks are popular for use in both commercial buildings and residences. They allow the transmission of light and serve as a deterrent to burglars. The smaller the brick, the more security is provided. Both vertical and horizontal reinforcement in fine-grained concrete or mortar is required.



Round or flat steel bars can be used to augment the structural integrity of the brick lattice. They must be strong enough to withstand attack by bolt cutters and saws. The lattice should be such that at least four bricks must be destroyed in order for a person to climb through the hole. The bars are anchored securely, so that they cannot be removed.



39_2.1.8 Laminated-Isolated Glass

Laminated glass consists of two or more panes and is separated by plastic interlayers. This material is utilized to resist bullets, penetration, explosion, and perforation. If the glass is shattered, fragments are held in place by the interlayer. The security rating of laminated glass is based upon thickness, number of panes, and interlayer material. Based upon thickness and design, laminated glass should be resistant to the following forms of attack:

- **Chemicals;**
- **Temperature extremes;**
- **Mechanical attacks with hammers, chisels, picks, pickaxs, pendulums, axes, saws, diamond cutting tools, grinders, drills, and explosives. Extensive testing has demonstrated that a five-pound pickax is the most suitable weapon for attack.**

Laminated panes are also utilized where bullet resistance is required. Properties that determine the resistance to high-velocity projectiles include:

- **Total thickness of the panes;**
- **Number of interlayers or polycarbonate panes;**
- **Construction of the frame and fittings: material and dimensions;**
- **Means for securing the glass within the frame;**

- **Means of securing the frame to the surrounding structure;**
- **Direction and intensity of attack;**
- **Splinter projection properties.**

Laminated glass is provided in two primary configurations: **silicate glass panes** and **silicate-polycarbonate.**

39_2.1.8.1 Silicate Panes with Plastic Films

Silicate panes are interleaved with plastic layers made of polyvinyl butyral to form a cohesive bond. Thickness of the interlayer and ambient temperature will determine resistance to penetration. Reduced temperatures cause the interlayers to become brittle, which reduces their resistance to attack. Composite glass panes are extremely heavy. One square meter of glass, 400 mm thick, weights approximately 200 pounds.

39_2.1.8.2 Silicate-Polycarbonate Glass

Polycarbonate material is mainly used as a primary glazing, or as a moveable secondary pane. The chemistry allows the shape to be changed, allowing adaptation to diverse requirements. Silicate-polycarbonate panes are bonded with a gelatinous-type synthetic resin. This glass is produced in thin panes, with a high degree of resistance to forced attack. The size of the panes is limited, however, due to the differences in thermal expansion characteristics between the two substances.

Polycarbonate is a thermoplast material. Its color ranges from completely transparent to yellowish, and its translucency is about equal to standard glass. Specific gravity is 1.2 (expressed in g/cm^3), or 50% less than that of glass. The material was developed for its tough and elastic properties to resist blunt force penetration by bending, but not breaking. Thus, rocks and dull instruments will not destroy the integrity of the surface.

However, it is relatively simple to drill, saw, and shatter this type of glass with the proper tools, as it has higher notch sensitivity than other materials. There are differences in identical polycarbonate formulas which are caused by fluctuations in quality during manufacturing. The material is not adversely affected by temperature, unless it drops below -100C. At that point, it will lose some of its toughness and become brittle. It

has a heat-expansion coefficient that is eight times greater than glass.

Several drawbacks may be experienced when polycarbonate material is utilized. Careful attention should be paid to the following issues whenever this type of glass is installed:

- **Special and complicated frames are required due to the weight and thickness of the composite glass;**
- **The mountings for glass must be constructed to be stable on all sides;**
- **A greater depth of glass will require special mountings;**
- **Discoloration and reduced light transmission will occur;**
- **Polycarbonate panes can be easily cut using simple tools and without creating any noise;**
- **This material is not suitable for display windows without other protection and should only be used as a secondary pane of glass;**
- **Glass-breakage alarm systems do not work on this type of material;**
- **Based upon chemical properties of hardened glass, static loading occurs that can often lead to the panes becoming dirty;**
- **The material is more sensitive to chemicals than is regular glass;**
- **Once mounted, it is very difficult to determine if polycarbonate or acrylic material has been installed. The latter has a much lower resistance to blunt force instruments;**
- **The greater heat-expansion coefficient requires that special installation guidelines be followed;**
- **The size of the panes must be restricted;**
- **Carbonate glass can be drilled or sawn.**

39_2.1.9 Shatter-Resistant Films

Sheets of polyester film measuring .05-.1 mm thickness can provide an added shatter-resistant exterior surface to other forms of glass. They are tough, resistant to tearing, and absorb ultraviolet rays. Additional benefits include solar protection

and prevention of outsiders looking into a building.

Available in clear or metalized films (coated with a thin film of precious metal), they are applied with a special adhesive to the inside surface of a window. There are four primary advantages to using these films:

- **Material retains splinters from broken glass;**
- **Small improvements in ability to resist penetration;**
- **Can be applied to existing windows;**
- **A slight time delay can be caused to burglars.**

There are many disadvantages to shatter-resistant films:

- **Transmission of light is reduced;**
- **Cleaning can damage the surface of the film;**
- **Reduction of noise caused by the breaking of glass during a burglary;**
- **Surface can be pierced or slit with a sharp blade or knife once the pane has been broken;**
- **Glass-breakage detectors do not function properly;**
- **The setting time is 3 - 4 weeks;**
- **Based upon extensive tests at the German Property Insurers' Association in Cologne, there is little if any increased resistance to perforation, at impact energies of from 250 - 370 J. This contrasts with claims of manufacturers regarding perforation-resistance, burglary-resistance, and bullet-resistance characteristics of these films.**

Impact energy of 249 J is equivalent to the force delivered by a 4.1 kg steel ball dropped from a height of 6.2 meters (about 20 feet). In a test to determine resistance to impact, a projectile thrown at a first-floor window with 360 J of force would have broken through the film and fallen into the protected area.

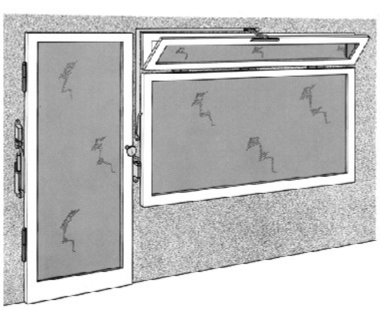


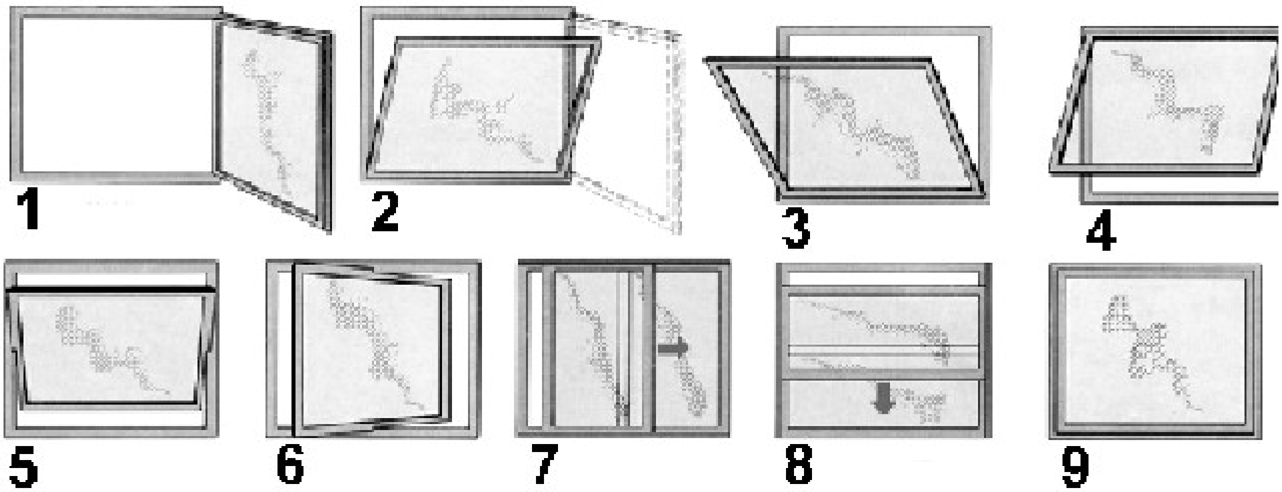
39_2.1.10 Secondary Panes of Glass

Secondary panes of glass are utilized as an additional barrier to protect against smash-and-grab burglaries. The subject is covered in more detail in Section **19.0**.

39_2.2 Windows

A window used as a method of access is a prime target. This is because they are among the weakest parts of a building. Generally, the pane is shattered, then the door handle is manipulated to open the lock. Windows that cannot be opened or that are secured with a lock are not as inviting a target. The removal of glass shards and splinters prior to entry presents both a delay and danger of injury, to say nothing of the distinct noise.





Certain primary measures can be taken to secure windows against easy entry. These include:

- **Windows should be well illuminated, especially on ground floor;**
- **Ground floor windows are particularly vulnerable, especially if set back from the street;**
- **Do not consider any windows as inaccessible, even on upper levels. The height of the window above ground floor must be considered;**
- **Key locks should be utilized on any window that can be easily reached from the outside, including those accessible to projecting walls, canopies, drainpipes, or ladders;**
- **Windows that are never opened should be secured with screws into the frame;**
- **Added security measures may be necessary in instances where windows cannot be observed or where noise from glass-breakage will not be heard. Such action might include:**
    - **Installation of alarm trips on windows, such as lead foil, high-frequency sensors, embedded wires, photoelectric beams, volumetric sensors, vibration detectors, and magnetic contacts;**
    - **Window bars or other physical security devices;**
    - **Folding and detachable shutters;**
    - **Roller shutters and locking device;**

- **Lexan or other synthetic polycarbonate glass;**
- **Glass bricks or honeycombed concrete;**
- **Panels made of acrylic (Plexiglas) can be easily melted with a soldering iron, torch, acid, or cigarette lighter. They must be protected by gratings;**
- **Verify the security rating of safety glass. There will be an identification stamp etched in one corner;**
- **Panes can often be forced out of their housing or dismantled from the outside. Gratings must be anchored in order to secure windows properly;**
- **If bars are utilized to protect windows, cross-joints must be constructed to prevent a car jack or other implement from prying them loose;**
- **Cellar windows must be protected due to their location and because they are often of simple construction. Burglars prefer them as a point of entry. If bars and gratings are utilized, they should be constructed to prevent the use of bolt cutters, saws, and other power tools.**

39_2.2.1 Display Windows and Showcases

Display windows and showcases are a prime target for smash-and-grab burglaries; they are rarely used for entry. Risk should be assessed based upon the value of items displayed, and the volume and quantity of such merchandise.



Physical protective measures as well as alarms are recommended. Devices and appliances that can augment security include the following:

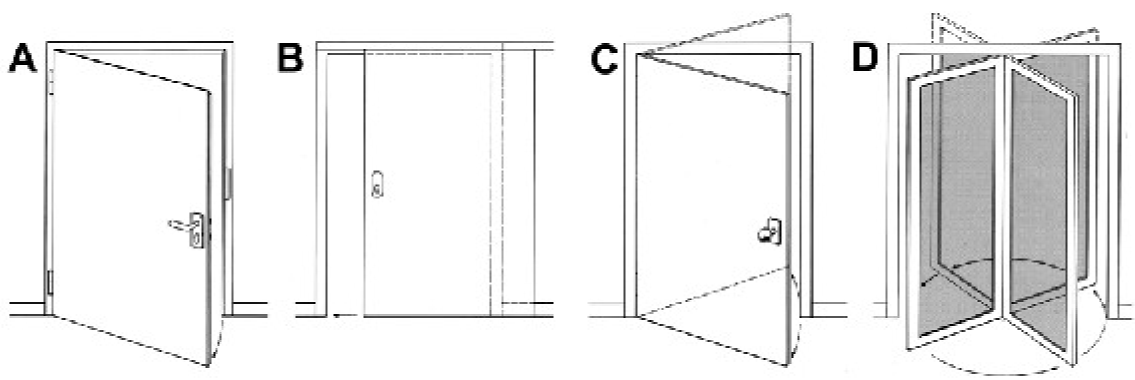
- **Lighting, especially halogen and strobe, when combined with local alarms can help to scare off burglars;**
- **Plainly visible cameras can also act as a deterrent and aid apprehension;**
- **Roller shutters with a blocking device to prevent their being raised;**
- **Roller or folding grating;**
- **Detachable grating that is inside or outside of the window;**
- **Falling grating;**
- **Laminated glass;**
- **Bullet-resistant glass;**
- **Secondary panes of glass;**
- **Fastening of objects using screws, chains, or other devices;**
- **High-quality locks;**
- **Prevention of removal of goods by "fishing" them between panes of glass.**



39_2.3 Doors

This section describes the different types of doors, based upon their design, construction, and vulnerability to attack. Unfortunately, criteria for choosing a door is usually based upon other factors such as space, intended use (passage of people or goods), design, and appearance. Security is often a secondary concern. A door is an obvious and favorite target of burglars for many reasons:

- **They provide the primary ingress and egress to most buildings;**
- **They provide the primary route for transport of stolen goods from the premises;**
- **They can be forced open, often quickly and with little difficulty;**
- **They can, in many cases, be bypassed inconspicuously;**
- **Little noise is created during forcible entry.**



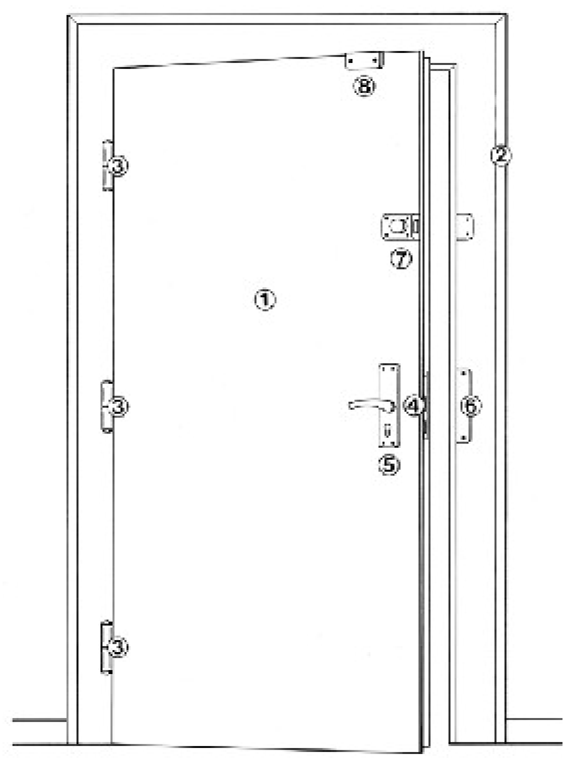
39_2.3.1 Types of Doors

The following primary classification of doors shall be considered in this chapter:

- **Standard door;**
- **Swinging door;**
- **Sliding door;**
- **Four-leaf revolving door.**

Within each classification, nine subcomponents and systems provide the capability for a door to perform its function:

- **Leaf;**
- **Frame;**
- **Hinges;**
- **Lock;**
- **Escutcheon;**
- **Strike plate;**
- **Security bolts;**
- **Method of engagement;**
- **Surveillance devices.**

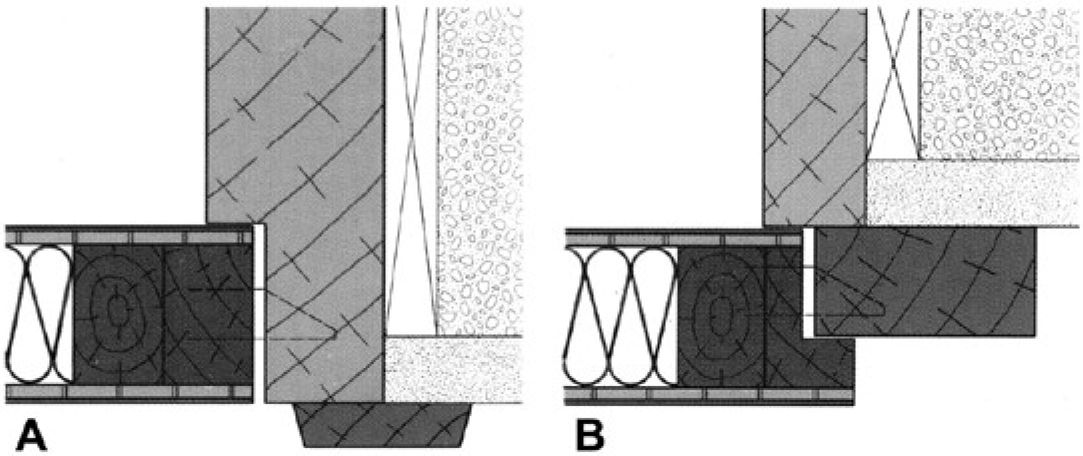


39_2.3.1.1 Method of Engagement

Doors can engage the frame and strike plate in two configurations: **flush mounted** and **offset.** A **flush-mounted** door has three advantages: simple leaf design, simple hinges, and low

cost. The disadvantages are that the lock bolt is unprotected and easy to reach when doors open to the outside.

The design of an **offset door** protects the bolt and opening, making them difficult to break open. The leaf design is more complicated and thus more costly. In addition, the leaf is usually weakened on one side, based upon the installation of the lock.

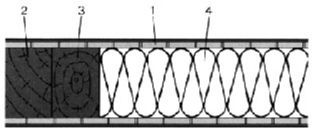


39_2.3.2 Component Analysis: Construction and Security

This section evaluates the components of a door and their potential security deficiencies.

39_2.3.2.1 Leaves

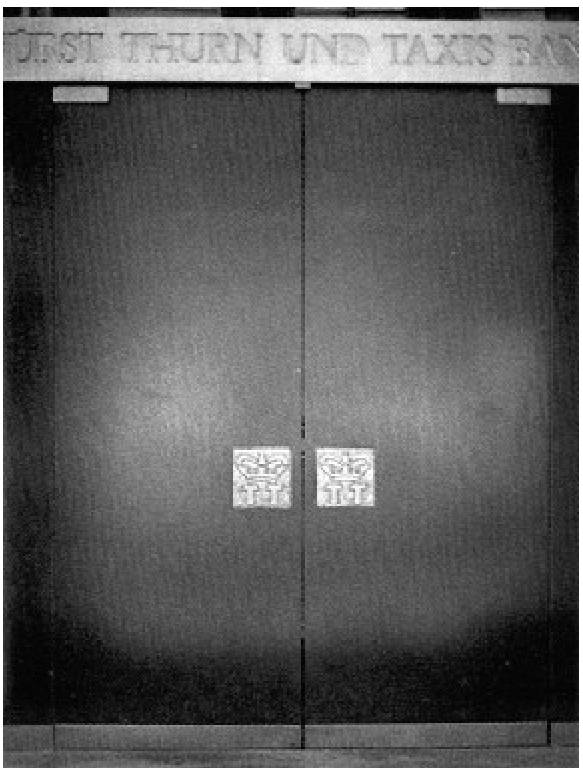
The leaf comprises the major portion of the door. It is usually made of metal, glass, plastic and synthetics, or a combination of these materials. The security of door leaves depends in part on the profile, the strength of escutcheons, and the reinforcement of profiles.





39_2.3.2.1.1 Glass Leaves

A door that is made completely of glass is generally constructed with a single pane of **prestressed safety glass**, varying in thickness from 8 - 12 mm. Glass doors must be regarded in the same manner as windows with respect to security. If burglary-resistant laminated glass is utilized, it is not suitable as an all-glass leaf; framing is required on all sides.



There are three critical characteristics for prestressed safety glass:

- **The glass is up to six times more resistant to**

bending forces than ordinary glass;
- **It is harder at the surface than ordinary silicon-based glass;**
- **Shock from a pointed source will cause fracture and shatter.**

The reference to glass doors as “safety doors” is misleading and has nothing to do with security. It merely indicates that the glass, when shattered, will break into small blunt pieces to prevent injury.

Glass inserts are used in all forms of doors. The panes are generally supported by strips on both sides, surrounding notches or openings into which the glass is set, or by putty. Proper protection can be afforded by the use of a grid of burglar-resistant glass with retaining strips screwed into place.

39_2.3.2.1.2 Plywood Leaves

Multilayered plywood leaves are inexpensive, simple to produce, and are the most commonly used material within buildings and residences. Security is dependent upon the configuration of both the center and surface layers. Many different materials are used for inner layers of doors. These include:

- **Plywood;**
- **Honeycomb plastic;**
- **Cardboard;**
- **Paper;**
- **Hard fiber lattice;**
- **Chipboard sticks;**
- **Pressed straw;**
- **Glued solid wood sticks;**
- **Wood fiber plates;**
- **Chipboard;**
- **Solid frame and filling.**

39_2.3.2.1.2.1 Glued Solid Wood Sticks or Chipboard

Center layers of glued solid wood sticks or chipboard sticks cannot be characterized as solid wood door leaves. They provide little security against forced attack from simple tools.

39_2.3.2.1.2.2 Honeycomb Layers

Honeycomb layers of material do not offer any security, unless they are reinforced with surface layers.

39_2.3.2.1.2.3 Solid Frame and Filling

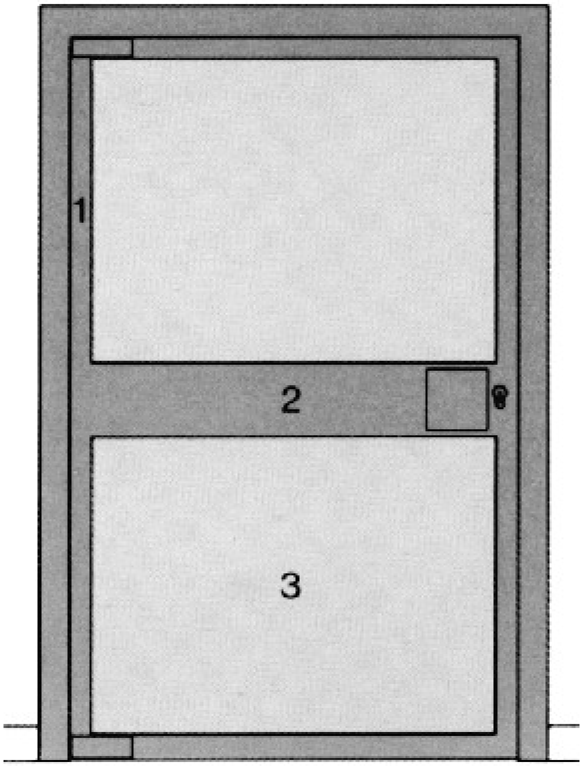
Leaves may be constructed from smooth or compressed wood filling. In either case, they provide little security. Generally, smooth material is only 5 - 12 mm thick, and pressed wood fillings are 16 - 22 mm thick.

39_2.3.2.1.2.4 Solid Frame and Solid Panels

Door leaves having solid wooden panels provide resistance to attack and are used on perimeter doors. Materials such as steel plate or solid hard woods can be used as the core, sandwiched between outer panels. Other materials, such as plastic, metal, glass, or glued wood provide less protection and rely upon metal frames.

39_2.3.2.1.2.5 Metal Frames

Slender frame profiles made of aluminum or other light metals should have transverse reinforcements, and centerpieces surrounding the lock. These will increase the stability of the leaves and resist bending by levers, pry bars, and other wedges, thus keeping the lock bolt from being pried from the strike plate.



Certain design parameters of door leaves with metal frames can affect security. Issues that must be evaluated include:

- **There is often a large gap of up to 20 mm between the leaf and frame, offering access for wedges;**
- **Reinforced profile locks must be utilized with a small opening between the leaf and frame;**
- **Long security shields for profile locks are generally not available;**
- **Bolts are often relatively short (less than 20 mm), based upon the dimensions of the frame;**
- **Locks with swing, hook-type, or extra length bolts should be utilized to prevent jamb spreading;**
- **Penetration-resistant glazing should be utilized;**
- **Grids on the inside of doors may be employed. However, they are often made of light aluminum and provide little protection.**

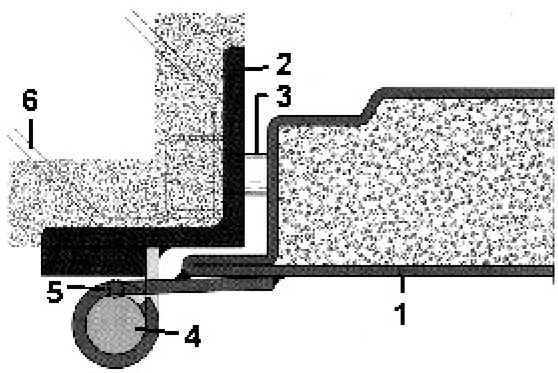
39_2.3.2.1.2.6 Synthetic Door Leaves

Burglar-resistant door leaves can be produced with steel frames having glass-fiber reinforced plastic shells on both sides. These will provide security if they are at least 5 mm in thickness on each side. A reinforced shell behaves similarly to a polycarbonate panel, without the vulnerability to impact. Such leaves are often more than 60 mm thick and thus can be fitted with high-quality locks and escutcheons.

39_2.3.2.1.2.7 Steel Door Leaves

Doors with steel leaves are used for fire protection. These often contain double panels and will provide resistance to forced-entry. The following security measures should be taken to insure that doors would not fail during a forced-entry attempt.

- **Utilize high-security lock cylinders;**
- **Hinges should not be fitted externally;**
- **Hinge pins must be secured in position;**
- **Hinge bolts should be welded in place;**
- **Hinges must be mounted to protect them from cutting and blunt force attack;**
- **Steel plate, more than 2 mm thick, may be utilized as a surface covering for even greater security. Such plate should be bolted from the inside.**



39_2.3.2.2 Door frames

Frames can be manufactured from wood, metal or synthetic materials. Leaves and frame are often not made of the same material, and so each must be evaluated individually for strength and resistance factors. There are at least three types of frames:

- **Low security and internally mounted**

frames;
- **Frame and door leaf of same thickness;**
- **Steel-profile frames.**

39_2.3.2.2.1 Low Security and Internally Mounted Frames

These are provided to cover the interior surface of the masonry around the door openings and are used in conjunction with strips that cover joints of the door casing. Weak chipboard, rather than solid wood, is generally used. Frames are normally glued rather than bolted or nailed to the wall. A sharp tool can be used to separate the materials, allowing removal of the door from its hinges. Likewise, the hinges and locking plates are usually fastened to the strips, thus providing no security. Doors may also be hinged flush to the edge of the frame, leaving a gap between frame and leaf. This can provide direct access to the lock, bolt, and strike plate. It is also common for a gap to exist between the wall and frame, based upon the type of mounting.

39_2.3.2.2.2 Frame and Door Leaf of Same Thickness

Outer doors as well as heavy internal doors are often mounted in frames that are designed exclusively to secure the door leaf. Usually the leaf and frame are of the same thickness. Past construction practices required that such frames were cemented to the wall with masonry anchors. Today, dowel pins and long bolts are the primary means of fastening; the space between frame and masonry is filled with a soft material.

39_2.3.2.2.3 Steel-Profile Frames

Properly engineered and installed steel-profile frames are more resistant to forced-entry than their wooden counterpart. In order to ensure security, they must be reinforced and rigidly connected to the wall, with no leverage points. Single-leaf door frames must be fastened with flat anchor supports. Welded-on casings around bolts and latch openings, welded hinges, and metal exceeding 2 mm in thickness will improve the chances of surviving a forced attack.

39_2.3.2.2.3.1 Security Requirements for

Installing Frames

The following guidelines should apply for the installation of frames to insure maximum resistance against forced-entry:

- **Door frame and leaf should be flush mounted, facing outward;**
- **Doors should open to the inside;**
- **Hinges should be located on the inside surface of the door;**
- **The door frame should be secured by a continuous bottom threshold;**
- **Steel-profile frames and cases may be utilized for added security. These can be built into the wall during construction or held in position by cast cement mortar.**

39_2.3.3 Supplemental Security Components for Doors and Associated Hardware

A wide range of additional security components is available for doors. In the following material, reference will be made only to the most common systems that are suitable for later installation.

- **Door chains and brackets made of heat-treated steel must be securely fastened to the door, leaves, frames, or walls. If not properly attached, they may fail from the application of force, such as caused by kicking the door;**
- **There must be minimal clearance for the door to open with a chain attached. If sufficient room exists to insert an arm or manipulation device when the door is ajar, a rubber band may be attached to the end of a night chain to pull it to the unlocked position upon closing the door;**
- **Locking bars and padlocks can provide increased security to doors and gates. Safety hazards must be considered, because these devices can only be locked or unlocked from one side;**
- **Locking bars and sliding bolts must be fabricated with heat-treated materials;**
- **Panic bars on double doors can be easily bypassed by sliding a hooked tool between the doors and catching**

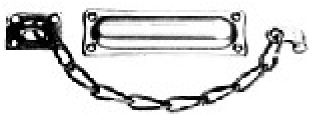
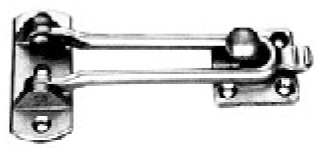
the moving arm. A device called an astragal can be installed to prevent the practice;

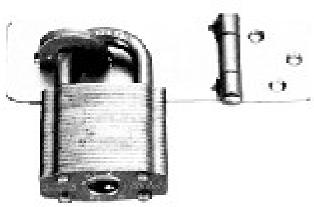
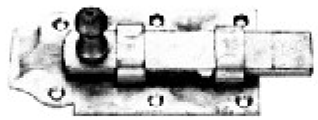
- **Fixing screws should be completely covered by a locking bar or should be designed to prevent bypass;**
- **Sliding bolts at the top and bottom of a door should be used on all entrances that do not require opening from the outside. Mounting screws must be installed at a right angle to the direction of the application of force;**
- **Bolts should be secured in a locked position with a padlock;**
- **Box locks may be utilized instead of mortised inset locks. These devices can pose special security concerns, including:**

    - **When mounted on hollow door leaves, the rear mounting screws must not extend into hollow cavities. The manufacturer may provide outer cover plates that are screwed on from the inside;**
    - **Box locks cannot be securely mounted on frames made of chipboard. Steel plate or angle plate should be utilized;**
    - **If mounted on doors with glass panels, the box lock must be capable of being locked from the inside;**
    - **Mortise bolt locks are preferred to box locks.**

- **Supplemental locks must have the housing fitted securely on the frame or in the wall;**
- **If electromagnetic locks are utilized, the release button must be protected by some form of shield. This will prevent a flexible wire from being routed under or around the door to activate the button;**
- **Electromagnetic locks must be tested frequently to insure that they have not been surreptitiously bypassed. A thin piece of paper or plastic covering of the surface will defeat the magnetic field and render the lock ineffective;**
- **Double bolt or cross-bolt locks can be fitted to the inside of a door to increase security with the addition of the following hardware:**

- **Solid steel bolts on both sides;**
- **Bolt projection by 80 - 100 mm, controlled by a gear-wheel;**
- **Use of profile cylinders.**

39_2.3.4 Burglary-Resistance Standards

Based upon extensive testing, the following security standards apply to doors:

- **The frame must be securely fastened in the wall;**
- **The leaves, whether made of wood, metal, or plastic, must offer adequate resistance to burglary attempts;**
- **Wooden-leaf doors should not have hollow cavities;**
- **Doors should have at least three heavy hinges;**
- **Any door that opens to the outside should have suitable security devices or hinge bolts;**
- **Primary and supplemental locks must be capable of withstanding a substantial load;**
- **The lock must be protected from external tampering;**
- **Cylinder locks must always be fitted with a drillproof escutcheon. It must be bolted on from the inside with screws measuring at least 8 mm in diameter;**
- **Strike plates must be constructed of high-quality steel;**
- **Strike plates must be properly fastened;**

- **Openings in steel-profile frames for latches and bolts must be suitably reinforced;**
- **There should not be any glazed openings or letterboxes in the door leaf.**

39_2.3.5 Balcony and Patio Doors

Balcony and patio entrances are favorite targets of burglars because they usually have inferior doors and locks. Generally, entry is effected by breaking a pane of glass in an unprotected door near to a locking handle or by defeating the locking mechanism. Bypass of locks is often accomplished by drilling into the frame.

Swinging doors and windows present a higher risk of bypass, especially if found in the tilted position. If the brace is severed or forcibly disengaged, the door can be easily opened. Locking handles and bolts offer no protection in such case. It is suggested that energy-saving mountings that provide a very narrow gap be utilized.

Lifting doors are easily compromised. A hole is drilled above or next to the lever, then a rod is inserted. The lever is released and the door is raised with a crowbar. The best solution appears to be a lockable "shoe" that fits over the actuating lever on doors and windows. Lockable shoes must cover the lever, thereby preventing its movement. Additionally, the shoe or other device must be incapable of being unscrewed or broken. It is recommended that such devices be utilized on all locks that control sliding or lifting doors.

39_2.3.6 Sliding Windows and Doors

- **Sliding glass doors and windows move horizontally within a track. They can be removed by lifting out of that track. This practice can be prevented by installing two panhead metal screws in the top of the track at each end of the door. They should almost touch the top of the moving frame when the door is in the closed position;**
- **If an obstacle, such as a board or broomstick is utilized to keep a sliding door in place, it should be high enough to prevent the door from being lifted above the obstacle;**

- **Inexpensive latches on windows should be replaced due to their simplicity in design and bypass capability;**
- **Be certain that latches on sliding doors are not installed upside down. In such cases, they can be vibrated to the open position;**
- **The catches or locking pins on double-hung windows can often be compromised with a thin blade knife or by drilling. Secondary locks should be installed;**
- **French window locks should always be protected to prevent the insertion of a thin blade to lift the locking lever;**

Case example: removal of sliding glass door. Courtesy of Don Shiles.

39_2.4 Hinges

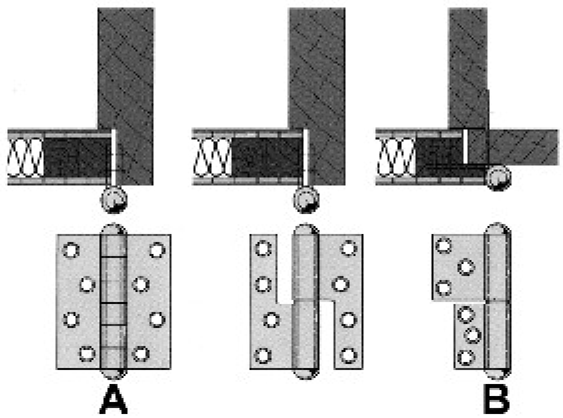
Hinges are comprised of interleaved metal plates that rotate around a central axis and are used to connect a door with its frame. Their design and attachment is important and contributes to the overall security of the door and frame. Simple hinges do not provide sufficient security against unauthorized opening; they should be augmented with hinge bolts. They must be anchored to the wall like a strike plate, independently of both the door and frame to provide added support.

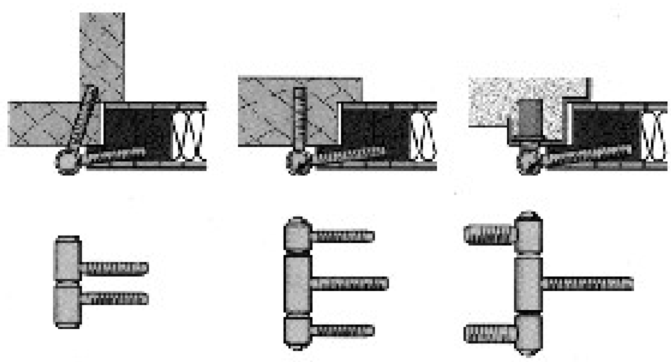
Hinges and forensic evidence. Courtesy Don Shiles.

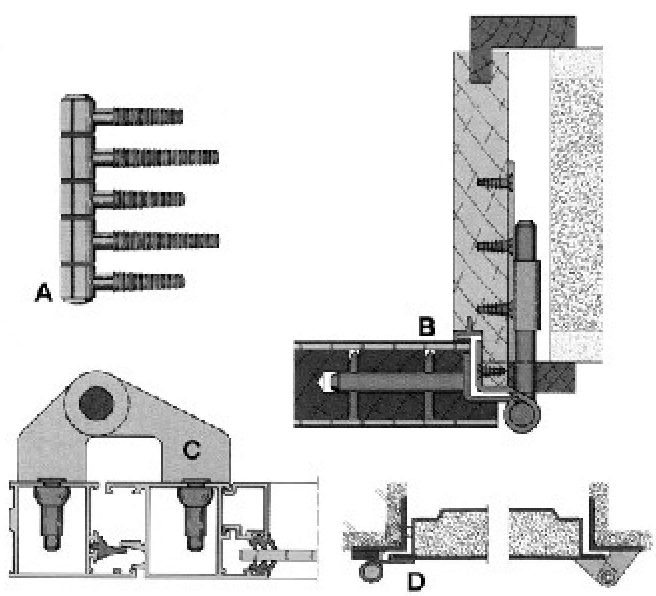
39_2.4.1 Classification of Hinges

Hinges are available in many configurations, based upon their method of fastening. The basic designs include:

- **Screw-on hinges for door leaves flush with the frame;**
- **Force-fit hinges for offset door leaves;**
- **Drill-in hinges for various types of door frames;**
- **Weld-on hinges.**







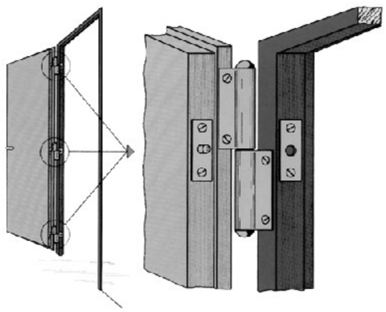
39_2.4.2 Installation Requirements and Security

The following guidelines relate to the security of doors, frames, and hinges.

- **Three hinges should be utilized;**
- **The door must not be subject to distortion or being forced out of position;**
- **The sealing and heat-insulating effect of the door can be improved by the proper installation of hinges;**
- **Drill-in hinges should have five or more bolts;**
- **Door leaves should be as strong as the hinges and fastenings;**
- **Heavy studs and bolts may be butt-welded to the hinge;**
- **Special hinges may be used with chipboard frames;**
- **>12 mm hardened bolts can increase the load that hinges can bear;**
- **Fastening plates should be utilized on the other side of the frame with bearing bolts or studs, reducing the likelihood that the door can be pulled loose;**
- **High-security hinges must be fitted while the door is being hung;**
- **Insure the proper fitting of hinges on doors made of wooden-profile sections;**
- **Reinforcement plates or fastening bolts must be utilized and fitted properly;**
- **Weld-on hinges will offer the maximum security on metal doors;**
- **Hinge pins should be welded in place, or hinges should be equipped with special pins to prevent their removal.**

39_2.4.3 Hinge Bolts

The purpose of a hinge bolt is to reinforce the hinges between door leaf and frame when the door is closed. Hinge bolts are essential, especially when used with poorly designed hinges or with doors opening outwards. Bolts should be positioned near the hinges, as this area is the least subject to pulling, torque, and other forces. Two and preferably three hinge bolts should be utilized per door.



All hinge bolts work on the same principle: a cylinder or disc fits into a drilled hole or slit exactly opposite. When mated, the male and female portion of the bolt will provide additional structural integrity to the hinges.

39_2.5 Door locks

Our discussion of door locks shall relate to bolts, strikes, latches, and related components. For commercial applications, mortise configurations are most common and will be used as the example for the following discussion. Internal locking mechanisms, such as wafer, lever, and pin tumbler, are described in **Chapters 13-16.**

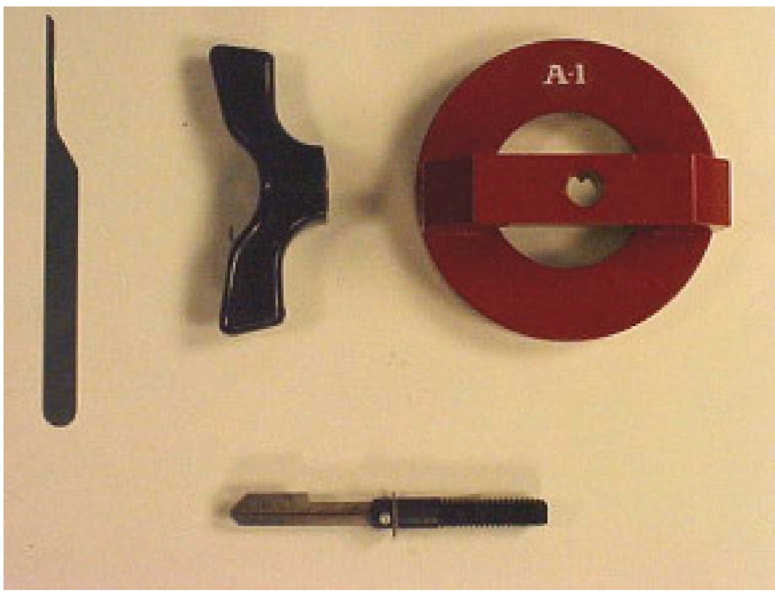
39_2.5.1 Security Guidelines for Locks and Locksets

See **Chapter 10** for detailed evaluation criteria of high-security cylinders. UL and European security standards are set forth in **Chapter 37.** Design parameters and security enhancements for locks and locksets can provide increased resistance to forced-entry, including:

- **Prevent tampering by completely enclosing the lock housing;**
- **Lock housing should be made of heat-treated steel, at least on the side that is exposed to attack;**
- **Heat-treated bushings must be used for the escutcheon to provide adequate support and protection;**
- **The locking bolt should be heat-treated;**
- **The bolt should extend into the lock housing to prevent shearing;**
- **Warded mechanisms should never be used, as they**

offer no security;

- **Lever locks should contain at least seven or more levers to offer pick resistance;**
- **Lever locks should utilize asymmetrical double-bitted keys;**
- **Escutcheons often have one-piece bolts of insufficient thickness on tubular frame locks;**
- **Kwikset, Weslock and similar locksets should be augmented with dead bolts to prevent manipulation of the spindle-tab or spring release;**
- **Be certain that all cylindrical locksets are tightly fastened to the door so they cannot be unscrewed.**






A-1

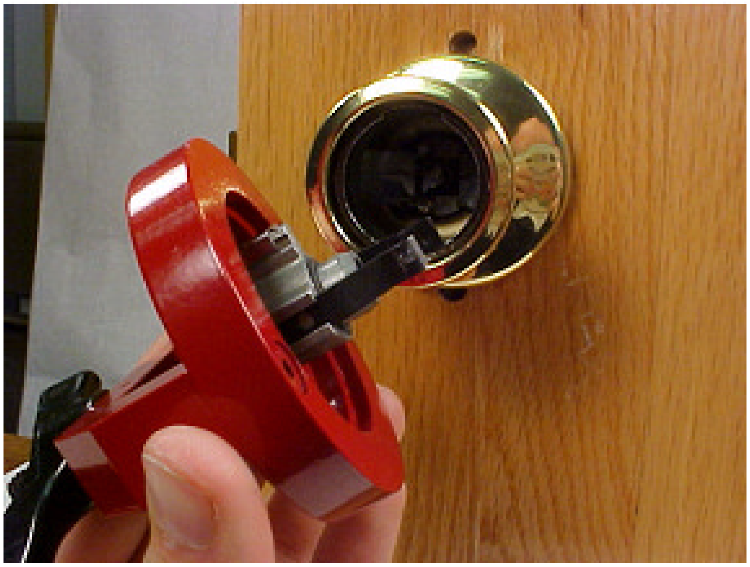




Figure LSS+3901 The Kwikset cylinder key-in-knob assembly may be removed quickly and easily with a special tool to release the two retaining clips. A vicegrips or pliers may then be inserted to manipulate the bolt. Courtesy of Medeco.

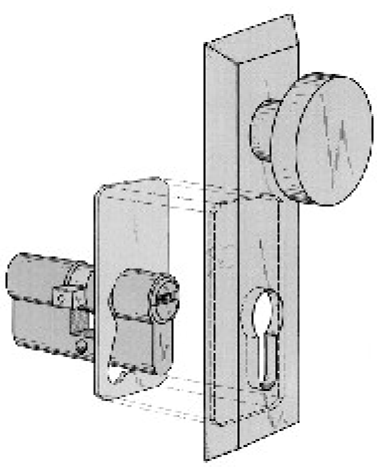
39_2.5.1.1 Supporting Hardened Metal Plates for Cylinder Locks

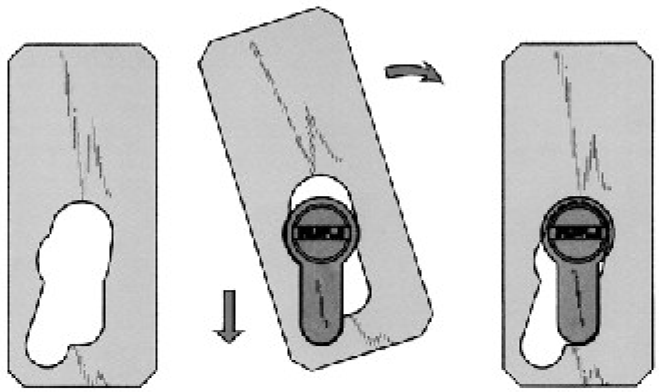
As has been described in **Chapter 32**, cylinder locks can be forcibly removed from their mountings unless properly anchored and protected. There are several methods to accomplish this,

including:

- **The cylinder can be wrenched loose by attaching to the protruding portion of the lock from the handle mounting or rosette. Once the outer lock has been removed in this manner, the bolt can be withdrawn with a hook-wire, screwdriver, or other simple tool;**
- **A hole can be drilled into the lock above the pins, then a piercer can be inserted to drive the internal mechanism away from the bolt;**
- **A dent puller can be used to forcibly remove the plug or entire assembly. This requires that a metal screw be tapped into the keyway, then withdrawn;**
- **A metal screw can be tapped into the keyhole, then violently removed with a nail puller;**
- **Using a long wedge-shaped tool that has a slot slightly larger than the outline of the profile lock, the cylinder can be worked loose.**

These methods of attack can be made more difficult or frustrated by the installation of a supporting hardened metal plate that is at least 2 mm thick. A notch is cut into the cylinder, which keeps the lock from being removed by pushing, pulling, or twisting.





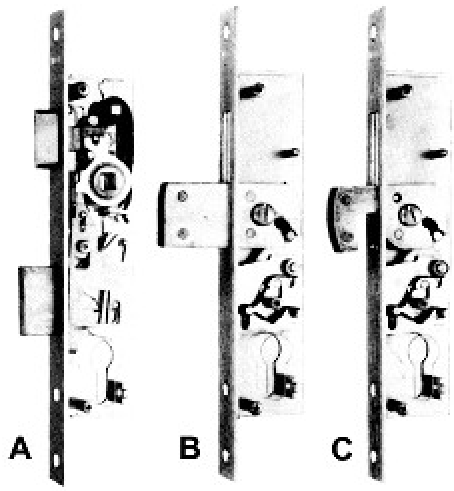
39_2.5.2 Bolt Systems

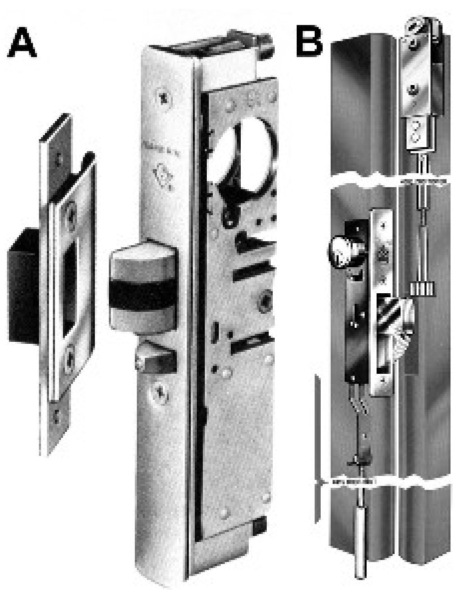
The use of a particular bolt will depend upon the design of the door, frame, and lock.

39_2.5.2.1 Bolt Systems for Tubular Frame Locks

Mortise locks used on slender metal frame doors can have three different kinds of bolts: **dead, hook,** or **swing.** The characteristics of each bolt will determine the security against forced methods of attack. The following guidelines apply to tubular frame lock bolts:

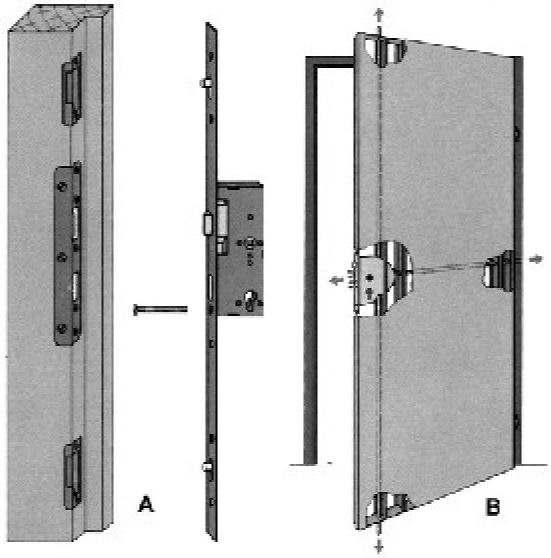
- **Dead bolts can usually be thrown once to a length of 10-12 mm., although some may reach 20 mm. This is often insufficient to overcome the potential for jamb spreading of metal door frames and leaf, and the gap between the two. The bolt may only extend a few millimeters into the strike;**
- **Swing bolts usually have a vertical orientation within the housing when in the unlocked position. Their length is not restricted by the characteristics of the frame, allowing them to be extended up to 30 mm. Bolts are usually of laminated design, especially when employed in swinging doors. Heat-treated steel or aluminum ceramics are often used;**
- **Swing bolts with a hook-bolt are popular for use on sliding doors and allow solid linking to the strike plate.**





39_2.5.2.2 Rollstud and Multipoint Bolt Locking

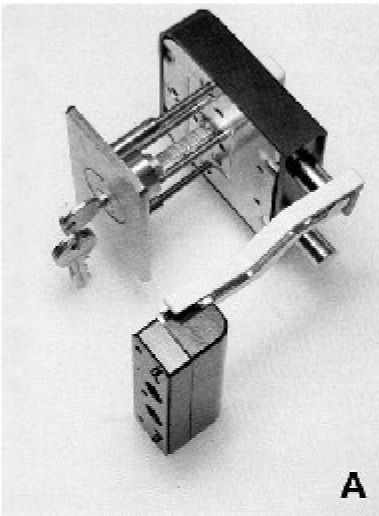
A rollstud or multipoint locking design provides for a central locking mechanism to control several bolts or locking pins. These systems can improve the odds of surviving a forced-entry attempt. They can also enhance thermal insulation and soundproofing characteristics of the door.

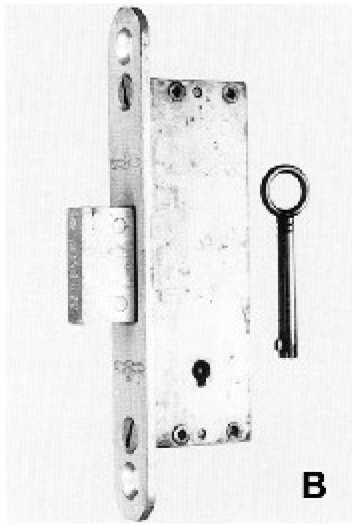


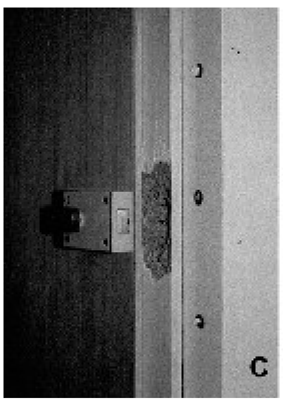
Security issues regarding these forms of bolt systems include:

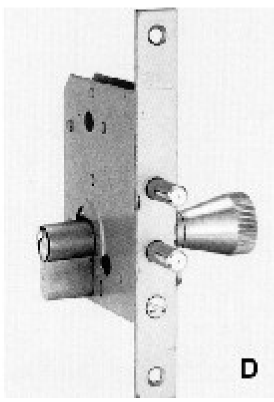
- **Bolt systems may not provide the required security, based upon a throw length of less than 8 mm;**
- **Improper fitting of door and bolts or studs will reduce overall security;**
- **Lock openings can often be forced out and removed in chipboard frames;**
- **Central point or multipoint vertical and horizontal bolt systems should not be retrofit to doors for several reasons:**
    - **The housing is sometimes wider than the recess in the door-leaf reinforcement frame;**
    - **Bolts cannot be properly fitted into doors with fillings due to lack of space availability;**
    - **Special tools are required for such installations;**
    - **Horizontal bolts do not offer adequate support for hinges;**
    - **Locks and escutcheons often cannot withstand a heavy load;**
    - **One cylinder that controls a multipoint bolt system may require excessive torque to turn the key, resulting in fracture. A better system utilizes a separate control of the secondary**

bolts, with the main bolt being locked by the key;
- **The strike plate, its fastenings, and escutcheon, all must be sufficiently strong to provide security for a multipoint locking system.**









39_2.5.2.3 Compromise of Lock Bolts

There are several common techniques for bypassing bolts on cylinder locks. An analysis should be undertaken to insure that the following techniques cannot be applied:

- **Bolts on inactive double doors should be incapable of being unlocked when both doors are closed;**
- **Automatic door-closing mechanisms can be bypassed by**

the placement of a pad to prevent proper alignment of the latch with the strike. The door will close but not lock;

- **Clear tape can be placed over the strike in order to prevent entry of the latch;**
- **Obstructions can be placed in the strike hole, preventing full extension of the bolt. Even a dead bolt can be worked to the open position if it does not fully enter the strike;**
- **Jamb spreaders, described in Chapter 32, can be utilized to bypass short-throw bolts and secondary bolts. One solution is the three-point locking system;**
- **If sufficient clearance can be created, a shove-knife or linoleum knife can be utilized to bypass a latch bolt;**
- **If the secondary bolt on a spring latch is defective, then the primary bolt can be withdrawn with a "Z" tool or flexible loid. The "Z" tool is a bent piece of wire that is inserted between the door and stop. The end will catch the bevel and force it into its housing. The loid tool is formed from a piece of celluloid and is used to push the bolt out of the way of the strike;**
- **Mail slots, transoms above doors, and pet doors can provide a point of entry to reach doorknobs, latches, and other release mechanisms;**
- **A threshold under a door can provide access to allow manipulation of a knob, handle, or latch from the outside. The remedy is to place a lip or other obstruction to block entry of a wire or shim.**

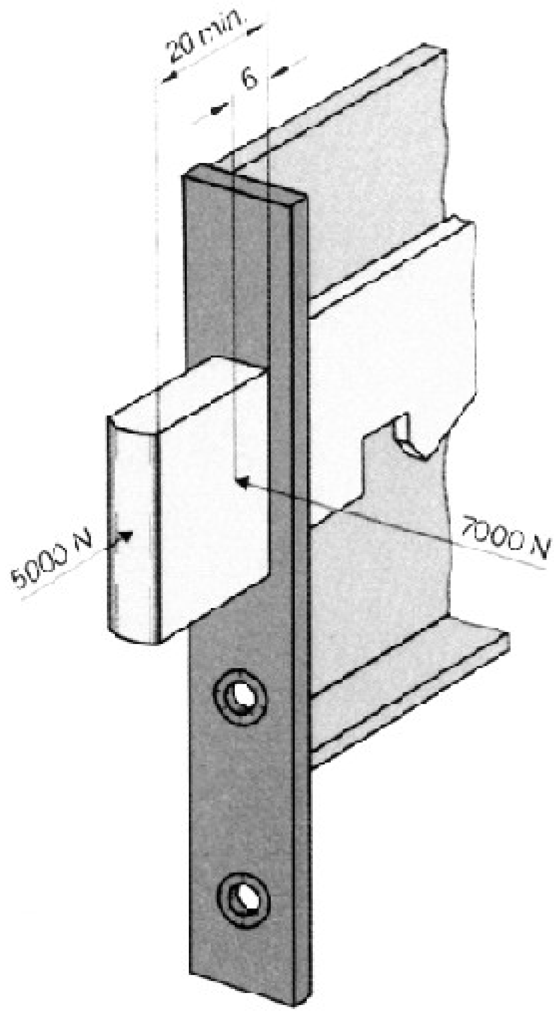
39_2.5.2.3.1   Forces Applied to the Lock Bolt

Standards have been adopted based upon forces that are encountered by lock bolts. Typically, these guidelines will specify the following requirements for each component:

- **Door frames constructed of wood or steel profiles must withstand a force of 7,000 N applied to the frame at the strike plate or recesses in the strike plates, hinges, or hinge bolts;**

- **Door leaves must withstand a force of 7,000 N that is applied to primary or secondary locks, hinges, and hinge fastenings;**

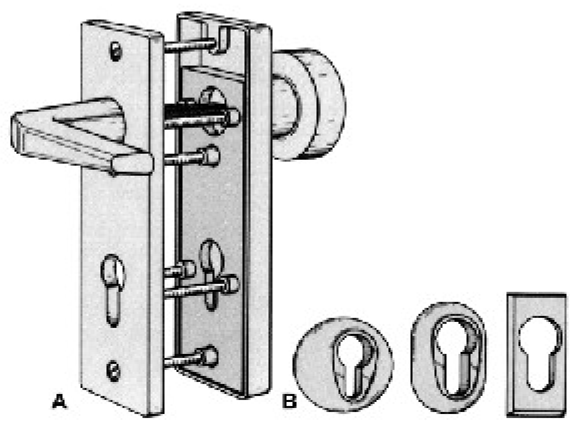
- **At the intersection of the diagonal lines across the door from top to bottom, the leaf must withstand three impacts of 2,000 J each.**



39_2.6 Escutcheon

Were it not for a security escutcheon or brace covering the mortise lock, any cylinder could be quickly removed and the bolt retracted. Guidelines for escutcheons include:

- **Rosettes or shields must not be screwed to the outside front of a lock;**
- **Rosettes often fail to provide adequate security;**
- **A cylinder must not protrude from the escutcheon by more than 2 mm;**
- **A security escutcheon should create a narrow close-fitting sleeve around a cylinder;**
- **It must be difficult to use a tool to obtain access to a cylinder.**



Escutcheons must:

- **Be affixed from the inside with bolts of at least 8 mm in diameter;**
- **Provide added support for the lock;**
- **Protect the lock from being drilled;**
- **Be made of solid, heat-treated steel.**

39_2.6.1 Security Escutcheon (short shield) and Security Rosettes

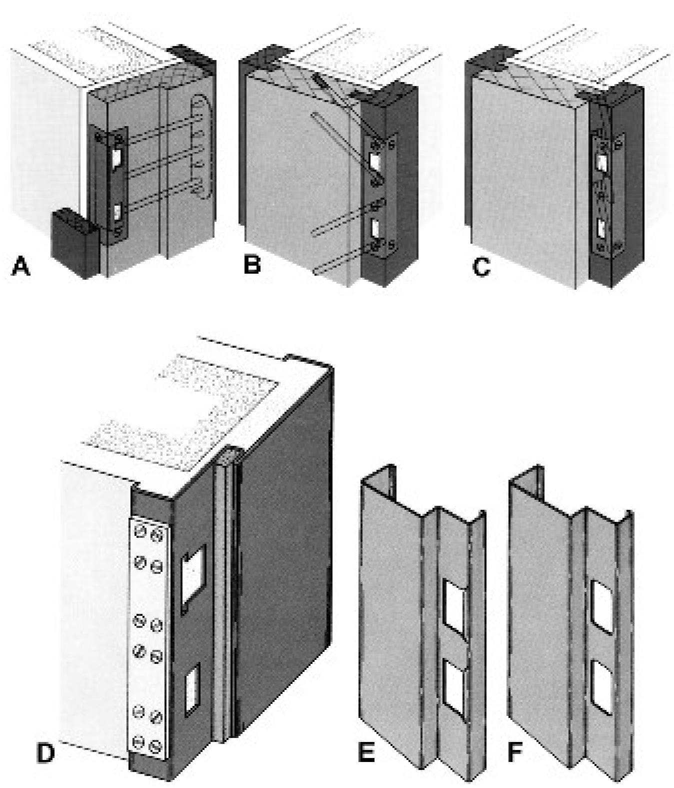
Security escutcheons are also referred to as short shields. These covers can usually accommodate only small-diameter bolts of not more than 6 mm. Using several bolts through all of the holes in the housing does not increase security. Additional risks are presented by light-alloy shields with support cams and steel-threaded inserts, because they may break when torque is applied.

Locks and cylinders can best be protected by using a long

rectangular shield that is made of solid steel. In the alternative, a steel base-plate that is bolted from the inside above and below the lock housing will often suffice. This shield should be affixed with long bolts that have a diameter of 8 mm. Solid steel escutcheons are hard to drill and will retain the cylinder tightly in position, making it more difficult to force loose. If light alloys must be used, then inserted cast-steel plates can be added.

39_2.6.2 Lock and Strike Plate

The strike plate is considered as part of the escutcheon and must be specifically made for the door upon which it is installed. If fitted in a solid frame made of high-quality wood, a security strike plate without any additional support in the wall (or frame) can provide adequate security. Even a light load of approximately 1.0 kN can be enough to wrench loose a simple strike plate. As a comparison, shoulder pressure generates a load of about 2.0 kN and a forceful kick will amount to approximately 5.0 kN. A dog-spike bar and wedge can produce a force of more than 10 kN.

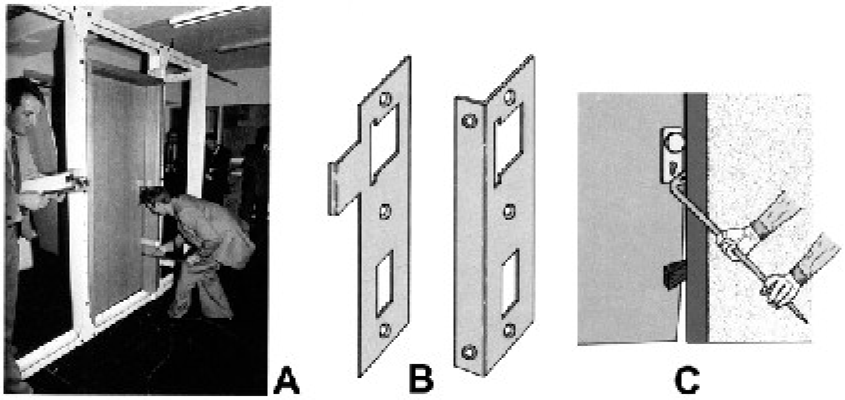


39_2.6.3 Strike Plate Security Deficiencies

The following security deficiencies occur with inadequate strike plate hardware:

- **The fact that a large number of screws are used to fasten a strike plate does not guarantee security. Nor does the length of the strike plate provide a reliable index as to strength. In fact, long plates tend to be weaker than short ones. The optimum length is less than 20 cm;**
- **There is often too small a distance between the recesses for the bolts. This can weaken the frame, making it more susceptible to forced-entry;**
- **Strike plates should be fitted prior to assembly of metal frames. Installing them later can cause damage to the frame;**
- **Strike plates should be made of high-quality materials, such as stainless steel;**
- **Security strike plates should have additional anchors in the wall. These can offer resistance to forced-entry and provide reinforcement for the frame;**
- **If added anchors are utilized, damage can be caused to walls, necessitating major repairs. This is especially true if they are made of brick. If holes are drilled into reinforced concrete, rebar may be encountered. If this occurs, the strike plate cannot be properly fitted because of inadequate anchor depth;**
- **Reinforcement members can be welded to steel-profile frames around the strike plate recess. This can provide increased security;**
- **Aluminum frames without strike plate reinforcement are weaker than steel. They must be thicker near the strike plate and reinforced by the plate itself;**
- **Recesses in strike plates mounted on steel-profile or metal frames should have rounded corners. Sharp corners can crack or fracture;**
- **Stainless steel reinforcement plates, measuring about 5 mm in thickness, should be utilized in steel-profile frames that have simple recesses for**

the bolt and latch.



A B C

PART D: Internal Protection

Internal Access Protection

The following discussion identifies critical areas within a facility that usually require special protective measures. Security hardware, construction techniques, organizational procedures, and installation guidelines are examined.

39_3.0 Access Control

Access control provides primary protection of property and persons against burglary, robbery, sabotage and espionage. It is inherent in any security program and must be considered for entrance and exits to all buildings, as well as for vehicles used for transporting high-value items. See the discussion in section 23_3.0.

The concept of access control can take many forms, from the simple distribution of keys, codes, and identity cards, to complex systems. Today, sophisticated computer-based systems are available to meet any access security requirement. These include mechanical and electromechanical locks, proximity identification cards, magnetic coded cards, biometric sensing systems, retinal scans, and alarms.

Access control is dependent upon and customized for a particular business and its unique characteristics. Placement of facilities and staff, location of valuables, design of the building or structure, and traffic patterns must all be taken into account.

Ultimately, people, including criminals, must pass through access points. The correct hardware and supporting policies and procedures must be properly implemented to restrict access, yet not impede it.

39_3.1 Biometrics

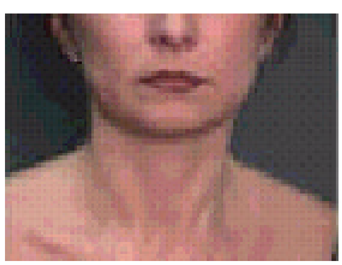
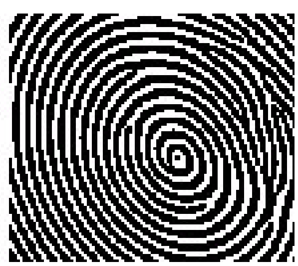
LSS202: Ross Anderson on biometrics

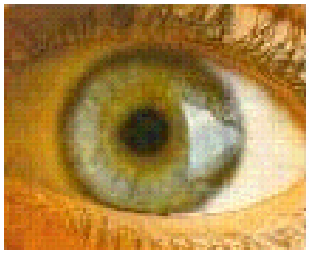
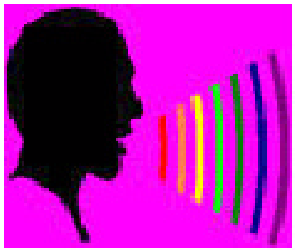
Biometrics involves the use of a security protocol wherein authentication or identification relies upon a human property:

- Some aspect of an individuals anatomy or physiology;
    - hand geometry
    - fingerprint
- Deeply ingrained skill;
- Behavioral characteristic;
    - hand written signature
- Combination of features
    - voice

The use of biometrics certainly predates the computer era, and generally involved the use of voice, signatures, facial features and fingerprints. In fact, early criminologists such as **Bertillion(439)** thought they could identify criminals by the shapes of their heads. Other forms of identification in relation to biometrics helped to form the basis for the **New York State Bureau of Identification.** The primary biometric technologies are described in the sections below. During the past twenty five years, many systems have made their debut into the marketplace, now becoming a multi-billion dollar a year industry.

The primary biometric indicators are:

There are a number of general issues that can affect the validity and reliability of any biometric system, and which must be understood by anyone implementing biometric technology for user identification or authentication. Certain issues are technology dependent and some relate to the environment into which a system is placed. Generally, attended biometric systems are more reliable than those that are unattended. The deterrent affect cannot be understated with regard to criminal conduct.

Issues that may affect the validity of any system include:

- **Environmental conditions**
  - noise
  - dirt
  - vibration
  - unreliable lighting
- **Alcohol or drug intake;**
- **Stress levels;**
- **Changes in environmental assumptions**
  - closed to open systems
  - small to large systems
  - attended to unattended (can be very tricky to implement for valid results)
  - cooperative to recalcitrant subjects
  - verification to identification
- **Methods that are used to index biometric data;**
- **Age and freshness of a sample (such as a fingerprint);**
- **Forged signature;**

- **Use of a recording or facsimile:**
    - voice recording or synthesizer
    - photographs (iris codes)
    - imprints on contact lenses (iris codes)
    - molds (fingerprints)
- **System is not accurate for all people, and some segments of the population may not be suitable candidates:**
    - elderly
    - manual workers
    - dark colored eyes, large pupils
    - disabled people and amputees
    - illiterates
    - poor
    - ethnic minorities
- **Legal challenges;**

- **Political and religious challenges:**
    - religious, Christian Fundamentalists (Revelation 13:16-18
- **Collusion;**
    - employee and user
    - disloyalty

- **Degrading of samples provided as the constant value for a user;**

- **False repudiation (signatures that appear different but pass for identical);**

- **Statistical errors in accuracy of a particular system. There is one chance to get it right, but N chances to get it wrong;**

- **Stacking of biometric systems may not increase reliability and lower error rates.** A combination may improve either the **false accept(440)** (FAR) or **false reject rate(441)** (FRR), but not both. This is especially true when a very precise technology is combined with an imprecise one;

- **Improper use of a system for identification, rather than for authentication or verification.** A system that has been designed for authentication may fail when it is used to introduce evidence

for another purpose;

39_3.1.1.0 General Defeat Strategies for Biometric Systems

There are three primary methods to attack a biometric system, summarized below. Each type of technology is subject to specific defeat techniques, detailed in subsequent sections.

- **Spoof the system by using data that has been created or synthesized. This attack requires that biometric information be obtain from the target, such as fingerprint or photograph;**
- **Utilize artificial data in a "replay attack." This involves sniffing of input lines to the sensor, then replaying that information to the system. It can be a relatively simple matter to capture information from the biometric sensor, via USB lines. USB Snoop for Windows (software based) and USB Agent (Hiltex) which is a hardware based device. The USB Agent is essentially invisible, and records all exchanged information on a foreign PC. The process will allow reconstruction of information and images sufficient for successful log in to the biometric device;**
- **Attack the data base directly, by exchanging information used as a reference for authentication within the system. Forged user data may be input into the system, so long as administrative rights with the proper permission sets have been obtained. Failure to encrypt all information within the data base can aid an attacker.**

39_3.1.1 Handwritten Signatures

The use of the handwritten signature dates back to China and is perhaps the second earliest form of biometric authentication of the individual, facial recognition being the first. Over time, carved seals replaced the use of signatures for the elite and wealthy in the Orient. In Europe, the reverse was true; seals were first utilized to confirm transactions, and later, signatures became predominant. Today, most commercial transactions are executed with handwritten signatures. The issue now is their replacement with electronic signature authentication.

Fraud through forgery is often easily accomplished, and depends

in large measure upon the examination of signatures for authenticity by the accepting party. In banks, this is essentially non-existent except for large drafts. Even with credit card signature panels, few clerks really pay attention, at least in America. Depending upon the country and local custom, there are special security conventions that surround the acceptance of signatures for certain types of transactions. In some cases, authentication must be secured from a recognized party, such as a lawyer or notary.

There are three key issues with regard to the authentication of a signature: **form, ease of forgery, and legal validity.**

39_3.1.1.1 Automatic Signature Recognition and Verification

Banks have a need to automatically and accurately verify large numbers of handwritten signatures on checks. This can be a very difficult image processing task. Presently, the procedure is often accomplished manually by an on-screen comparison of the check with the account holders original signature. As a consequence of the difficulty in correctly recognizing signatures, the use of ***signature tablets*** has gained acceptance. These devices digitally record the characteristics of the lines as well as the dynamics of the writer. That is, the velocity of the hand, at what point the pen was lifted from the tablet, interruption of strokes, and other criteria. Such tablets are used in high value transactions, but their use is also widespread in credit card transactions in order to capture, but not validate the signature.

False accept and reject rates are not yet acceptable for mass commercial transaction processing at the retail level. Referred to in the banking industry as the fraud (accept) and reject (insult) rates, it means the probability of accepting a false signature, or rejecting a valid one. Generally, a low false insult rate will result in a high false acceptance rate, unless a biometric indicator is combined with human monitoring. Then, a higher reject rate can be tolerated because it can be verified through other means.

39_3.1.2 Face Recognition

Facial recognition is probably the earliest form of personal identification. It is believed that much of our cognitive functions developed in order that we might recognize each other.

We can surely do it better than any automated process. Today, the facsimile of this process drives identification and authentication. That is, a photograph that is attached to a drivers license, passport or other official form is relied upon as prime identification, which then allows the issuance of other security clearances and devices (keys, access cards, smart cards, identification). Unfortunately, identification of individuals in person is much more reliable than from a photograph.

Automatic facial recognition is fraught with problems due to the nature of the photographs. Those taken for identification utilize proper lighting, angles, and recording media. Mistakes can still easily be made. Images from video tape, or even more difficult, from surveillance cameras, can prove of minimal value. Movement, lighting, viewing angle, perspective, and expressions all contribute to unreliability. Unfortunately, an error rate of one percent or less is almost impossible to achieve with facial recognition, in comparison with other forms of biometrics. Countermeasures to defeating these systems have been implemented, including reaction to bright light (pupil contraction) and blinking to indicate a live subject. This system may foil the use of laptops that display a video in front of the detector.

39_3.1.2 Defeat of Facial Recognition Systems

Facial recognition systems are subject to compromise through the use of photographs and video images of the authenticated user. In one scenario, notebook compuers with images that are displayed in front of the sensor in a facial recognition system can easily defeat security. To combat this, some manufacturers have introduced "live checks." However, these too can be defeated by adding motion to a short video clip. This implicates that information from an individual that is captured by a video camera in public can be used to simulate that individual at a secure facility;

39_3.1.3 Fingerprints

Fingerprint recognition currently represents a high percentage of biometric technology implementation, such as shown in the photographs below. These safe locks utilize fingerprints, with or without entry of a number, as the means of authentication. These particular devices are manufactured by **STB microtechniques SA** in Switzerland. Readers are utilized in a wide range of access control functions, even including desktop computer access.

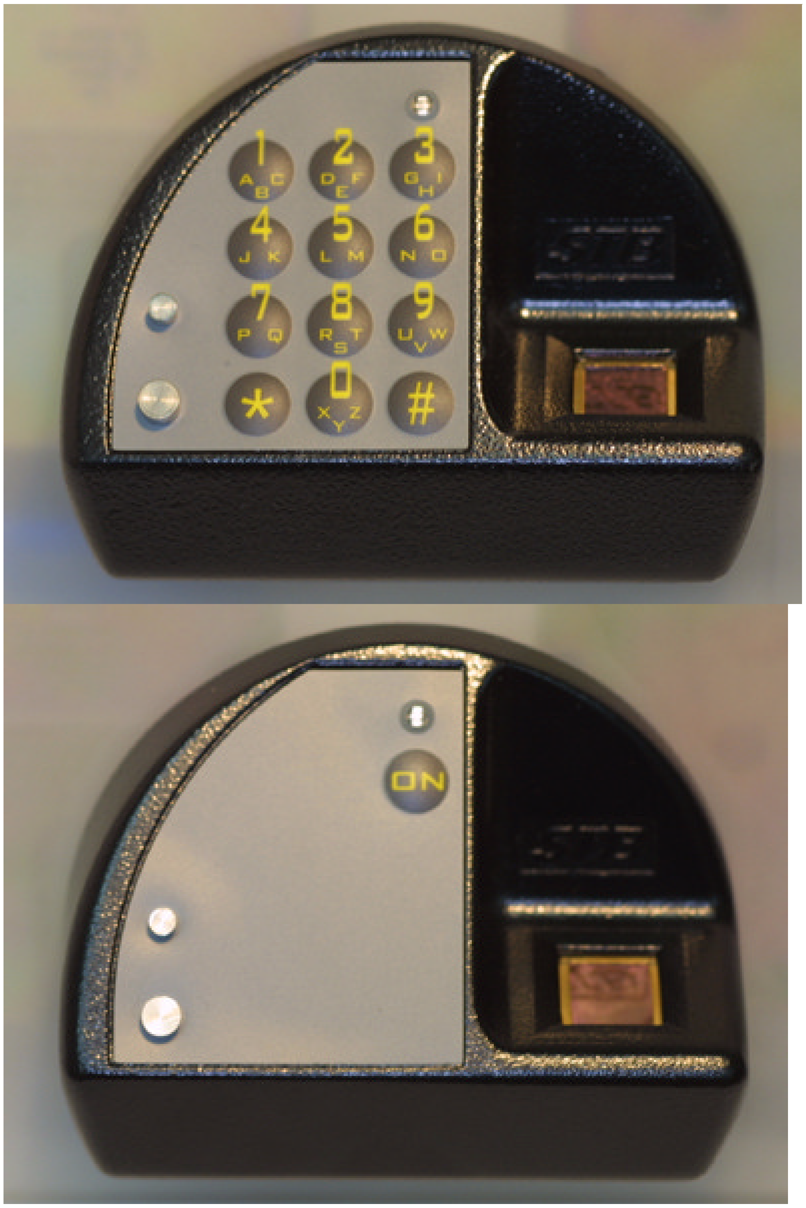


Figure LSS+3902 Fingerprint recognition is utilized in the STB electronic combination lock for safes.

Fingerprint readers utilize CMOS capacitive arrays, optical scanners, or thermal recognition systems. The chips that utilize capacitance typically have 65,000 pixels, abd they analyze ridges that cover the finger tips, called ***minutiae***. The sensor detects lines or troughs and translate this into capacitance values. Differences in patterns (arches, tents, whorls and loops, branches, and end points) allow for automatic identification by converting the individual values into an 8-bit gray scale, then

extracting about 20 minutiae. Optical scanners utilize prisms or diffracting grids that are illuminated by light from color LEDs and photographed by a CCD or CMOS camera. Another type of optical array utilizes a light-conducting fiberglass surface directly linked to a CMOS chip element. The finger is placed on the array and is illuminated from below. In the thermal design, a CMOS-Finger-Chip sensor, such as Atmel's FCD4B14, consists of a total of eight parallel rows with 240 sensor pixels each. As the finger is moved **across** the sensor, heat is applied to the finger tip. Very small variances in temperature are measured between ridges and valleys of the fingerprint.

Fingerprints were originally developed as a means of criminal identification by a number of individuals working independently. In the seventh century, the Chinese legal code allowed their acceptance as an alternative to a seal or signature. They were utilized in Japan in the eighth century, in Ireland and in Italy in the seventeenth century. The first systematic implementation for identification appears to have been in India in the middle nineteenth century, when William Herschel used them to stop pensioner fraud and to prevent rich criminals from hiring poor people to serve their sentences in jail. In the 1870s, Henry Faulds, a medical missionary in Japan, discovered fingerprints and made Darwin aware of them. Darwin then contacted Galton to develop a classification scheme. The police began using fingerprints in 1900 when Edward Henry became Chief of the Metropolitan Police in London. Henry improved upon Galton's classification system through a technique known as binning (use of individual bins to hold classification information). Henry assigned one bit for each of ten fingers when a whorl was present in that finger. A total of 1024 bins were created (2^{10}). This technique reduced the number of records that would have to be manually searched when attempting to match a print.

There are many automated fingerprint classification systems in use by law enforcement agencies today. For security applications, there are readers, such as shown above, that can authenticate an individual in real-time for access control and verification of credit and banking transactions. In Europe and North America, there has been resistance to the use of fingerprints in commercial transactions as an invasion of privacy.

There is a probability of false matches, given the huge data bases that have now been developed. Impressions can also be obscured by "noise" from dirt, oils, mode of impression, the nature of the surface material, and the skill of the examiner.

Although the accepted number of match points is 16, this number may in fact be too low in certain instances. The identification by fingerprint is not infallible, which can also lead to erroneous conclusions. There have been instances of false fingerprint evidence that has been used to convict a criminal defendant. Prints can be transferred using adhesive tape or from the use of molds.

Automated systems can have problems recognizing prints from certain individuals, such as those with scars, manual workers who routinely damage their finger tips, young and elderly with faint prints, amputees, those with birth defects, or the rare instance where an individual does not have fingerprints.

39_3.1.3.1 Defeating Fingerprint Systems

Fingerprint readers, especially earlier generations, have been defeated through a variety of methods. These include:

- **Breathing on the sensor, thus making the previous image visible;**
- **Use of a mold to recreate a fingerprint;**
- **Placement of a thin-walled water-filled plastic bag onto the sensor surface;**
- **Dusting of the sensor with fingerprint powder or graphite powder, then using adhesive tape or film to lift the print from the source material. The fingerprint can then be superimposed onto the scanner and will be read a high percentage of the time;**
- **Some optical scanners can be bypassed through the use of a simulated finger, rather than a two dimensional image:**
    - Use of photo-sensitive lacquer to reproduce the image of a fingerprint in a three dimensional configuration;
    - warm candle wax can be used as a mold to impress a fingerprint, then a silicone impression can be taken, much like that described in other sections of this book for making keys;
    - use of a lifted fingerprint on cellophane tape or film, overlaid onto the scanner, with a halogen light source that is directed onto the scanner from about 30cm, causing intense back-lighting and increased contrast;

39_3.1.4 Iris Codes

Recognition of iris code patterns as a means of personal authentication appears to present the most reliable and secure method of biometric access control. Like fingerprints, every human iris has unique characteristics that are capable of measurement. Such codes are set after about one year from birth and will never change. They cannot be altered and are easy to capture for the purpose of identification. The iris code may be many times more complicated and random than a fingerprint, and thus presents the potential of a very low error rate in detection. Iris codes are formed between the third and eight month of gestation and do not appear to be influenced by genetics; formation follows no guidelines. Thus, patterns for identical twins will differ, and for each eye of one individual will vary.

In practice, a 256-byte code is generated from an extraction process utilizing a signal processing technique (Gabor filters) by analyzing a series of concentric rings that extend from the pupil to the outside of the iris. There is a high repeat rate when the same iris is computed more than one time, which may not be the case with fingerprints. Because of the coding technique, there are several commercially available iris recognition sensors that can process the information in real-time. Iris codes offer the lowest false accept rate for any biometric authentication system. The Department of Energy has conducted extensive tests and found a false accept rate of zero. The equal error rate is better than one in one million. If a false reject rate of one in ten thousand can be tolerated, then the theoretical false accept rate would be less than one in a trillion.

In order to capture an acceptable image for processing, several hundred pixels must be available. This means that the individual must be fairly close to the scanner, which has raised certain issues with respect to privacy and intrusiveness. Distances between eye and scanner can vary from a few inches to two or three feet. Within a controlled environment, the distance between individual and scanner is not relevant, but in a retail or commercial setting, it can become a problem. Other issues that can cause problems would include blinking, eyelashes over the eye, nystagmus, and sunglasses.

39_3.1.4.1 Defeat Techniques for Iris Code Recognition Systems

Specific defeat techniques for iris code systems include:

- Photograph presented to the scanner of the target iris, in an unattended operation. This may become a problem if iris codes are widely used in commercial and banking applications, because code data will be obtainable and can be replicated;
- Print the target pattern on contact lenses;
- Print a high resolution iris image on paper, then cut a small hole for the pupil area and utilize a live subject for the pupil;

39_3.1.5 Voice Recognition

Voice recognition systems are utilized in a number of application including telephone banking, identification of military personnel, secure telephone systems, NSA applications, and access control into critical areas. The goal of such systems is quite different than in forensic applications (forensic phonology), such as the identification of an individual who made a telephone bomb threat, or the analysis of many speech exemplars to identify one speaker.

Two terms are often confused with regard to voice recognition systems. In regard to user identification and authentication, ***speaker recognition*** is a synonym, and denotes a technology of identifying a speaker from one or more spoken words. ***Speech recognition*** systems have been developed to translate the spoken word into text, and to ignore individual characteristics that are utilized in voice recognition. Several complicating factors must be accounted for in any biometric system that utilizes voice as a means of authentication:

- Noisy environment;
- Real-time decipher;
- Verification of the speaker, or recognition of one speaker from a larger group;
- Whether recognition is text-dependent.

39_3.1.5.1 Defeat of Voice Recognition Systems

There are potential defeats for these systems:

- **A speaker may train himself to replicate another's voice that would be acceptable to the recognition equipment;**
- **Intercepted audio samples could be segmented by each syllable, utterance, or word, then reconfigured to form different words;**
- **Use of digital signal processing (DSP) to accomplish real-time voice forgery;**
- **Voice morphing systems that could be utilized to alter components of a speakers voice to match that of a target.**

39_3.1.6 Other Systems

There are many other biometric systems that are in development. These include:

- Facial thermograms, utilizing infrared images, that map the surface temperature of the face;
- Unique shape or characteristic of a body part or movement:
    - shape of the ear
    - gait
    - lip prints
    - vein patterns in the hand
    - scent recognition
    - keystroke dynamics (typing patterns)
    - hand geometry (originally from anthropometrics, developed by Alphonse Bertillion)
- DNA typing

39_4.0 Blocking Time Relay on Vaults and Strong rooms

A blocking time relay is utilized on vaults and strong room within a bank to thwart holdups. They should be considered as a supplement to other forms of burglar alarms and electronic monitoring systems and are used in conjunction with time locks that protect locking mechanisms. These systems are designed to detect unauthorized entry into secure areas and may be programmed for up to nine or more days. An alarm is triggered whenever primary locks are opened or the alarm system is deactivated during times when entry is not allowed. Holdup switches are routinely incorporated within the control panel in case of

hostage situations.

39_5.0 Central Cash Area Design

The design of this area must be carefully planned to prevent holdup. The physical facility must not be adjacent to external walls, nor should it allow exterior access.

39_5.1 Holdups

Holdups or the threat of violence against employees cannot be prevented by the use of central cash handling. However, the system does provide a delay to signal an alarm. In addition, special bait money can be sent to the robbers.

Closed-circuit video will often connect the cash office with counter areas serving the public. Personnel in the cash office are thus in a position to provide direct information to police in the case of a holdup. Isolation locks should always be installed into access points leading to the central cash rooms. In addition, day time-delay locks, such as the S&G CS401, should be utilized. Thieves are then confronted with an insurmountable problem.

39_6.0 Centralized Money Supply for Banks (Pneumatic Dispatch Tubes)

The concept of centralized counting rooms became popular in the 1970s in order to combat robberies. Their primary purpose is to remove large amounts of cash from open counter areas, and prevent access by robbers. During business hours, currency is stored in a central cash office that is within a secure area that is inaccessible to all but authorized employees. Pneumatic tubes are utilized to transport cash and supporting documents between the counting area and tellers, drive-in counters, night safes, and ATMs. Service areas in many locations are further protected by bullet-resistant glass. When large amounts of cash are required, the teller will order the currency from the central cash office.

The normal procedure for obtaining cash from the central facility can entail:

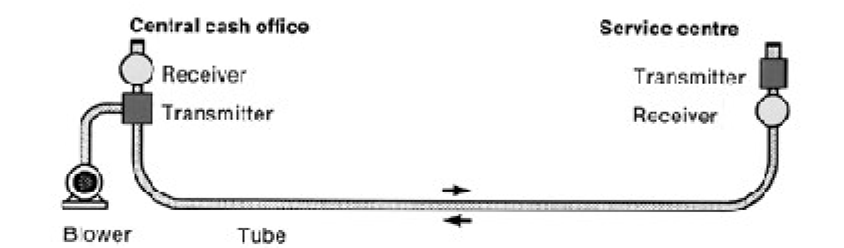
- **The customer initiates a withdrawal request directly into the pneumatic system, through an automatic**

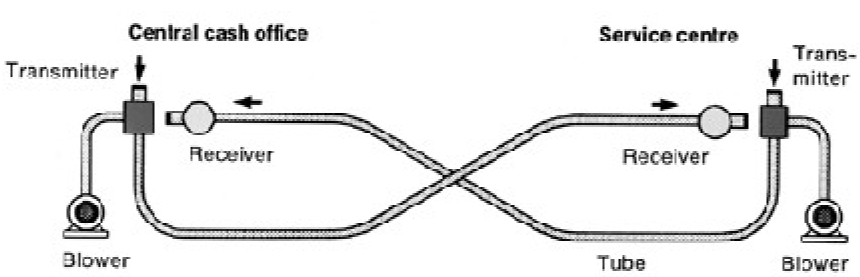
teller machine, or the customer service agent can enter the transaction into a computer terminal that is responded to by personnel in the cash center;

- **The requested amount is returned to the service center after appropriate internal verification;**
- **The amount is given to the customer by a teller, or the customer receives the money directly from the transport tube;**
- **The deposit of cash requires the reverse procedure.**

39_6.1 Pneumatic Tube Systems

Simplex and duplex transmission systems are used in pneumatic transport. In a simplex design, one tube is utilized for two-way transmission. A blower switches from pressure to suction, depending upon where the tube is going. In the duplex mode, two separate tubes are utilized. Transfer speed is usually about twenty feet per second. Disruption of transport by robbers is difficult because only one tube is sent at a time, and receipt is registered on the system. Thus, the cash center can interrupt the transfer of additional containers.





39_7.0 Daytime Cash Dispenser

The use of daytime cash dispensers can reduce the risk of daylight robbery by limiting the amount of cash that is in the control of tellers. Such devices allow large deposits and

withdrawals of cash by customers, without the necessity of transporting currency from the central cash vault.

The systems resemble a vending machine, except they dispense different denomination bank notes. Security is enhanced by electronic time lock control of each dispensing slot so that access to currency is mechanically prevented. In operation, bundles of bank notes of various denominations are placed within individual pigeonholes by a teller. They are then dispensed to customers upon demand. Deposits are made in the same fashion. Daylight cash dispensers can be thought of as safe-deposit boxes for currency and which are under the control of the bank. They prevent access by robbers to increased amounts of currency that is usually on hand during business hours.

39_8.0 Desks and File Cabinets

Desks and filing cabinets are particularly vulnerable to simple bypass techniques.

- **Drawers can be pried open if the lock vertically engages the fixed portion of the desk. A long screwdriver or wedge can be inserted between the top edge of the drawer in order to force sufficient clearance to pass the bolt;**
- **Gang-locking bars on desks can be raised to release all drawers;**
- **File cabinet locks can be bypassed using a stick knife to release a spring-loaded locking dog at the rear of the keyway;**
- **The back of file cabinets should be checked to determine if they are solid or if they will allow bypass of the boltwork;**
- **Long thin metal strips can often be inserted to the side or above a drawer in order to release a gang locking system.**

39_9.0 Electric Strikes

Certain electric strike designs may be bypassed by simulating a magnetic field near their release mechanism. For this reason, only strikes with solenoids should be utilized. Some of these devices may also be circumvented with a thin wire that is used to

activate the release mechanism or bolt release block. This problem can be resolved by installing a metal plate on the outside edge of the door.

Rapping is another technique to withdraw the locking bolt. This can occur because in certain models there is limited internal travel of the release mechanism, making it subject to shock.

39_10.0 Locking Systems

A description of different locking systems is presented in **Chapters 13 - 16**. Keying systems are described in **Chapter 11**. A locking system is a combination of devices that provide for access control on several different levels. The implementation of such schemes is done for three reasons:

- **Increase in key security;**
- **Simplified organization;**
- **Greater ease of access.**

Keying systems may include many levels of access. These are normally identified as:

- **Grand master key system;**
- **Master key system;**
- **Central locking system (Maison);**
- **Combined central locking system with master key.**

39_10.1 Unauthorized Access to Keys and Locks

Keys, locks, keying systems, locking systems, and secure containers can be compromised in many ways which is described in **Chapters 29-32, 35-36**. Primary methods include:

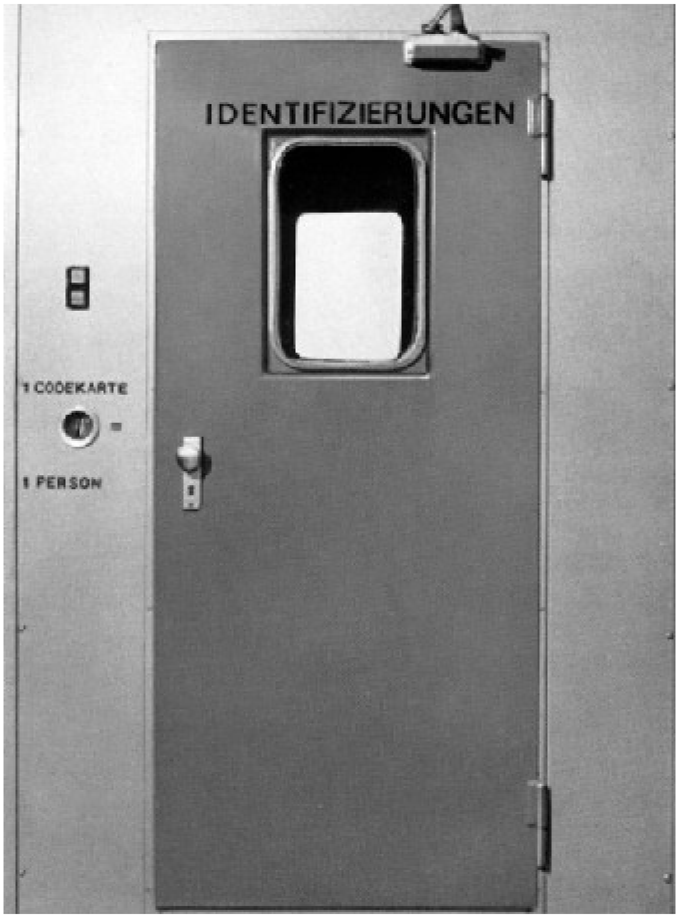
- **Decoding;**
- **Picking;**
- **Impressioning;**
- **Failure to change the combination of locks for new tenants;**

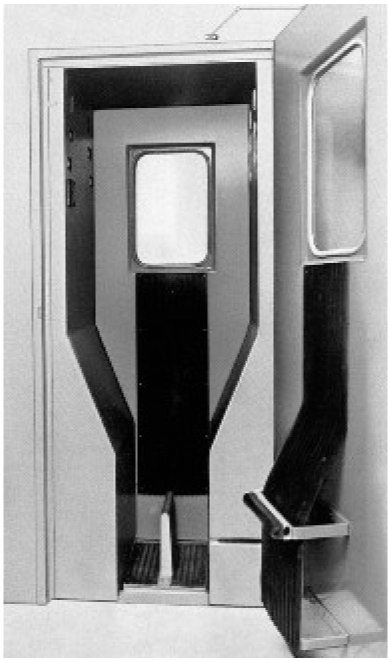
- **Failure to change factory combinations in safes and vaults;**
- **Failure to change digital combination for access control points, such as gates, garage doors, loading docks;**
- **Code numbers on keys and locks;**
- **Observation of combinations.**

39_10.2 Compromise of Locks on Entry or Exit Doors

Unless properly designed, entry and exit points can be easily compromised. Such bypass usually occurs when doors are left open or there is poor key control. A **siphon** or **isolation** door or lock is often the solution to access control problems. This is comprised of a chamber that has one entry and exit door. Each operates independently and is mutually exclusive. It is the same scheme used in prisons to prevent escape. In high-security applications, only one person at a time is permitted to enter; taking of hostages is impossible.

Isolation locks are utilized in high-security installations where a high risk of espionage, sabotage, or terrorist threat exists. Such locations include transportation control centers, power generation, water and waste processing, industrial, military, and communications facilities. Banks, cash offices, and armored car installations can also utilize the technology to prevent robbery.


IDENTIFIZIERUNGEN
1 CODEKARTE
=
1 PERSON



An isolation lock requires a specified sequence for access:

- **Open the access point with a key, code, card, fingerprint, retinal scan, or other secure means;**
- **Enter the chamber;**
- **Entry door automatically locks;**
- **Verification of authority to enter;**
- **Exit door released and opens;**
- **Individual passes through the exit point.**

Security can be heightened by taking the following steps:

- **Limitation of time when the entry point can be opened or accessed;**
- **Depress two separate control buttons simultaneously on each side of the chamber;**
- **Metal detectors;**
- **Sensors to detect presence, such as floor mats that must be touched prior to the exit door opening.**

39_10.3 Money Locks for Armored Cars

Any vehicle that carries currency and negotiable instruments is

an obvious target. Most robberies occur during loading and unloading of armored cars at a customer premises or central banking facility. The safest way to transfer cash requires transport vehicles to load and unload within secure areas called money locks. These are designed much the same as the locations within detention facilities that are used for loading and unloading of prisoners. Money locks are specifically designated locations that allow control of ingress and egress. They are equipped with heavy-duty electrically controlled gates that can only be activated from within the secure area. Ideally, a second perimeter gate must be passed through before gaining access to the money lock. Much like a prison, the facility should have electrically interlocking mutually exclusive gates. Only one can be opened at a time.

The proper procedure requires that the vehicle is driven into the lock and the entry gate is closed. After a security check, the vehicle is loaded or unloaded and then allowed to exit. Surveillance of approach routes must be easy to maintain and should not involve traffic through underground garages. An escape route must also be provided for transport staff in case of holdup or other emergency. Entry and exit should only be possible with proper identification and should never be accessible to the public.

39_10.3.1 Specific Security Guidelines for the Use of Money Locks

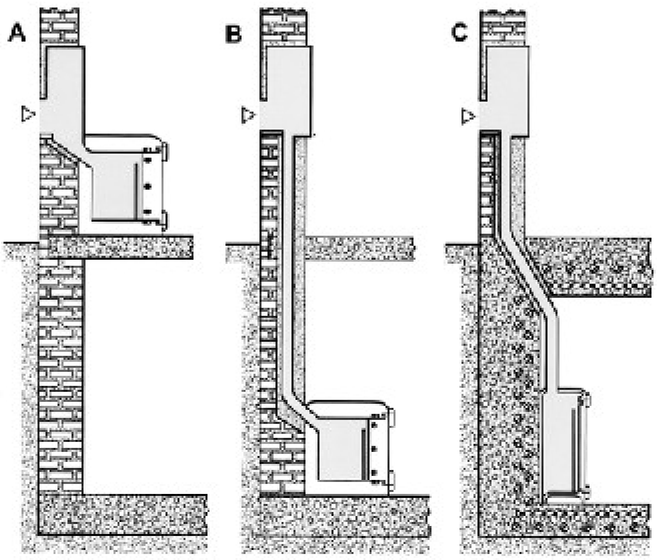
- **Approach of the courier vehicle should be announced to the bank prior to its arrival in order to avoid dangerous delays of entry;**
- **Courier staff should not be able to gain direct access to the security center that controls the money lock. Even when the vehicle is inside the lock, staff should not be allowed to exit until cleared to do so;**
- **Transfer of valuables should be accomplished through a one-way transfer counter that is controlled from a secure vantage. Bullet-resistant glass should always divide such areas;**
- **Currency and other valuables should not be stored in any location that is subject to access by staff who could be taken hostage by armed robbers;**
- **Holdup alarms should be installed at several**

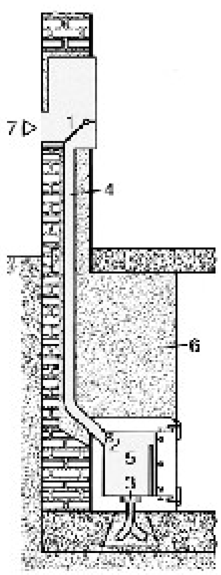
locations within the lock and control center;

- **Internal money transport from the lock should not lead through areas accessible to the public.**

39_11.0 Night Depository Safes

Banks and other institutions utilize night safes to allow customers to make deposits after hours, in the form of currency contained in envelopes, money bags or cash boxes. Night depositories can be accessed by using a key or code card.





Although there are many different designs, these security containers usually contain the following components:

- **A vault door with a deposit drawer;**
- **A shaft leading to the receiving safe;**
- **An armored stand-alone safe to receive and store currency, or a vault contained within a strong room.**

Night safes are modeled after three basic designs:

- **A deposit drawer and receiving safe in which the customer directly makes the deposit. The stand-alone safe is usually located on the ground floor;**
- **The deposit is transmitted to the receiving safe through a shaft and is not directly connected;**
- **A deposit drawer is placed at a remote point, and the receiving safe is located inside a strong room.**

39_11.1 Security Guidelines

Certain security guidelines must be followed to insure the integrity and safety of the receipt and storage of customer deposits. These include:

- **The safe must be placed in an observable position, preferably visible through a front window;**
- **The deposit point should be located in a well-lit position;**
- **Drive-up deposit facilities are popular and lower the incidence of robbery of patrons;**
- **The entry point should contain a mechanism that places the deposit envelope, bag, or box at a steep angle in order to insure that it is dropped into the safe;**
- **The connecting shaft between entry point and safe should be constructed of a minimum of 4 mm steel pipe to insure resistance to forced attack. The shaft should be surrounded with reinforced concrete of at least 20 cm thickness;**
- **A high-security cylinder must be utilized on the**

access door to the vault;

- Safes should be bolted to the floor or set in concrete in order to prevent removal or forced access;
- An automatic flap should be installed to prevent removal of contents through the deposit slot;
- If cash containers are deposited into the safe, then they should be made of non-magnetic material;
- Holes should be bored into the depository to prevent the use of water as a means to floating out the contents;
- An electronic monitoring system should be installed to include:
    - Panic alarm inside of the vault door and accessible to a customer making a deposit;
    - Surface monitoring of the shaft as well as joints between deposit slot and shaft;
  - Magnetic contacts should be used on safes not located within a strong room;
- Seismic detectors should not be utilized, as they may be set off frequently as a result of containers hitting the walls of the shaft or safe;
- Capacitance and proximity systems should be used on safes not located within strong rooms.

39_12.0 Padlocks

Poorly designed padlocks and hasps can offer the thief many opportunities for bypass. If padlocks are utilized to protect a secure area, the following assessment of vulnerabilities should be undertaken:

- A stick knife, straight knife, or stiff wire can often be manipulated through the keyway to retract the locking dog to release the shackle;
- A stiff wire or hairpin can be used in certain padlocks to rotate the locking mechanism that extends ball bearings toward the shackle;
- Failure to change factory combinations;
- Certain padlocks are programmed with progressive combinations. These number sequences are easy to test;

- **Gate locations can be tested by applying pressure to the shackle and then rotating the dial past every number. Likewise, the third number in a combination sequence can be determined by pulling on the shackle as the dial is rotated;**
- **Hasp design and hinge pins can be compromised by cutting, requiring that hasps be anchored with heavy bolts;**
- **Combinations can be easily decoded in Corbin Sessamee and other thumbwheel locks on briefcases and padlocks;**
- **Code numbers stamped on the padlock can be interpolated and used to produce keys or the correct combination;**
- **On certain thumbwheel mechanisms, the combination can be viewed when the lock is in the open position;**
- **Warded locks can be easily picked or bypassed with skeleton keys;**
- **Padlocks can often be rapped open by striking the side of the case with the shackle depressed. This will cause locking balls or dogs to "bounce" momentarily;**
- **Curved stiff shims or "sneakers" can be used to bypass locking dogs. They are wedged between the shackle and body and then rotated to separate the dog from the recessed portion of the shackle. They will not work with ball bearing locking.**

39_13.0 Peepholes (Viewing Lenses) in Doors

Peepholes are a simple and inexpensive addition to any security program. They have been employed in the hotel industry for many years and should be installed in secure areas where video monitoring is not available. They allow an employee to observe activity in front of a door, with a typical viewing angle of approximately 120°. Sufficient lighting should be available to allow all areas to be clearly seen. Mounting of peepholes should be done in such a way as to insure that they cannot be removed from the outside of the door and used as an access point for manipulation of locks.

39_14.0 Push-Button Access Locks

Mechanical and electronic push button locks are a popular form of access control. They require the proper sequence of depressions to actuate them. These devices can be compromised by observing deformities, wear, shiny spots, or dirt on the buttons that occur over time. Buttons may also be fingerprinted with UV indicating powder. The remedy for these techniques is to depress extra buttons after the combination has been entered or utilize a Hirsch scrambled keypad. In this configuration, the position of the buttons changes for each entry, making useless any information derived from dusting.

39_15.0 Radio Frequency Interference

The author has compromised certain mechanical and electronic locks and related devices with strong RF fields generated from a two-way radio. This can be an extremely effective method of bypass. In secure areas, locks should always be tested for this design deficiency. In one investigation, the author was able to circumvent an electronic parking meter system with RF at 800 MHz. In another case, several different magnetic locks were neutralized in the same manner.

39_16.0 Safe-Deposit Boxes

Every bank maintains safe-deposit vaults for the convenience of their customers. The containers provide little security and can be rapidly compromised with nose pullers. Thus, boxes must be stored in a secure strong room in order to afford maximum protection. See **Chapter 33-34**.

There are two types of locking systems used on safe-deposit boxes, depending upon the banking institution:

- **Dual locking system: Renter's lock and bank lock;**
- **Dual Locking System: Renter's lock and electronically controlled lock.**

Dual-control mechanical lever locks have been used in banks for over 100 years. However, in Europe some locations have installed electronically controlled devices to increase administrative control and security. In the electronic system, the bank employee enters the client’s data into the computer, which then releases

the lock. The box may be opened within a specified timing window, if the renter has the proper key. If not, the entire procedure will be cancelled. A complete audit of the transaction is stored for legal documentation. There are certain advantages to such centralized control systems. These include:

- **Fewer staff required;**
- **The client can open his box without the need to be accompanied by staff;**
- **Complete audit trail;**
- **The entire system is electronically monitored for tampering, failure to properly secure a box, or a customer attempting to open another box.**

39_17.0 Safes and Combination Locks: Compromise and Bypass

As detailed in **Chapters 34-36,38**, there are many methods to compromise and bypass combination locks, safes, and vaults. **Bypass** techniques pertain to physical methods of manipulation and forced-entry. **Compromise** relates to techniques that circumvent the normal security of the lock and container. Methods of compromise include:

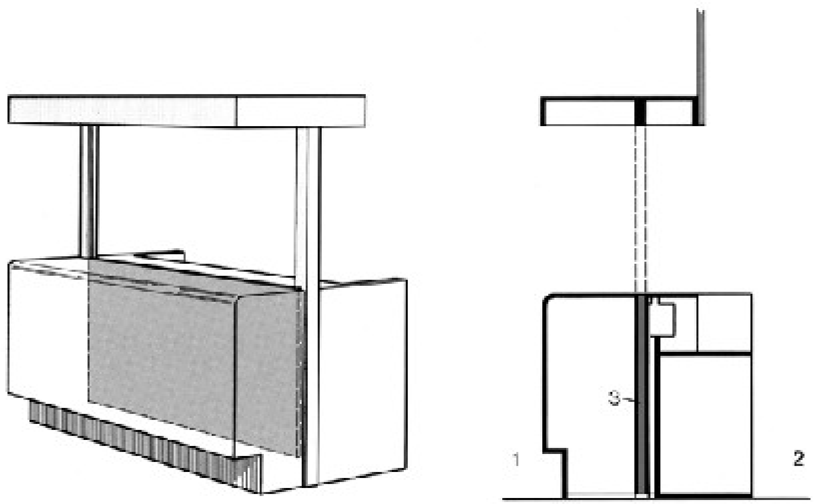
- **Failure to change factory combinations;**
- **Failure to maintain security of the combination. Many people cannot remember number sequences. In such cases, they ignore security procedures and leave the information where it can be found by unauthorized persons;**
- **Failure to properly secure combination locks by utilizing day-locking;**
- **Failure to utilize key-locking dials and dial rings;**
- **Improper use of key-locking dials and dial rings in lieu of actually engaging the combination lock;**
- **Failures to lock drawers that control secondary drawers. GSA specifications require that all drawers must individually lock in security containers;**
- **Drilling and replacement of components in order to hide the fact of entry;**
- **Covert acquisition of combination through**

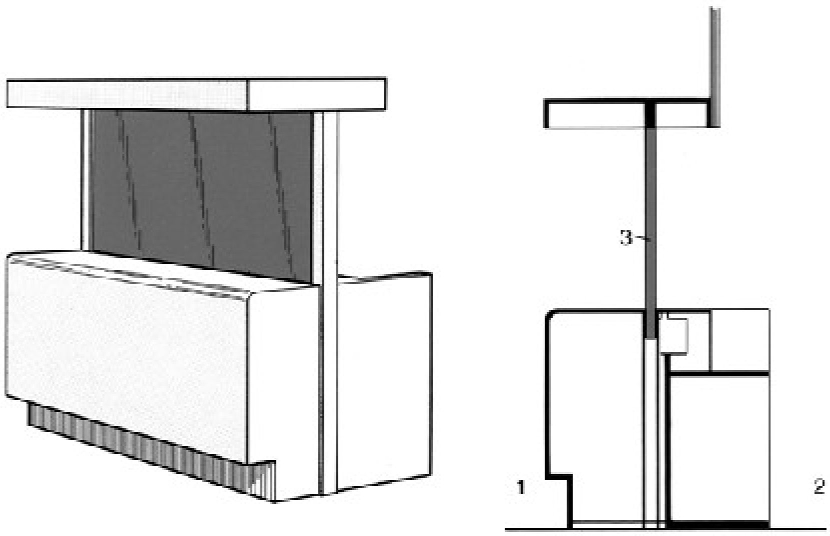
surveillance;

- **Acquisition of combination by reading position of wheel pack or changeable wheels while the safe is open;**
- **Failure to monitor the status of open safes and their combination locks;**
- **Failure to utilize spyproof dials;**
- **Fingerprinting of dials;**
- **Manual manipulation;**
- **Use of robot dialers;**
- **Radiographic imaging.**

39_18.0 Safety Counters in Banks

Special protection can be afforded to cashiers by the use of anti-bandit glazing systems. These optical and acoustic isolating safety counters are designed to separate the bank staff from customers in case of a robbery. They are not intended to protect customers but to prevent robbers from gaining access to cash and internal areas.



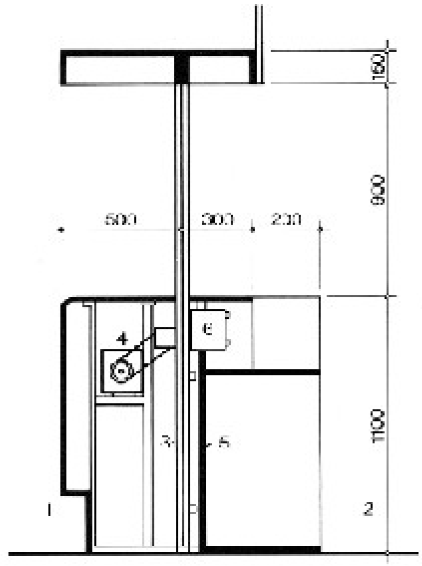


The systems require that a sufficient number of counter units are deployed to insure that all openings connecting staff and customer areas can be sealed. When an alarm is activated, a steel-plated bullet-resistant panel is raised from within the counter. This action requires less than one second from the initiation of an alarm. There are several advantages to such systems:

- **Robbers cannot gain direct access to staff. This also reduces the danger to customers;**
- **The panels are only raised in an emergency. Otherwise, normal operations are not affected;**
- **There is a greater chance that an alarm will be activated during a holdup, because the staff is protected.**

Disadvantages of such systems include:

- **High installation costs;**
- **Space utilization and design parameters may be limited, due to the shape of the counter elements;**
- **Moving panels may be blocked through jamming or by objects placed in their path. Glass panels may be installed on the customer side of the counter in order to eliminate this problem.**



39_19.0 Secondary Panes

Secondary panes of translucent material offer an economical and effective way of protecting display windows. They are often employed when laminated panes, roller shutters or bars are impractical. In many cases, it is difficult to tell that they are in place, because they do not interfere with the view of the objects on display. Secondary panes also can make electronic monitoring of display windows more effective. Glass-breakage detectors, vibration contacts, magnetic trips, or thin trip wires can be utilized to insure an immediate alarm in the case of forced-entry.

39_19.1 Mounting of Secondary Panes

Secondary panes can be mounted in three configurations: **immovable**, **wire-suspended**, and **moveable**.

39_19.1.1 Immovable Secondary Panes

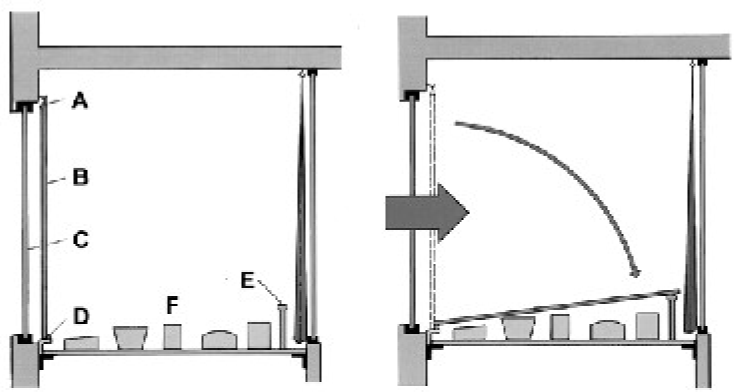
They are positioned in a frame behind the display window itself and consist of largely shock-absorbing material, preferably a polymer. The pane must be firmly affixed within the frame and the frame securely anchored in the display window. Physically, the panel must be high enough to insure that a burglar cannot climb or move over it.

39_19.1.2 Wire-Suspended Secondary Panes

A wire-suspended secondary pane is subject to circumvention by cutting the support wires.

39_19.1.3 Moveable Secondary Panes

A moveable pane, made of polycarbonate such as Lexan, is attached to the bottom end of the display window frame with a strong hinge properly fastened. A fine wire or magnet is utilized to move the pane into position. The panel is set to fall onto the objects displayed, thereby providing a cover. If the pane fully covers the display area, it is impossible for a burglar to reach the merchandise. To be effective, moveable panes must also be installed on any side-windows.

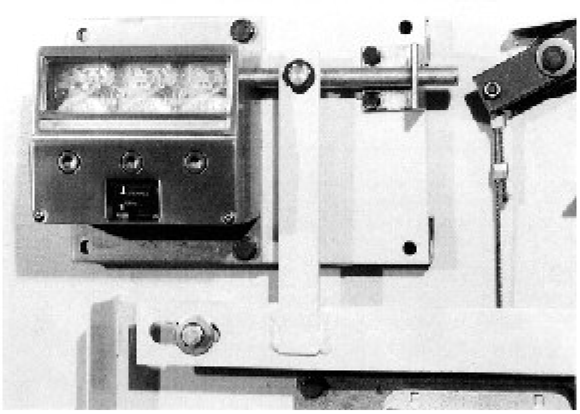


The separating wall that isolates the display window with the interior of the premises must be solid and stable in order to prevent an intruder from climbing into the premises, then lifting the secondary pane. Another barrier of translucent material, mounted in a solid frame, should present a further obstacle to entry to the building **through** the display window.

39_20.0 Time Locks

The origin and use of time locks was discussed in **Chapters 33** and **34.** The focus of the following discussion is on their use in preventing robbery and unauthorized access to secure areas. Time locks were invented to reduce the incidence of robberies and kidnappings involving the forcing of employees to open safes and vaults. They are an American invention and are extremely effective. It is important that the public be aware that time

locks are in use within the bank or other facility; signs are usually posted as a deterrent.



A time lock will block the boltwork for a predetermined time and can allow it to be actuated during a specified period. Entering the correct combination will not defeat the lockout, thus knowing the code or having the key will do no good. Time locks will not allow an unscheduled opening, even in an emergency.

The movements are usually equipped with two, three, or four individual clocks. Most are still mechanical, although electronic systems are gaining popularity because of the many options they offer. The devices are fail-safe, because each clock operates independently; each can release the block on the boltwork. Sometimes, one of the backup clocks is set to a lesser opening period in case of failure.

Mechanical time locks can usually be programmed for up to 144 hours. The microprocessor-based systems can be set for a year in advance, to include special dates and holidays. It is also possible to install blocking time relays as an alternative to time locks. These are remotely controlled and thus can be bypassed. They are not suitable to prevent hostage-taking during a robbery.

39_21.0   Tubular (Axial) Pin Tumbler Locks

Tubular locks are extremely popular in vending, alarm, and access control applications as described in **Chapter 17**. They are a pin tumbler mechanism and are configured so that the pins are oriented around a 360° circumference. When a key is inserted, it

depresses each of the pins to shear line in order that the core may rotate.

Some of these locks may be defeated by applying hair spray or 3M Spray-Ment adhesive to the pins to overcome the spring bias. When the proper key is inserted, the tumblers will stick at shear line. This will allow the plug to be turned later by using a torque wrench.

39_22.0 Video Surveillance Systems

The use of video has become an integral part of electronic security systems anytime local or remote monitoring of high-security areas is required. Video systems accomplish three essential functions: surveillance, identification, and documentation.



39_22.1 Components of the System

There are five primary components to any video system:

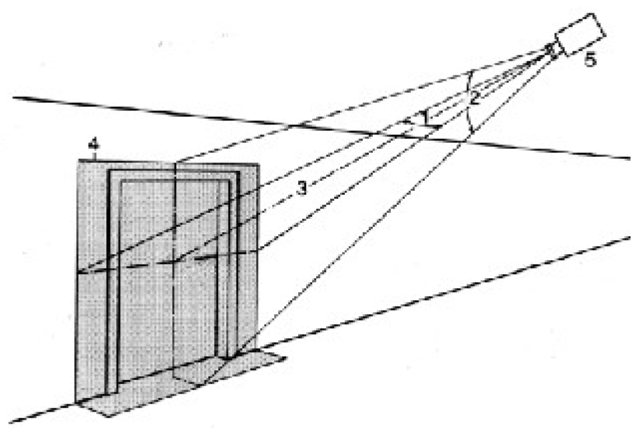
- **Camera;**
- **Encoding system;**
- **Transmission system;**
- **Monitor;**
- **Recorder.**

39_22.1.1 Camera

The function of any camera is to capture and convert visual images into an analog or digital signal. Today, cameras are based upon charge coupled device (CCD) technology. This integrated circuit is capable of converting a focused image into digital information on a single chip. A video camera consists of a lens, CCD, microprocessor to control synchronization, video amplifier, and impedance matching device to conform the output to a transmission link.

In older camera systems, an image was captured with a pickup tube. Depending upon vintage, these were known as a Vidicon, Newicon, Plumbicon, or Ultracon. The Vidicon is perhaps the most popular and is still in service in thousands of cameras. In any pickup-tube, a light-sensitive layer was activated by an electron beam, called a cathode ray. The beam was horizontally and vertically controlled through electromagnetic deflection coils.

Focus (mm)	⅔" pick-up tube Angle of image (degrees) horizontal	vertical	1" pick-up tube Angle of image (degrees) horizontal	vertical
4.5	89	72	-	-
6.0	72	58	94	77
8.0	58	45	77	62
12.5	39	30	54	42
16.0	31	23	44	33
25.0	20	15	29	22
50.0	10	7.5	15	11
75.0	6.7	5	10	7.3
100.0	5	3.8	7.3	5.5
150.0	1	0.75	1.5	1.1



39_22.1.1.1 Vidicon Tubes

Although today they are obsolete, the Vidicon was predominant for almost twenty years. Because many of the cameras are still in service, a brief amount of information will be provided here. The Vidicon offered the means of providing video cameras for the security industry, because the tubes had a long service life at relatively low cost. Consequently, the use of video became extremely popular and cost effective.

The tube is based upon a technology that builds an electronic image by interlaced scanning of individual lines. In the United States system (NTSC), each **field** is comprised of 262 lines. A **frame** is made up of two fields, for 525 lines. A Vidicon requires suitable illumination; it is not responsive to low light levels.

The tube also suffered from a high degree of inertia, wherein moving images could smear or appear to be sluggish. It also has a serious burn-in problem; a powerful light source focused on the same location can cause permanent damage. This was one reason for the camera failure during a transmission from the Moon; it was inadvertently pointed at the sun.

39_22.1.1.2 Other Pickup Tube Technology

The Newicon tube was an enhancement that allowed for both indoor and outdoor surveillance. It was light sensitive, with a low burning sensitivity and inertia. The device did not suffer from another common problem called blooming, wherein light dots would expand. Unfortunately, the Newicon was very expensive as compared to the Vidicon and was not practical for most applications. Infrared sensitivity was not particularly good, either.

The Ultricon was yet another replacement for the Vidicon and offered several advantages. It had high sensitivity to light across the entire spectrum, from ultraviolet to infrared. It did not suffer from burn-in and had a low degree of inertia.

The silicon intensifier target (SIT) is an image intensifier having an extremely high sensitivity to light. It is used in available-illumination cameras and early-generation night-viewing devices.

The Plumbicon was the most expensive pickup tube available and was used exclusively in studio cameras. It offered the highest image quality and could cost up to $100,000. The tube had very low inertia, low burn-in sensitivity, and fine resolution.

39_22.1.1.3 Charge Coupled Device

Today, virtually all cameras utilize CCD technology. This chip set contains a light-sensitive photo array that generates different signals based upon intensity and color. A microprocessor scans the individual elements at a rate of about 250,000 or more times per second. The CCD requires very low power levels and is quite small. Cameras can be built into any item and are ideally suited for undercover and surveillance work.

39_22.1.1.4 Camera Location

Cameras must be placed to provide the desired view without interference from external sources. Several issues must be

evaluated and considered in choosing the proper camera and placement location:

- **Type of camera: color or monochrome;**
- **Resolution of pickup tube;**
- **Correct lens, with focal length that will allow sufficient clarity of target area;**
- **Select location to provide an unobstructed view of target area;**
- **Avoidance of bright light sources that will interfere with the picture;**
- **Camera should not face windows;**
- **Outdoor cameras must be mounted at a sufficient height to prevent tampering;**
- **Utilization of a secure housing for outdoor placement.**

39_22.1.2 Encoding System

Video may be encoded in a number of different formats, depending upon transmission medium, storage requirements, and national standards. In the United States and many other North American countries, NTSC is the accepted format. In most of the rest of the world, PAL or SECAM has been adopted as the encoding protocol. These systems are all analog rather than digital. The difference in these formats relates to scanning rates, lines per field, bandwidth, and the method by which color is interpreted. NTSC and PAL cameras are utilized for surveillance applications, with the appropriate recorders.

In the future, images may be encoded in digital format, with high definition television (HDTV) on the horizon. Within a few years, HDTV may become the transmission standard in all industrial countries. It appears that the new system will provide superior resolution but requires a great deal of bandwidth to do so.

In surveillance applications, both analog and digital cameras are prevalent today. The NTSC format is still the most popular and cost effective, although this is expected to change in the next few years.

39_22.1.3 Transmission Link

The image output from a camera must be transported to a monitor

and recording device. The mode of transmission depends in part upon whether the signal is analog or digital, and if it consists of full motion video or a series of still images. There are several means to transmit a video image, including coaxial cable, fiber optic link, twisted pair, RF, Intranet network, or the Internet.

39_22.1.3.1 Cable

Coaxial cable is the primary means of transmission for video signals, because it is capable of transporting the required wide bandwidth associated with images. Coax is inexpensive and easy to work with and is usually terminated in “F” style crimp connectors. These are the same as used in the cable television industry. Images can be carried on cable for hundreds of feet without appreciable loss and attenuation. Depending upon the grade of coax, a run of up to approximately 800 meters (2,624 feet) can be utilized without an amplifier or repeater. With such equipment, signals can be transported up to three miles.

39_22.1.3.2 Fiber Optic Link

Converters and direct fiber outputs are now available on some video cameras. Using a fiber optic link, signals can be carried up to 30,000 feet without need for additional line amplifiers or equalization equipment. FO cable has extremely low loss characteristics and has the capability of carrying many video and audio signals within one fiber bundle.

Fiber is inexpensive, secure, and easy to terminate. It is also impervious to electrical noise and interference that may affect signals carried on coaxial cable. This characteristic is especially important in environments where equipment radiates such energy.

39_22.1.3.3 Twisted Pair

Twisted pair and two-pair systems have been utilized for many years to feed video signals a short distance. Standard telephone circuits can be employed to transmit still images and slow-scan video, negating the need for coaxial cable or fiber. Useable transmission distances may be up to one mile. Several vendors now produce equipment that allows a small encoding and impedance-matching unit to interface with cameras and recorders at each end of a twisted pair. Excellent quality can be obtained with these systems at a relatively low cost.

39_22.1.3.4 Intranet or Internet

Surveillance video is now being transported on internal computer networks (Intranets) and on the Internet. These systems offer many advantages, including:

- **Ease in transmission;**
- **Transmission infrastructure is already in place;**
- **High-quality digital images;**
- **Polling of locations;**
- **Increased range over traditional systems;**
- **Remote access and control functions;**
- **Dial-up access from remote locations;**
- **Transmission of images anywhere in the world over the Internet;**
- **Software for viewing, capturing and recording of images is readily available.**

39_22.1.3.5 Radio Frequency (RF)

Video signals can be transmitted with a carrier frequency on cable or in free space. If a carrier-frequency system is utilized on cable, then video signals are modulated on high-frequency carriers, so that many different sources can be carried on one link. These systems are utilized by cable television operators who may carry 100 channels on one coax.

Microwave link systems at 2.4 GHz and 8 GHz are also in wide use by government agencies. These provide for broadcast-quality video to be transmitted for a range of up to five miles. The author is routinely involved in covert surveillance operations that utilize 2.4 GHz body transmitters and cameras. These are used to feed video and audio from undercover operatives to remote receiving equipment. In such a system, the transmitter weighs a few ounces and is easily concealed. This same technology is utilized in fixed surveillance operations where cameras must be placed at remote locations not suitable for wiring.

Internet enabled wireless cameras are now quite prevalent and inexpensive. These generally systems utilize 802.11b protocol at 2.4 GHz and will allow for remote control of all functions. Each camera is assigned an IP address and can be addressed from anywhere in the world.

39_22.1.4 Monitor and Reproduction Technologies

A means to monitor and record surveillance video must be provided. These functions are usually combined within a control room or secure operations area. Traditionally, a bank of monitors coupled to video recorders allows security personnel to observe special locations within a facility. Although more expensive, color camera and monitor equipment is recommended for almost every application. The exception may be low light level situations that require increased sensitivity. Color cameras provide less operator fatigue and greater capability for identification. Differences in color can become extremely important, especially where there are many potential targets in one image.

Screen size and monitor location must be considered in terms of convenience, functionality, and ability to observe displayed information. The general rule is that the distance between monitor and observer should not be more than four to six times the diagonal size of the screen. The location of the monitor is important in order to reduce glare and enhance the ability to observe images.

Any video surveillance system must incorporate a time-date generator and identification of camera location. This data must be imprinted on the tape for evidentiary purposes. If a multiplex system is utilized wherein several cameras are integrated into one screen, then camera identification is especially important. Many recording systems capture quad frames that are composed of four different video segments. Each can be viewed as a full screen image, if desired. Each frame will contain its own identification information as to location and time/date.

39_22.1.4.1 Image Analysis Systems

Image analysis systems provide an alarm when there are definable changes in a video image. The technology allows one security guard to effectively observe many different locations by providing the means to target portions of an image for movement or difference. Any change will trigger an alarm, and activate a recorder. Certain areas of an image may be excluded from monitoring, also. These systems do not respond to gradual changes in the picture, such as caused by lighting level differences from clouds or transition from day to night. They will alarm in case of tampering or loss of supervision of the transmission medium.

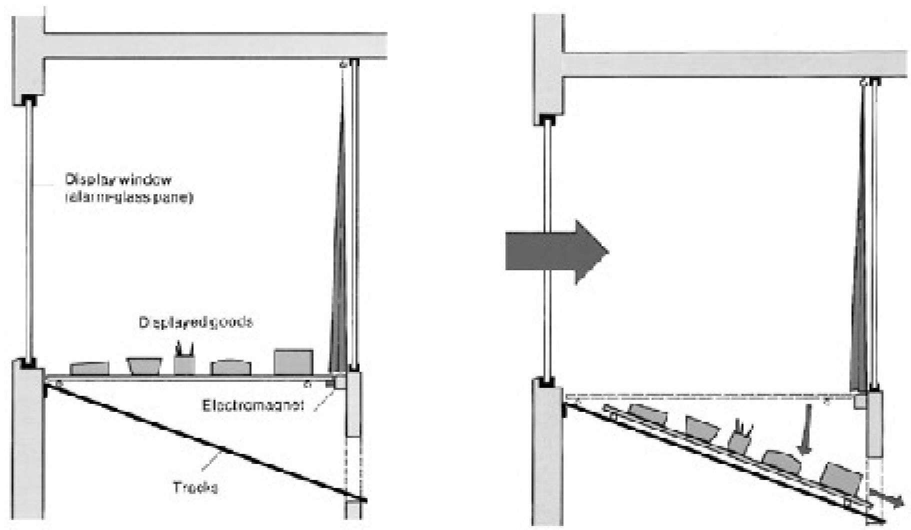
39_22.1.4.2 Video Recording

Video images and audio may be recorded on magnetic tape, hard drive, optical or magnetic disc. VHS and 8 mm magnetic tape is the most popular and cost effective. Recording may be done in real-time or time-lapse up to one month on one cassette. If time-lapse recording is utilized, it is recommended that 8 mm format be employed rather than VHS. In the author's experience, these systems provide superior picture stability and playback resolution.

39_23.0 Trapdoor Security Devices

Trapdoors are popular in Europe for the protection of merchandise in display windows. They are utilized to automatically remove goods in case of a smash-and-grab burglary. The platform is constructed as a moveable display surface that rolls into the interior premises upon initiation of an alarm. The panels are held in their normal position by an electromagnetic bolt. In case of glass- breakage, a signal is transmitted to the release system and the platform containing the goods roll into the store. Certain guidelines apply to the use of security trapdoors:

- **The display surface should not be larger than 4 square feet (1.5 m^2);**
- **The display merchandise must not exceed the height of the opening into the store, so that the platform is not stopped from moving;**
- **The entry point for the moving platform must be secure to prevent access from the window side.**



CHAPTER FORTY:

Alarm Systems

Master Exhibit Summary

foil

LSS401: E Field protection

LSS401: Buried Cable sensors

LSS401: Fence alarm system

LSS401: Microwave sensor systems

LSS401: Outside passive infrared sensors

LSS401: Photoelectric sensors

LSS401: Thermal imaging and sensing

LSS401: Video logging and capture systems

LSS401: Alarm contact devices, including magnetic switches

LSS401: Discussion regarding pressure mats

LSS401: Embedded screen wires

LSS401: Alarm foil

LSS401: Grid wires in alarm systems

LSS401: Ribbon switch material as a sensor

LSS402: Shock sensors for glass break detection

LSS402: Other types of shock detection sensors

LSS402: Trip wires in alarm systems

LSS402: Alarm monitoring systems

LSS402: Defeat techniques for different sensor technologies

LSS402: Glass break sensors and how they work

LSS402: Issues with microwave sensors

LSS402: Alarm sounders and notification devices

LSS402: Ultrasonic alarm sensors

LSS402: Proximity sensor technology

LSS402: Alarm defeat methods for dual technology devices

LSS402: Passive infrared sensor technology

LSS403: Fiber optic fence sensors

LSS403: Shock sensors utilized to protect fences

LSS403: Magnetic point sensors

LSS403: Dual technology devices utilized in outside environments

LSS403: Ross Anderson on alarm system monitoring

LSS403: Magnasphere technology

LSS403: DOE on perimeter sensors and their defeat

LSS403: DOE on alarm assessment

LSS403: DOE on sensor technology

LSS403: DOE on layers exterior protection

LSS403: DOE on a typical plan of attack on a facility

LSS403: Defeat of magnetic switches, including BMS

40_1.0 Introduction

LSS403: DOE on a typical plan of attack on a facility

The function of any alarm system is to reliably signal the entry of intruders or an irregular event within a protected area as soon as possible. Alarm systems do not prevent or hinder intrusion; they just provide an immediate notification so that action can be taken.

Alarms are now an integral part of most security systems. They utilize state-of-the-art electronics that offer a sophisticated array of technologies to sense intrusion or irregular events. This chapter will examine electronic monitoring systems, with an emphasis on procedures, functions, and individual components. To be effective, alarm systems must work in conjunction with other security measures that are based upon sound design and organizational practices. Adjunct security measures (defense in depth) include lighting, video monitoring, access control, physical security hardware, and guards.

Extensive materials have been added to this chapter regarding specific types of alarm sensors that did not appear in the Second

Edition. Much of this material has been excerpted from the ***Perimeter Security Sensor Technologies Handbook***, prepared by Naval Command, Control and Ocean Surveillance Center, In Service Engineering (NISE East), Electronic Security Systems Division. Materials and technical assistance have also been provided by Don McInnes PSP, SET, Jerrold Antoon, CPP, RL, and Ken Wippich, recognized physical security consultants in the alarm industry. Appreciation is also expressed to Fox Valley Technical College (Appleton, Wisconsin), ADT Security Services, Inc., Denning Electronics, and Nuclear Security Services Corporation for their input and assistance. Other materials were received from Ross Anderson, Cambridge Computer Laboratory, in England. Finally, video, graphics, and procedures manuals were supplied by the United States Department of Energy and the **DOE(442)** Office of Security and Safety Performance Assurance. Their assistance is greatly appreciated.

40_1.1 Alarm System Overview

LSS403: Ross Anderson on alarm system monitoring

Electronic monitoring is an indispensable part of perimeter and internal security. The primary goals and design parameters of any alarm system include:

- **Supplant physical barriers;**
- **Detect intrusion as soon as the event occurs;**
- **Notify authorities as soon as detection occurs;**
- **Complicate and delay ingress;**
- **Delay access and the collection of stolen goods or property or ability to reach a target;**
- **Require more time for egress;**
- **Make each phase of an intrusion more risky in terms of apprehension.**

Alarm systems should be designed to detect and signal an intrusion as soon as possible. This should provide a sufficient response time for personnel, commensurate with the value of the protected property. Each sensing device must be reliable, and subject to continuous monitoring for integrity. All critical points or targets of ingress and egress should be protected electronically.

Alarm reporting may occur by direct supervised connection (leased dedicated circuit or sub carrier circuit) to a central station, dial-up to a monitoring facility, wireless link, or local alarm to an internal control center. Local audible or optical warning systems may also be implemented as a deterrent. The effectiveness of any alarm system is based upon the following criteria:

- **Competent design;**
- **Redundant and overlapping coverage;**
- **Proper installation;**
- **Reliability of each component;**
- **Correct operation by employees;**
- **Protection against unauthorized bypass;**
- **Response time.**

Alarm systems should either be automatically activated, or have a fail-safe mechanism if staff forgets to activate them. Logs should be provided to indicate any alarm faults or activity. Inexpensive stand-alone devices on doors, often battery powered, cannot be considered as burglar alarms. An alarm **system** is comprised of sensors, control unit with backup power, and links to a central station or other monitoring facility.

Preliminary evaluation of alarm systems must include the following issues:

- **Type and design of control unit;**
- **Number of control units;**
- **Number of circuits to the central facility;**
- **Emergency power supply type and duty cycle;**
- **Complexity of the alarm system;**
- **Type and number of sensors;**
- **Vulnerabilities of each sensor;**
- **Identification of individual sensors, and analysis of each alarm condition that they are designed to detect;**
- **Anti-tamper and integrity circuits;**
- **Verification that all trips are functioning properly before the system can be activated;**
- **Electronic supervision of all alarm circuits.**

40_1.1.1 Operational Requirements

The utilization of security hardware and procedures depends upon the specific facility and unique requirements that it may dictate. Any **perimeter** security system has four primary goals: **deter**, **detect**, **document**, and **deny** or **delay** intrusion. Operational requirements must balance the factors listed below with respect to protection, technology and cost. Factors that influence the application of security measures include:

- **Type of facility or material to be protected;**
- **Existing culture and security awareness;**
- **Willingness to accept security countermeasures and follow procedures;**
- **Nature of the environment;**
- **Client's previous security experience and threat history;**
- **Any perceived threat;**
- **Nature and tempo of activity in and around the facility;**
- **Physical configuration of the facility to be secured;**
- **Surrounding natural and human environment;**
- **Weather variations;**
- **Traffic patterns;**
- **Access to the facility;**
- **Personnel and vehicle screening requirements and barriers;**
- **Potential threats that are unique to the type of facility;**
- **Budgetary considerations, including:**
    - **cost of hardware in relation to protected area;**
    - **cost of installation and maintenance;**
    - **construction costs;**
    - **alarm center modification that may be required.**

40_1.2 Regulations Regarding Alarms

The regulations and stipulations regarding the manner in which an alarm is to be activated are different for every jurisdiction. For example, in some places it is not permitted to combine silent alarms and audible alarms. Information about the relevant requirements can usually be obtained from the police. Many cities have enacted comprehensive ordinances and regulations regarding the installation, maintenance, programming, and reporting of

burglary and fire alarms. Failure to follow specified technical requirements can subject business owners to fines.

40_1.3 Alarm System Procedures

Organizational procedures must be adopted to insure reliable operation with a minimization of the potential for false alarms. In some jurisdictions, penalties are assessed for malfunctions that result in a law enforcement response. Alarm systems must be properly set by employees in order to function reliably. Those responsible for activation must be correctly trained in procedures relating to setup, malfunction, bypass of zones, and reporting. A system must be designed so that areas can be segmented and certain rooms deactivated for cleaning, maintenance, and other tasks. After-hours entry must also be considered.

Individual passwords for each employee should be mandatory so that entry and exit tracking logs are maintained. Access codes should be routinely changed, especially in the case of termination in employment status. Routine inspection of trips for bypass and to test all trips, especially normally open types, is essential.

40_1.4 Alarm System Considerations and Planning

Alarm sensors and systems must be selected and installed based upon the requirements of the specific location and object or area of protection. Suitable devices must provide adequate monitoring to insure the security of the asset or area and eliminate the prospect of compromise.

Certain types of alarm trips can be bypassed without much difficulty. For that reason, the planning and implementation of electronic protection should be done by knowledgeable technicians who thoroughly understand bypass techniques and idiosyncrasies of each classification of trip, as shown in the accompanying videos. Any alarm system that protects exposed objects must be designed so that it cannot be circumvented or avoided and that the correct device for the intended purpose is chosen.

Many considerations must be taken into account when planning and implementing an alarm system. Preliminary determinations include:

- **Will volumetric sensors are subject to false trips due to the construction materials utilized in protected areas. Microwave devices see through walls. Thus, it is important that proper tests be conducted to insure that movement in adjacent areas does not create false alarms;**
- **Has the appropriate classification of sensor been deployed for a specific application;**
- **Concentration of exposed objects within a limited area can lessen the cost of protection, although this can also make it easier for a burglar to collect goods;**
- **Physical security devices (fences, barriers) are just as important to an electronic monitoring system as sensors;**
- **Special precautions should be taken when electronic holdup switches and push buttons are used to manually signal an emergency because of the incidence of false alarms;**
- **Sensors that are tripped in the normal course of a robbery or burglary, such as bait money contacts, are desirable;**
- **The use of any detection device should not disturb work processes;**
- **Layers of perimeter security must be employed to delay or prevent entry. These include fence lines, in-ground sensors, and volumetric devices such as microwave and infrared.**

40_1.5 System Reliability

One of the most common problems with intrusion detection systems is that they can generate an inordinate number of false alarms. A high rate of false and/or nuisance alarms may cause the protective force to ignore or improperly assess an unauthorized intrusion. If a system is not planned and implemented properly, increased susceptibility to false and nuisance alarms will be the result. This is especially true when microwave sensors, infrared sensors, electric field sensors, seismic sensors, and buried sensors are employed.

False alarms result from many factors. Such issues can also be used as a cover for intruders in order to cause the protection staff to believe that a false alarm has occurred. Thus, lightning is a perfect cover for initiating multiple alarms to defeat a system. Specific vulnerabilities include:

- **High winds;**
- **Telephone ringing;**
- **Noise;**
- **Lights;**
- **RF interference;**
- **Heavy rain;**
- **Temperature extremes;**
- **Terrain irregularities;**
- **Animals (sounds and movement);**
- **Heavy snow;**
- **Air turbulence;**
- **Lightning;**
- **Vehicular vibration;**
- **Wind-blown dust and debris.**

System reliability, in terms of sensors, transmission links, and the central processor is critical. A reliability factor of 100 percent would mean that there were no false alarms and that the system would only react to a real intrusion or violation. Sabotage or compromise would always trigger an alarm. Unfortunately, this level of reliability is unattainable. Presently, over 90 percent of all alarms are false. This results from many factors, including employee error, environmental considerations, poor system design, and other issues that cannot be controlled.

In metropolitan areas, false alarm rates as high as 98 percent are common. The result: law enforcement is less willing to respond in a timely manner. Many jurisdictions now charge the property owner for false alarms. They have also enacted comprehensive ordinances for the installation and maintenance of all burglary and fire reporting systems.

Many factors and parameters contribute to a reliability rating. These include:

- **Resistance to tempering and compromise of any**

component within the system;

- **Supervision of all transmission circuits including internal links to each trip, and externally to a central station facility;**
- **Protection from malicious interference;**
- **Reliability of sensing device and immunity to false trips;**
- **Alternate power supply. Reliability requires that a system be capable of operating for up to 72 hours from a battery or other backup power supply. Automatic and uninterrupted switching to alternate power sources must occur;**
- **Wireless trips should be avoided, as they may not be reliable and can be subject to interference. Systems that use wireless technology that operate in the 305-316 MHz band or on carrier-current over power mains should be avoided, if possible;**
- **If wireless links to monitoring facilities are employed, redundancy must be built into the system.**

40_1.6 Intrusion Detection and Assessment, Threats, and Inspection

Assessment is often given the lowest priority in security system planning. The process provides an evaluation of a possible alarm condition and a response, which may include the deployment of a protective force, verification of an alarm with a sophisticated video monitoring system, sealing of certain areas, or the initiation of other procedures. High tech sensors, fancy consoles, and other sophisticated systems may cause one to lose sight of the fact that in the end analysis, a human must make a decision as to whether there is an intrusion, and react accordingly with an appropriate response. An intrusion detection and assessment system has four primary functions:

- **To alert the protective force to intrusion;**
- **Aid in alarm assessment;**
- **Allow the protective force to track intruder progress toward a target;**
- **Aid in assessing intruder activity and characteristics (for example, the number of intruders and whether they are armed).**

40_1.6.1 Failure to Properly Assess and Respond

Many design deficiencies in an intrusion detection and assessment system can lead to a breach in security and a failure to respond to a valid alarm appropriately. Such design errors can include:

- **A high rate of nuisance and false alarms may degrade operator response to real alarm conditions;**
- **Failure of a system to adequately identify alarm type and specific location can also degrade response;**
- **Failure of a system to clearly differentiate between tamper-indication, line supervision, and intrusion alarms;**
- **Multiple sensors are monitored by a single circuit;**
- **Computer-based systems are also vulnerable. Problems can arise because of erroneous software modifications and system configurations that cause program errors;**
- **Failure of the received signal from the detection device to provide identifiable evidence of the actual occurrence so that an operator can properly assess the situation and respond accordingly.**

40_1.6.1.1 Inspection Protocol

In order to properly assess the security of a specific site, inspectors must plan their method of evaluation, and gather a significant amount of information so that they are certain that they are properly assessing site-specific security risks and how they are being addressed. The individuals that are responsible for the site survey must accomplish the following tasks, prior to actually examining each component that makes up a security system. Specific issues that must be considered include:

- **Review of the site mission (obtained from a review of the documents and from interviews with operations office personnel and site representatives);**

- **Review of all documentation relating to a site, systems, and security. This would include:**

    - Organization charts;
    - Site security plans and procedures;
    - Security plans for temporary secure areas;

- Incident reports;
- Site/facility asset list;

- **Site maps indicating the location of layered security areas;**
- **Critical or sensitive areas that require special attention, including:**

    - vaults and vault-type rooms;
    - critical facilities;
    - controlled areas;
    - location of security posts;
    - classified areas;
    - vital equipment areas;
    - hazardous materials storage areas, including toxic and flammable chemicals and nuclear materials;
    - transfer routes for critical materials and assets;

- **Listing of the types of sensors employed;**

- **Local alarm reporting devices;**

- **Data transmission systems:**

- **Site lighting diagrams;**

- **Console equipment descriptions;**

- **All alarm procedures;**

- **Review of the assessment methodology employed (CCTV, video, and/or patrol response);**

- **Review of the vulnerability analysis, including consideration of:**

- Application of the design basis threat. In other words, what specific threats were identified for the specific site, and what system design components were integrated into the security system in order to protect against such threats;
- Review of site-specific threats to determine whether they

address local characteristics, including the insider threat;

- **Priority of site-specific threats target definitions and specific locations that are graded as to defense-in-depth measures that have been implemented. Specifically:**

- Type and location of potential targets;

- Compile a list of site assets, group them into appropriate categories, and determine potential impacts related to their loss;

- Pathways that can provide the lowest level of detection and/or shortest delay to ingress and egress;

- Listing of the protective elements identified in the vulnerability analysis for each security interest;

- **Review the validity of threat assumptions for current accuracy. This would include consideration of:**
    - Comparison of vulnerabilities against findings and resolution of past inspections and security surveys;
    - Review of protective methods employed at the location to be inspected;

40_1.6.1.2 Performance Tests

The following performance tests are recommended for alarms and intrusion-detection devices:

- **Exterior perimeter sensors;**
- **Interior sensors;**
- **Perimeter CCTV;**
- **Interior CCTV;**
- **Alarm processing and display equipment;**
- **Emergency auxiliary power supplies;**
- **Tamper protection and line supervision;**
- **Data collection activities;**
- **Alarm annunciation and sensitivity;**

40_1.6.1.2.1 Exterior and Interior Sensors

During inspection of any **perimeter intrusion detection assessment system** (PIDAS), inspectors should verify the following:

- **Examine the various types of sensors to determine whether they are complementary. They must consist of different sensor types that cannot be defeated by the same means, rather than just multiple layers of the same sensor;**

- **Confirm the existence of an effective testing and maintenance program for the PIDAS;**

- **Check the condition of the PIDAS ground for obstructions, mounds and valleys, and other terrain features that an adversary could use to avoid the detectors;**

- **Crossover and interface points should be checked to determine whether there are voids or blind spots in sensor coverage;**

- **Identification of PIDAS sectors that are susceptible to bridging as a result of their close proximity to tall buildings, fences, telephone poles, or light and camera structures;**

- **Evaluate any unsecured or unprotected access ways that could allow tunneling beneath PIDAS sectors;**

- **Within each alarm monitoring center, visually inspect all equipment, interview the operators, and verify information gathered during document reviews. Check the following:**

    - Operability of equipment;
    - Operators' familiarity with equipment;
    - Measures to protect equipment from tampering;
    - Determine if all alarms that are reported from the field are properly recognized and acknowledged, and that appropriate responses are made. Insure that all personnel understand their responsibilities with regard to assessment and reporitng;

- **At each exterior security sector or area where a PIDAS is employed, determine:**

    - Number and configuration of sensors;
    - Sensor alarm logic;

- Test frequency and methods;
- Preventive maintenance frequency and methods;
- Tamper-indicating provisions;

- **Provisions for repairing component failures;**

- **Determine the methodology utilized by staff to detect an intrusion at each security area. If more than one method of detection is used at a security area (for example, an electronic alarm system and direct observation from guard towers), determine how each system complements the other;**

- **Determine which system is considered the primary means of detection, and whether the combination (primary and backup) is effective;**

- **At selected interior security areas and storage areas, determine:**

  - Types of sensors that are used to protect building perimeters (including doors, windows, and other penetrations);
  - Testing and preventive maintenance and their frequency and methods;
  - Tamper-indicating provisions;
  - Provisions for repairing component failures.

- **Determine whether the facility has more than one central alarm system and, if so, the geographic area that each system covers. For each separate alarm system, verify:**

  - Central processing unit switching capability;
  - Tamper alarm features;
  - Adequate primary and backup power supply;

- **Determine the technical aspects of the system;**

- **Determine what the capability is for intrusion detection when the primary systems are out of service.**

- **Power Supplies:** Backup or emergency auxiliary supplies are required for all security systems. Verify the operability of these supplies. This procedure is normally accomplished in

conjunction with tests of lighting systems.

40_1.6.2 Assessment and Response

An evaluation of assessment and response of the system to various alarm conditions is essential in order to insure that security objectives of the facility are met.

A perimeter system, to be effective, must provide complete coverage. This is especially important in areas with alarmed fence lines that form a boundary between security area perimeters, and that also rely upon visual observation to assess alarms. One person should walk the perimeter fence line while others are stationed in the alarm center or observation posts (that are assigned responsibility for that portion of the perimeter). Each sector of the perimeter can be checked sequentially. In this way, the staff can verify that there are no blind spots. Moving randomly from post to post by inspectors is recommended.

- **Observe and verify the operation of CCTV systems, including:**

- Display monitors, during a range of lighting and weather conditions

- At different times of the day and night;
- Under various weather conditions. It may be wise to review tapes that have been produced on each video recorder that were made during different weather conditions;.

- Verify that camera and recorded video review capabilities are rapid enough to capture adversary activity. Generally, this is accomplished once during the day, and once at night;

- Fields of view;
- Adequacy of lighting;
- Blind spots or obstructions;
- Overlap with adjacent zones.

- **Identify the areas where direct visual observation is the primary means of detecting intrusion or assessing alarms. Determine:**

- Type of observation post (tower, portal, continuous patrol);
- Assessment aids available to protective force personnel (search lights, night vision devices, binoculars, camera zoom capability);
- Methods used by the facility to test effectiveness and maintain the requisite level of vigilance;
- Determine the operability of equipment and power supplies;
- Measures that have been implemented to protect equipment from tampering;

40_2.1 Primary System Components

Alarm systems that are available today can be simple and self contained, or highly sophisticated with many types of sensors. The inherent security within any system varies greatly. Every alarm system has four primary elements; **sensors, a central processor, transmission link,** and **local or remote method to receive and annunciate an alarm.**

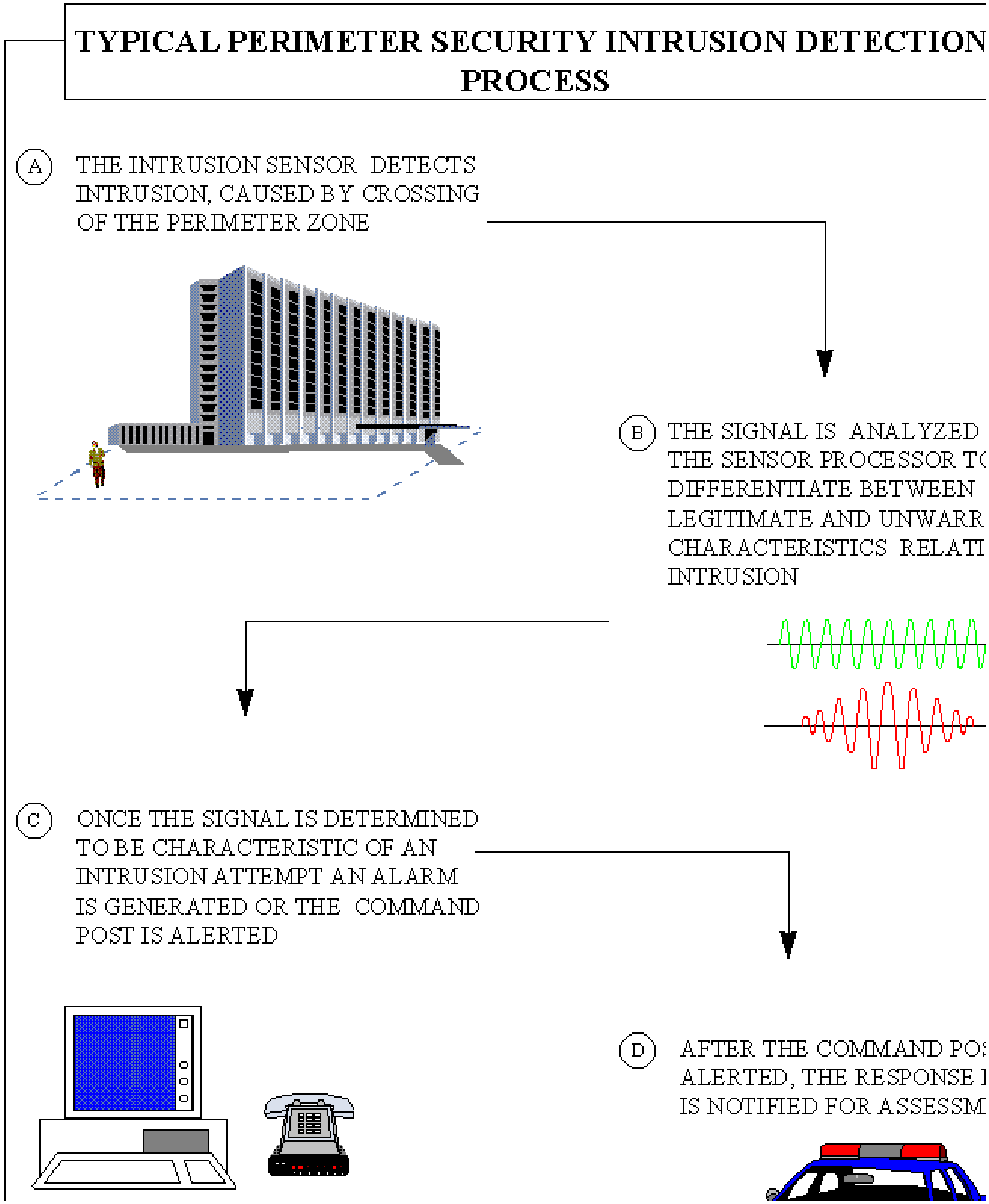

TYPICAL PERIMETER SECURITY INTRUSION DETECTION
PROCESS
A
THE INTRUSION SENSOR DETECTS
INTRUSION, CAUSED BY CROSSING
OF THE PERIMETER ZONE
B
THE SIGNAL IS ANALYZED
THE SENSOR PROCESSOR T
DIFFERENTIATE BETWEEN
LEGITIMATE AND UNWARR
CHARACTERISTICS RELATI
INTRUSION
C
ONCE THE SIGNAL IS DETERMINED
TO BE CHARACTERISTIC OF AN
INTRUSION ATTEMPT AN ALARM
IS GENERATED OR THE COMMAND
POST IS ALERTED
D
AFTER THE COMMAND PO
ALERTED, THE RESPONSE
IS NOTIFIED FOR ASSESSM

**Figure LSS+4036 An alarm system encompasses many components. This diagram represents
a typical perimeter security intrusion detection process. Courtesy Perimeter Security
Sensor Technologies Handbook.**

40_2.1.0 Technology Solutions

The sophistication of sensing equipment allows for the design of intrusion detection systems to meet virtually any requirements. The importance of the human element, combined with proper procedures, cannot be overstressed. It is the responsibility of personnel to monitor, operate and maintain all systems. Even more importantly, they must respond to each alarm and properly assess its validity.

Intrusion detection sensors have been designed to provide for perimeter and interior security, and include sensors for use in the ground, open areas, inside rooms and buildings, doors, and windows. They can be used as stand-alone devices with other sensors. In most applications, intrusion detection sensors are employed in conjunction with a set of physical barriers, personnel, and access control systems. The selection of sensors begins with a determination of what has to be protected, its current vulnerabilities, and the potential threat. All of these factors are elements of a risk assessment.

40_2.1.1 Sensor

This component is designed to detect changes based upon force and movement within a protected area. As will be described subsequently, there are many classifications of sensors, based upon the required level of surveillance and the environment. Although the proper integration of sensor technology into a coherent security system is relatively straightforward, it requires a system design analysis in concert with a review of parameters dealing with operational, installation, and specific security requirements.

Often, sensors have the capability of being utilized for both interior and exterior protection. Others have very specific limitations and function. The exterior sensor is utilized to detect entry into zones that create a perimeter of protection. In contrast, the interior sensor will be employed to detect penetration within an enclosed area, or movement within that

area.

In most applications, two or more sensors complement each other to provide added coverage, reliability, and a reduction in false alarms. Sensors can be set to work in tandem; their detection must be coincidental to verify an alarm condition.

The output configuration for most sensors is fairly standard: relay contacts to indicate alarm and tamper conditions. The output is generally linked by two or four wire conductors, often protected by a resistor network (end-of-line resistor) to indicate a change in line characteristics that would indicate tampering, opening or shorting of the circuit. In this way, monitoring and supervision can thus be assured.

40_2.1.1.1 Detection Factors

There are seven primary factors that will affect the Probability of Detection (PD) for most sensors (including volumetric). Each factor must be analyzed in choosing the appropriate sensing technology for a given location. The critical factors include:

- **Amount and pattern of emitted energy:** The sensor will perform more effectively as the more definitive is the energy pattern;

- **Size of the object:** A larger sensed object will result in a higher reliability that it will be detected;

- **Distance to the object:** The sensitivity of the sensor is optimized at shorter distances;

- **Speed of the object:** The greater the movement of the target, the more reliable will be the detection;

- **Direction of movement:** A target that is moving faster and laterally from the sensor will be detected more reliably than a target that is moving slowly and straight-on. As will be seen, this is dependent upon the characteristics of each sensor;

- **Reflection/absorption characteristics of the energy waves produced by the intruder and the environment (e.g. open area, shrubbery, or wooded);**

- **Contrast between the target and the environment:** The greater

the contrast between the target object and the overall reflection/absorption characteristics of the environment (area under surveillance), the greater the probability of detection.

40_2.1.1.2 Sensor Applications

Sensors are generally classified by their application and sensitivity to certain kinds of events. They are designed for specific environments and for exterior or interior deployment. Throughout this chapter, different applications are described, together with possible countermeasures to reliable operation.

40_2.1.2 Central Processor and Control Unit

A central processing unit receives information from one or more sensors, analyzes the data, and initiates the appropriate action by sending a valid alarm to a responding agency or local alerting device. There are many different kinds of monitoring systems, all with varying options. Regardless of the brand, most processors perform the same functions: they interface with a variety of sensors, evaluate the information, annunciate an alarm, and display the trip and location. Today, most system are computer-based and utilize Windows, DOS, or UNIX operating systems. Some rely upon proprietary software, developed by a specific vendor.

Most units contain one or more microprocessors to provide sophisticated functions that include:

- **Ability to simultaneously monitor up to 128 or more individual trips;**
- **Simple operation of control functions;**
- **Clear layout of instruments and components;**
- **Sophisticated and reliable anti-tamper systems;**
- **A logic evaluation unit that analyzes the status of many different types of sensors and properly responds to signals or signatures that are based upon preprogrammed criteria;**
- **Supervision of internal transmission links between sensors and the central processor. These monitoring facilities must constantly evaluate the wiring or links between detectors, processors, and local activating devices. The monitoring system may be based upon a constant signal, fluctuating signal, or**

a combination of each. The processor must be capable of measuring interference with transmission links by sensing a change in loop resistance, differences in line current, or other parameter. All components, including detector housings, junction boxes, conduit, alarm units, and wiring must be continually monitored;

- **It must be impossible for the user to place the system in an armed mode unless all trips are functioning properly;**
- **It must be impossible for the user to cause a false alarm by placing the system in an armed mode because a trip is not properly set or is malfunctioning;**
- **The processor must have the ability to evaluate the coincidence of signals from complex trips that incorporate more than one sensing technology, to insure device redundancy and reliability;**
- **Ability for programming of individual trips for entry-exit, perimeter, interior, fire, burglary, holdup, temperature, water and other hazards;**
- **Ability to create different zones of protection for immediate or delayed perimeter, interior, and entry-exit;**
- **Ability to program specific criteria for a trip within any zone;**
- **Ability to determine the method of signal transmission, including local alarm, direct central station connection, dial-up, and wireless;**
- **Ability to individually authorize any number of employees for entry and exit into specific zones and to track log-in;**
- **The processor can be activated with a keypad, key switch, door lock, wireless device, from a remote center, or automatically, based upon a preset time or event.**

40_2.1.3 Transmission of Alarm Signal

One of the primary functions of a central processor is to alert responsible individuals or agencies that there is an alarm. Reporting can take many forms that is based upon individual security requirements. The options for reporting include:

- **Local alarm to a light, bell, siren, pager, radio system, or internal control panel;**
- **Wireless transmission to central station;**
- **UL central station alarm that is connected by a direct link to the processor;**
- **Dedicated central station monitoring facility that is connected with a dial-up circuit, direct hardwire circuit, cellular radio connection, carrier current, dedicated radio system, or satellite link;**
- **Police department or answering service termination on a dial-up or direct connection basis.**

40_2.1.3.1 Wireless Links

There is an increasing use of wireless devices to link sensors with alarm processors, either on premises, or at a central station. Some of these devices are quite simple in design, while others utilize cellular or spread spectrum, digital encoding, and code hopping. However, many can be compromised through various means, including:

- **Code grabbers;**
- **Grounding an exposed antenna;**
- **Jammer transmitters to blind or desensitize the receiver;**
- **Cutting or removing the antenna;**
- **Simulation of acknowledgement from alarm processor or central station;**
- **Denial of service attacks.**

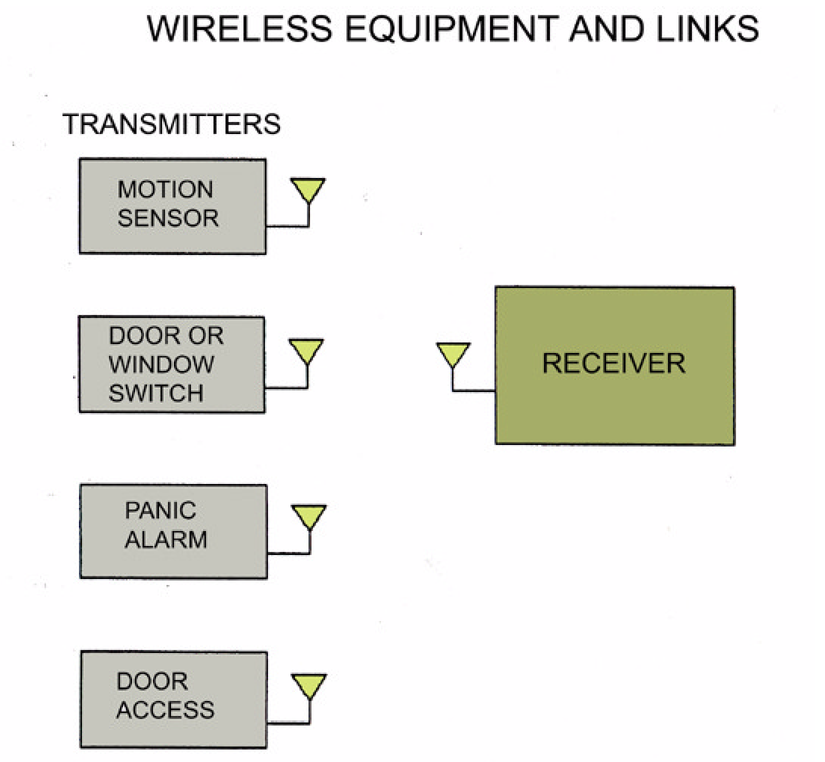




Figure LSS+4037. One of the original dial-up alarm reporting devices, used in

the nineteenth century.

40_2.1.4 Reporting Systems

The signaling format by which an alarm signal is actually transmitted varies by equipment manufacturer, although there is industry standardization to some extent. Reporting systems include:

- **Analog tape dialers or solid state devices5///////5555555555555555555555/ that provide a non-supervised verbal message as to the type of alarm and location to a specific telephone number. These are usually transmitted by dial-up and are not reliable;**
- **Digital dial-up systems that transmit information regarding location, subscriber account, and identification of trips, using a variety of signaling formats, including:**
  - **DTMF (touch tone, high and low speed);**
  - **FSK (frequency shift keying);**
  - **SF (single-frequency pulse tone);**
  - **Data (serial);**
  - **Proprietary data format;**
  - **Encrypted data;**
- **Voltage and current sensitive loop monitoring at direct-wire central station;**
- **Voltage reversal or current sensitive loop monitoring at direct-connect monitoring center;**
- **Wireless protocols:**
  - **spread spectrum**
  - **packet**
  - **discreet frequencies**
- **20 Hz sub carrier.**

Sometimes, a manufacturer will utilize a proprietary transmission protocol that can severely reduce future system expansion or upgrade, and will limit the choice of competing equipment. In such systems, special processors may be required to interface between central and field processing elements of the system.

40_2.1.5 Alarm Signal Receiver or Annunciator

LSS402: Alarm monitoring systems

LSS402: Alarm sounders and notification devices

The receipt and resultant display or announcement of an alarm depends upon whether the termination is local or remote and silent or audible. There are many alarm assessment systems that can provide both visual and audible alerts. Today, many systems are computer-based and will display alarm status on a flat panel display, CRT, LCD, or a detailed multilevel map of a protected area. The status of a trip and the immediacy or priority of required action is also an option on many systems. The integrated reporting systems can provide an excellent comprehensive view of the status of protected premises or facilities.

40_2.1.5.1 Local Alarms

Local alarms are of limited value, especially in rural areas, and are usually installed as a deterrence in order to reduce damage or loss. Typically, the system may sound a loud bell or siren, turn on lights, lock doors, or alert a pager. They are particularly valuable for signaling fire, flood, temperature, and environmental conditions. The local alarm must be loud and denote by its sound that it requires action. The system should also have some sort of automatic reset or shut-off feature to provide for false trips. Unfortunately, local alarms are largely ignored in major cities due to the high false alarm rate.

40_2.1.5.2 Remote Central Stations

The alarm signal may be directly transmitted to a monitoring center. Although a local indication may also be provided, silent alarms are often the rule, especially in banks and other facilities where the threat of hostage-taking is of concern.

The central station operation offers twenty-four hour service, security, repair facility in most cases, and assurance that the system is working properly. Central stations usually have direct links to the radio rooms of the area police departments to alert them immediately of incoming alarms and to reduce response time. In addition, many of the companies have their own radio dispatched vehicles and armed guards to respond to the alarm. The personnel are trained to interpret the validity of alarm signals and can make a determination as to whether or not to dispatch

police cover. Many remote monitoring sites are now using video over TCP/IP to verify alarms. The use of a central station will often lower the insurance rates for a particular business.

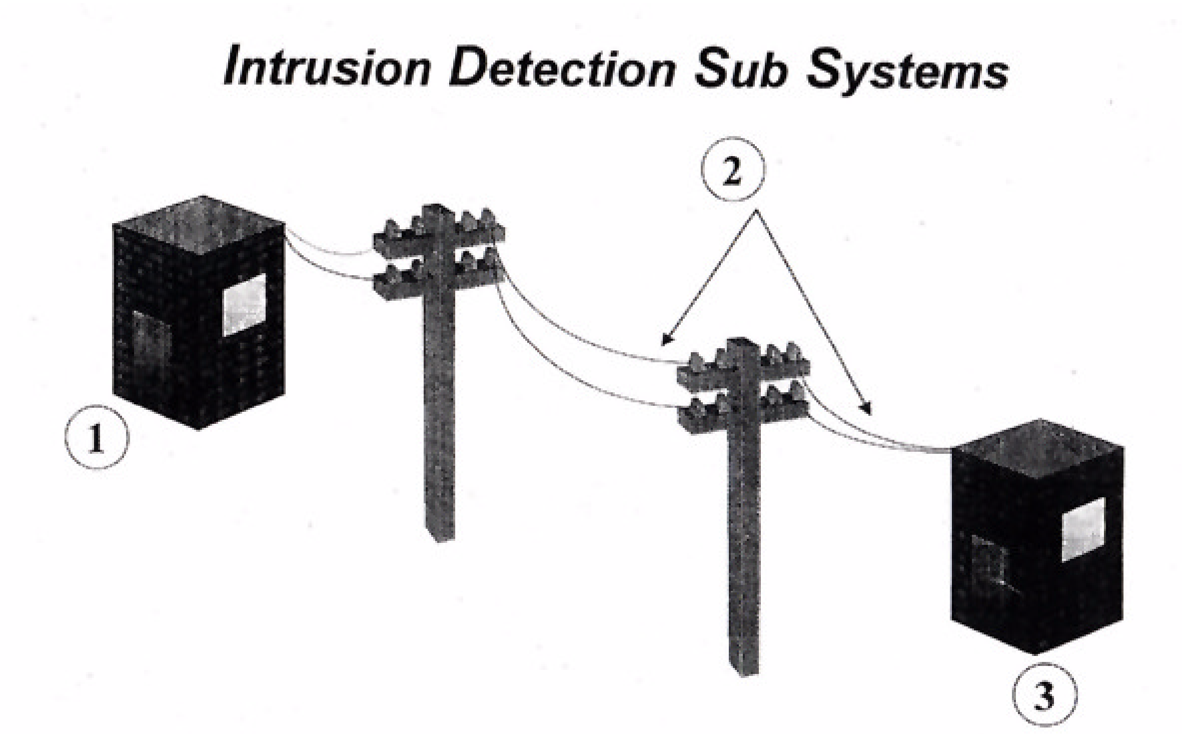


Figure LSS+4070 Intrusion detection sub systems are concerned with three primary areas: (1) protected premises, (2) transmission links, and (3) security command and monitoring center.

UL certified central station monitoring facilities exist in every major city. Many companies also monitor alarm circuits on a nationwide basis by dial-up over telephone lines. These facilities receive detailed information regarding the location of the alarm and identification and designation of trips. Upon receipt of a signal, the alarm center will notify the proper agencies and individuals from a list provided by the customer. This process can usually be performed in less than one minute.

Links to central monitoring facilities can take many forms: dial-up, wireless, or direct connection. Multiplexing of signals may also occur over a single link, channel, pair of wires or path. This allows data transmission from several sources to utilize one link, through a combination of polling, sampling, monitoring and interrogation. There are two primary multiplexing schemes that utilize one common path for transmission: **frequency**

division and **time division.** Frequency division multiplexing is a process for the transmission of two or more signals by sending each signal at a different frequency. Time division multiplexing allows transmission of two or more signals at different time segments.

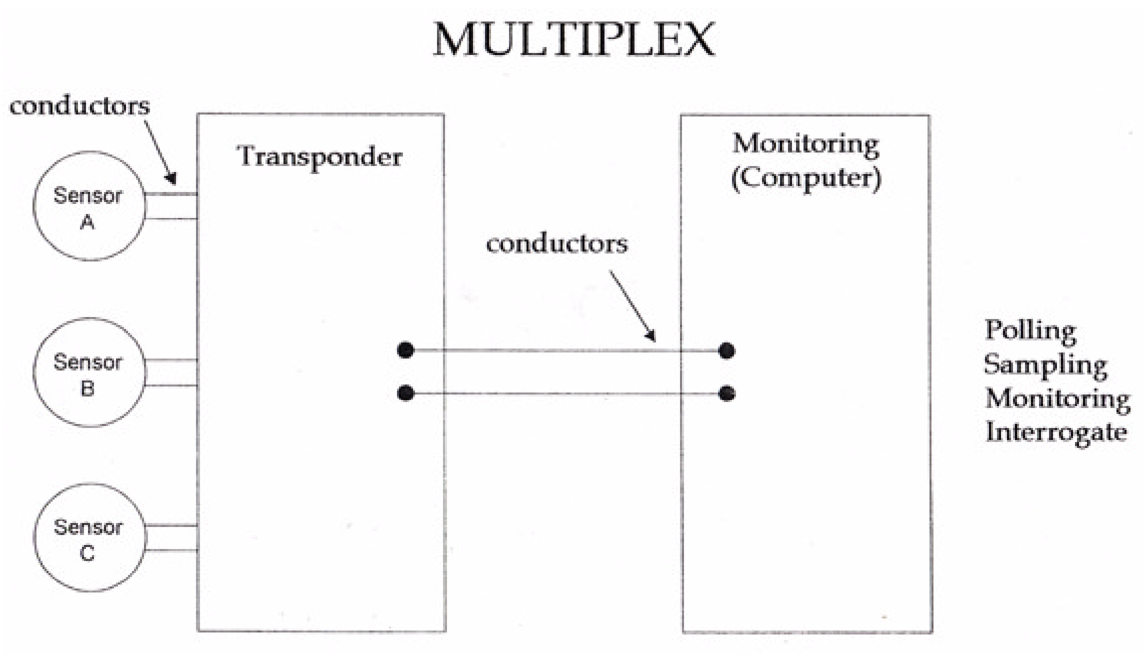


Figure LSS+4071 Signals can be multiplexed over one transmission path from several different sources.

40_2.1.5.2.1 Transmission Security and Supervision

Circuits to central station facilities are directly connected, dial-up, RF link, or sub carrier. Line supervision is inherent in direct-wire links and will vary, depending upon the security that is required. There are three recognized levels of supervision: **high security electronic line supervision** (HSELS), **medium security electronic line supervision** (MSELS), and **low security electronic live supervision** (LSELS). Whatever degree of supervision is implemented, the system should be capable of detecting cutting, shorting, and spoofing.

- **High Security Electronic Line Supervision (HSELS)**

HSELS is line supervision that either cannot be compromised or can only be compromised by a person with technical expertise and

knowledge of the system, using intensive pre-attack computer analysis. The only line security technique meeting HSELS requirements is full data encryption using, at the minimum, the National Bureau of Standards (NBS) Data Encryption System (DES II), or equivalent, with a user changeable key. It is recommended that HSELS only be employed in installations that protect critical assets where the associated sensor system normally provides security comparable to that of the HSELS. This level of encryption is only effective if the key is changed on a periodic basis and the associated sensor system provides comparable security to that of the HSELS.

The use of HSELS for transmission links result in:

- Line security that generally far exceeds the security of the underlying system;
- Higher initial equipment cost;
- Higher operating costs because of the requirement to periodically change the encryption key.

- **Medium Security Electronic Line Supervision MSELS)**

MSELS refers to line supervision that can only be compromised by a person with technical expertise and knowledge of the system, substituting a complex device (microprocessor, microcomputer, or multiple active logic devices) on the data lines. MSELS requirements can be met by using polling or multiplexing techniques. This form of line supervision can further be enhanced by: using a randomly selected start point for each polling cycle and randomly selecting whether to poll in an ascending or descending order on each polling cycle. Polling in a random sequence assumes that the polling time is not degraded.

MSELS provides line security that is comparable to the security afforded by most sensor systems. Therefore, use of MSELS is recommended for all but the most critical installations. Security of systems that employ MSELS can be further enhanced by making data lines less accessible (burying and installing in rigid conduit) and by ensuring that all sensor lines between the remote collection device and the sensors are kept within the protected area.

- **Low Security Electronic Line Supervision (LSELS)**

LSELS can be compromised by a person with technical expertise and

knowledge of the system, substituting a simple passive device (resistor, capacitor, inductor, or combination of these) or active device (tape or digital recorder or simple filter) on the data lines. Line security techniques meeting LSELS requirements are voltage and current loops using end-of-line termination impedances, tone, and phase systems. These techniques are normally utilized in systems with a separate data line that is run to each sensor zone.

LSELS is recommendation for use only in the simplest of installations which are small in size, and entirely within a protected structure. Security of systems using LSELS can be further enhanced by making data lines less accessible (burying and installing in rigid conduit).

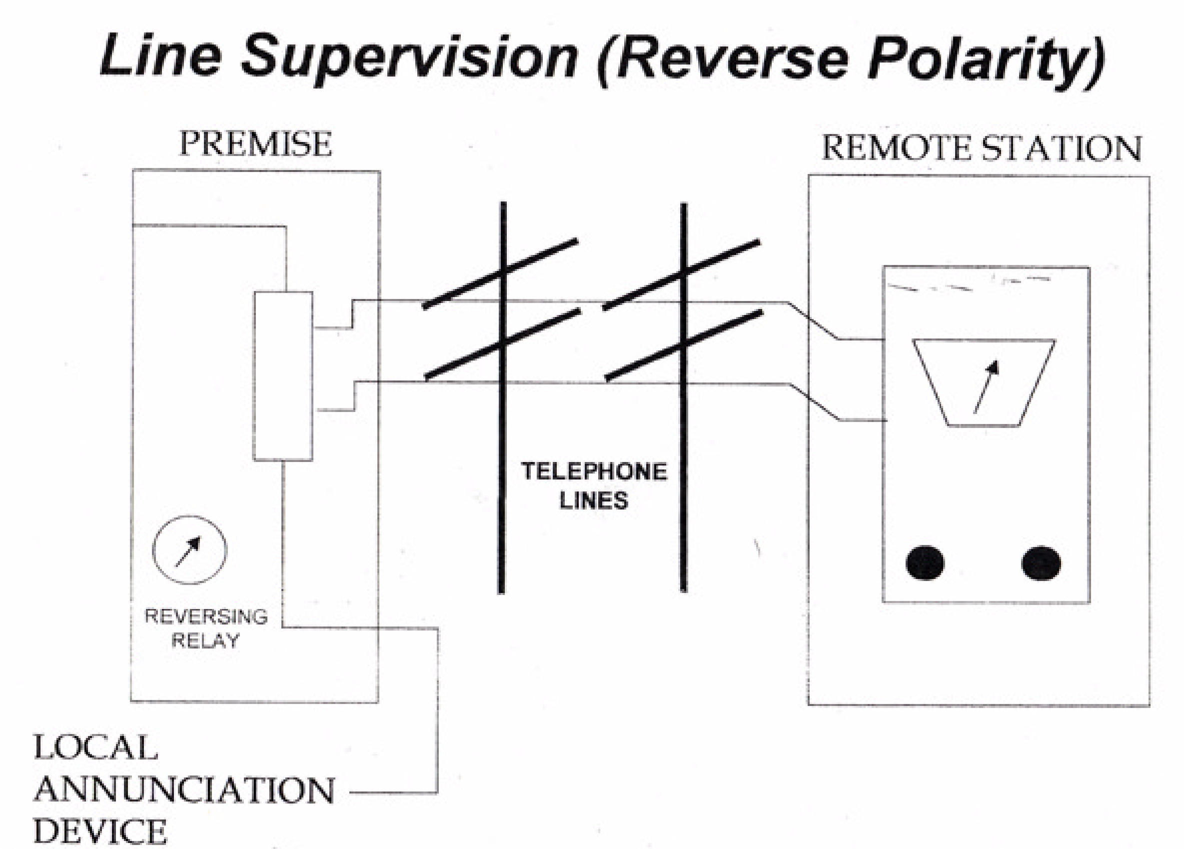


Figure LSS+4072 Line supervision can take many forms. Reverse polarity is a very old technique that requires the DC polarity of the circuit to reversed upon an alarm condition.

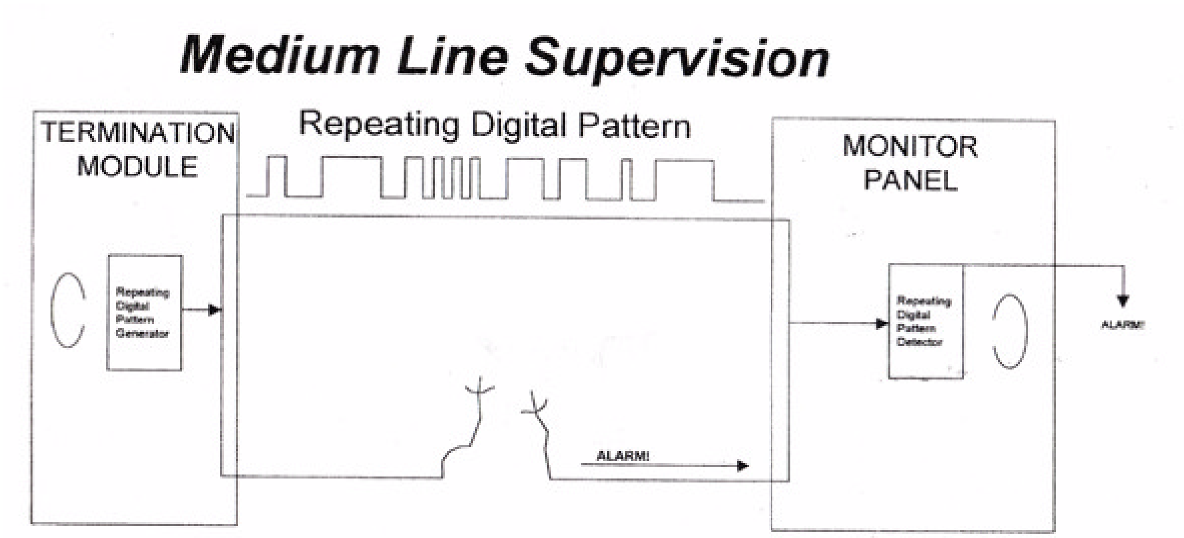
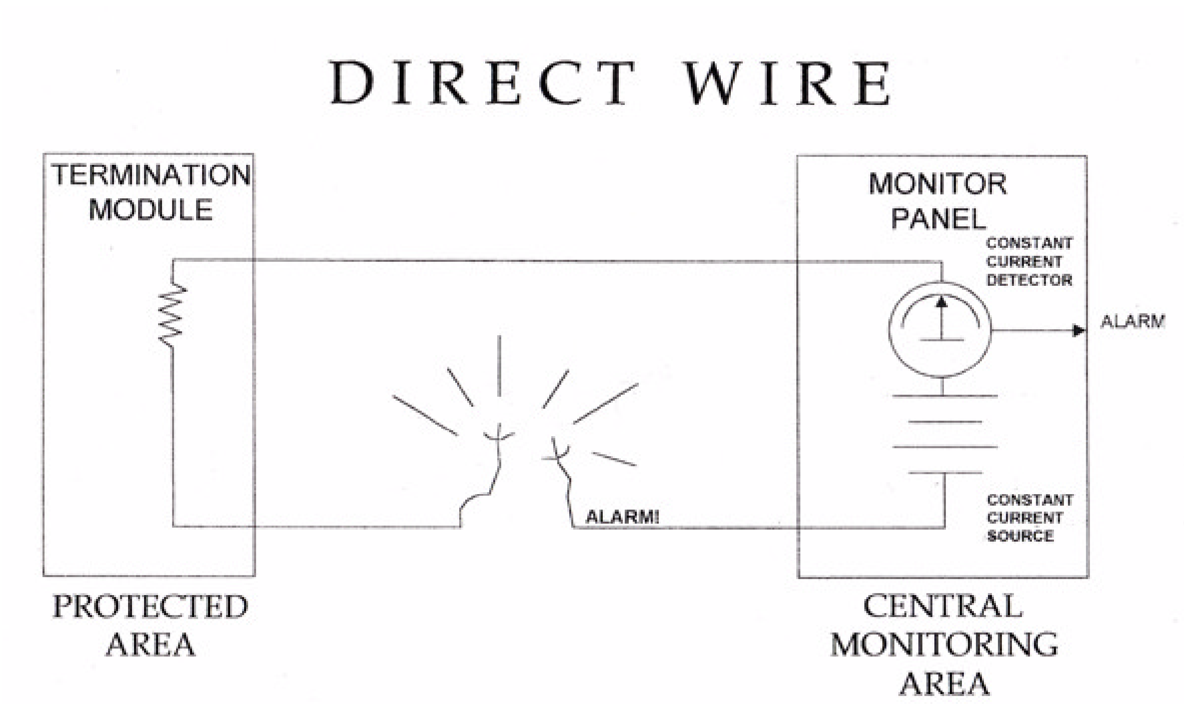


Figure LSS+4073 Medium line supervision provides a level of security that requires an intruder to have technical expertise and knowledge of the system to be able to bypass it. These systems can often be sniffed and spoofed by inserting devices along the transmission path, as shown in the diagram.

40_2.1.5.2.1.1 Direct Connection



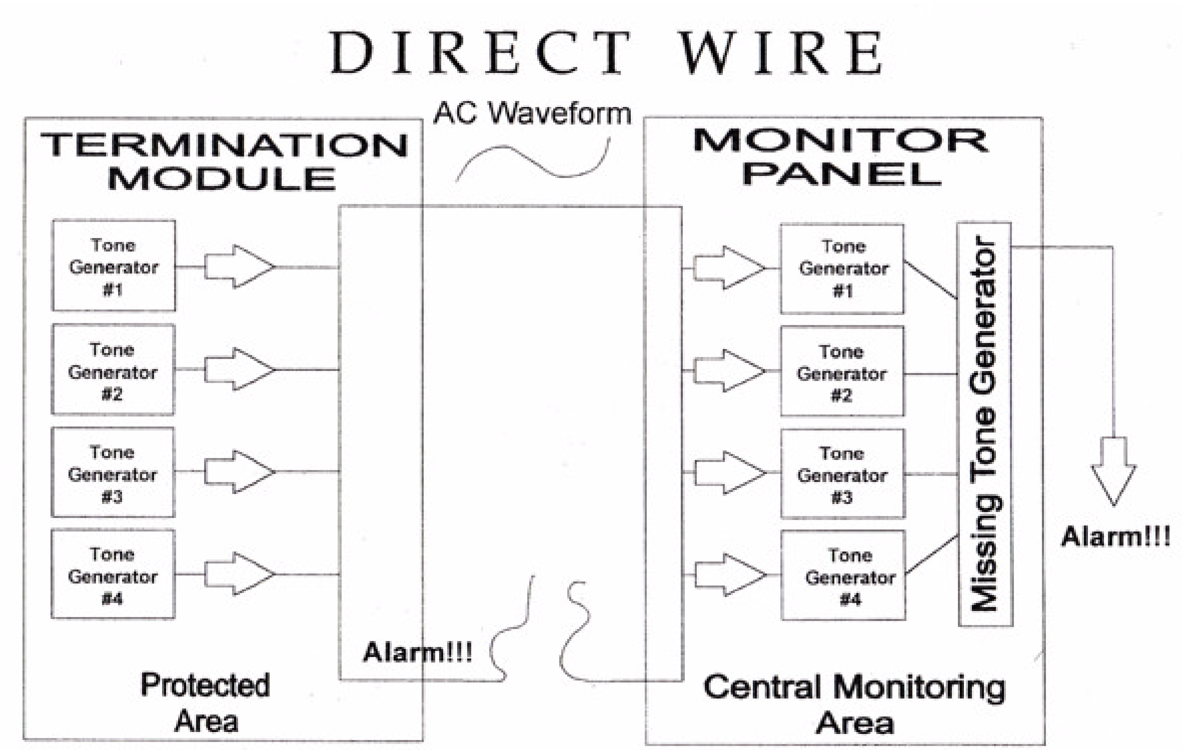


Figure LSS+4074 Direct wire line supervision provides for continuous electrical monitoring of the circuit. These circuits can be easily evaluated and spoofed. The diagram (top) shows a basic circuit that would allow an intruder to measure the DC current on the loop and insert a supply to simulate a normal condition.

Direct connection central stations or monitoring centers provide a higher level of security monitoring. In such instances, the transmission security or resistance to compromise depends upon the transmission method, as well as the level and type of line security. The level of line security and method of supervision to the circuit is determined by the anticipated threat and security level that is needed. False alarms may still be experienced, and these are generally due to telephone company maintenance, wiring errors, weather conditions, or routing failures.

Direct-wire circuits require a dedicated path between the local alarm processor at the premises and the central station facility. Circuits are electrically monitored for continuity using current, voltage, or digital signaling and periodic handshake. In older systems, up to fifty subscribers were tied to one pair of wires. Each location would have an encoder or sender that would generate a specific electrical address, much the same as in the older telephone step-relay offices. A series of pulses would identify

the location to the central station.

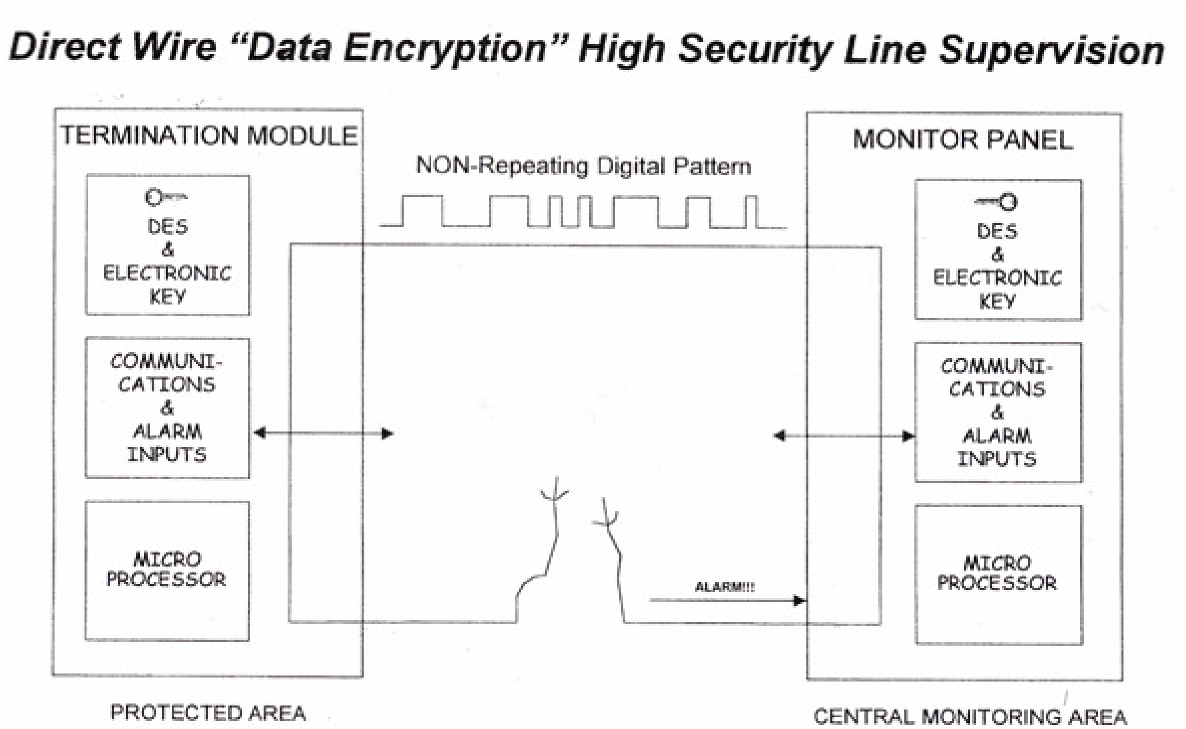


Figure LSS+4075 Data encryption high security line supervision provides the greatest protection for transmission links against interception. Encrypted data makes it extremely difficult to spoof, even if sniffer devices can be inserted along the transmission path.

Today, encrypted data is employed between the alarm processor and central station to insure security. Spoofing and denial of service attacks can be made more difficult but still occur.

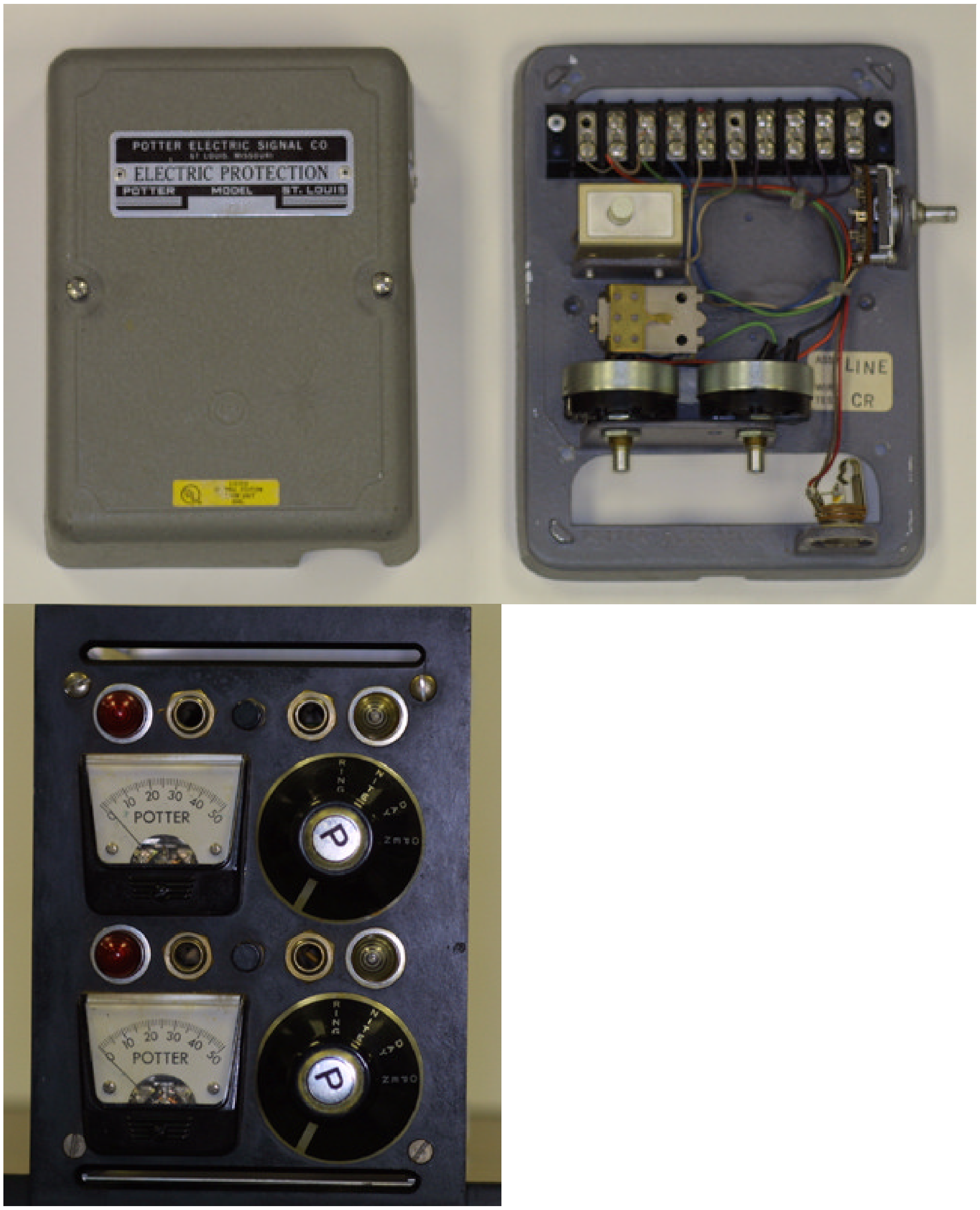


Figure LSS+4042 An early alarm transmission unit for central station application. The direct wire circuit had to be balanced both at the transmitter located on premises and the receiver at the central station.

40_2.1.5.2.1.2 Dial-Up Telephone Circuit

The normal dial-up (digital dialer) circuit using the public switched telephone network is the most common form used in the

alarm industry, and can be easily circumvented. For this reason, such systems are not utilized for banks and other high security installations. Although UL does certify a dial-up arrangement, it requires two independent paths to the receiving station, one of which may be wireless. Unfortunately, this level of supervision can be defeated by cutting all telephone lines that terminate in the local facility, unless wireless links are also employed.

Dial-up systems are not electrically supervised. This means that they can be circumvented without the receiving site being aware of the bypass. Although some dial-up arrangements do require periodic reporting, this may not provide adequate security.

Dial-up systems can be defeated in a number of ways, including:

- **Access the alarm panel through the use of a remote programming code. Then, change the telephone number for the alarm center. The panel may also be reprogrammed not to report any alarm condition, or a change in zone designation can be made;**

- **Inject a high voltage surge on the telephone line to damage the interface circuitry on the panel;**

- **Bridge the phone circuit at the demarcation point outside of the premises, preventing the panel from seizing dial tone;**

- **Physically cut or disconnect the telephone circuit from the subscriber premises;**

- **Call the number that is assigned to the alarm panel, thereby making it impossible for the system to obtain a dial tone;**
- **Cut a trunk line that feeds the central telephone office, thereby preventing the completion of a communications path from the alarm panel.**

40_2.1.5.2.1.3 Wireless Transmission Paths

Wireless transmission paths between protected premises and monitoring facilities are utilized to an ever increasing degree. The integration of cellular or spread spectrum links has provided path reliability and redundancy for alarm reporting and can make bypass of these systems extremely difficult.

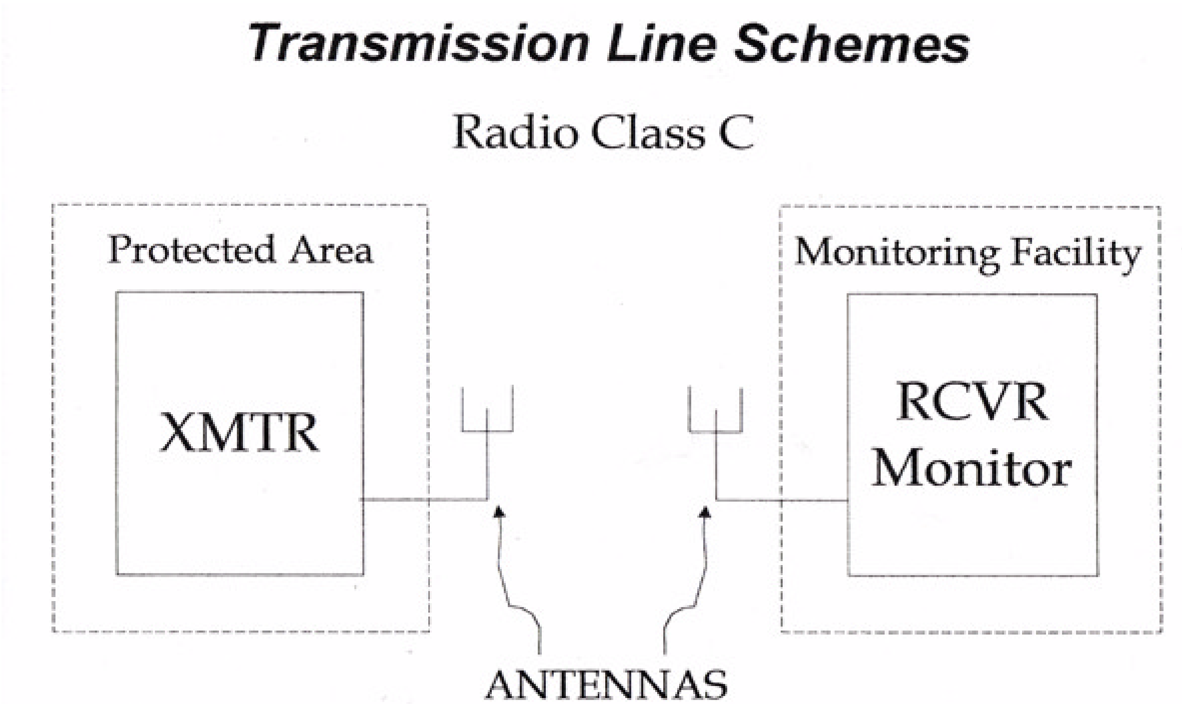


Figure LSS+4076 A basic wireless link consists of a transmitter and receiver.

40_2.1.6 Power Supply

Most alarm systems are backed up by battery for enhanced reliability. Critical consideration should be given to the power supply for any monitoring system because of the vulnerability in case of failure. The system design must integrate power backup for all components, including sensors, reporting, assessment and response. See the discussion below.

40_3.0 Specific Types of Sensors

This section will describe the different classification of sensors and their individual characteristics, including operating principles, application considerations, and typical defense measures. They are categorized by their function and sensing technology, although all sensors can be divided into volumetric and non-volumetric classifications:

CLASSIFICATION OF SENSORS

CONTACT and CONTINUITY DEVICES	Magnetic contacts Balanced magnetic switch Mechanical switch Photoelectric Taut-wire Pressure mats Switches Foil
CAPACITANCE and PROXIMITY	Electric field Capacitance Strain sensitive cable Magnetic point detection
VOLUMETRIC PROTECTION	Microwave Dual-technology IR/Microwave Radar Ultrasonic
HEAT SENSING	Passive infrared Interior active infrared Exterior active infrared Thermal imaging and sensing
RESPONSE TO PRESSURE CHANGES	Audio sensors Acoustic detection (air turbulence) Passive ultrasonic Active ultrasonic Shock Wall vibration Fence vibration Fiber-optic wall and fence In-ground Fiber-optic Ported coax buried line Balanced buried pressure Glass break detection
LIGHT ACTIVATED	Photoelectric Light level sensing
VIDEO SYSTEMS	Video motion detection

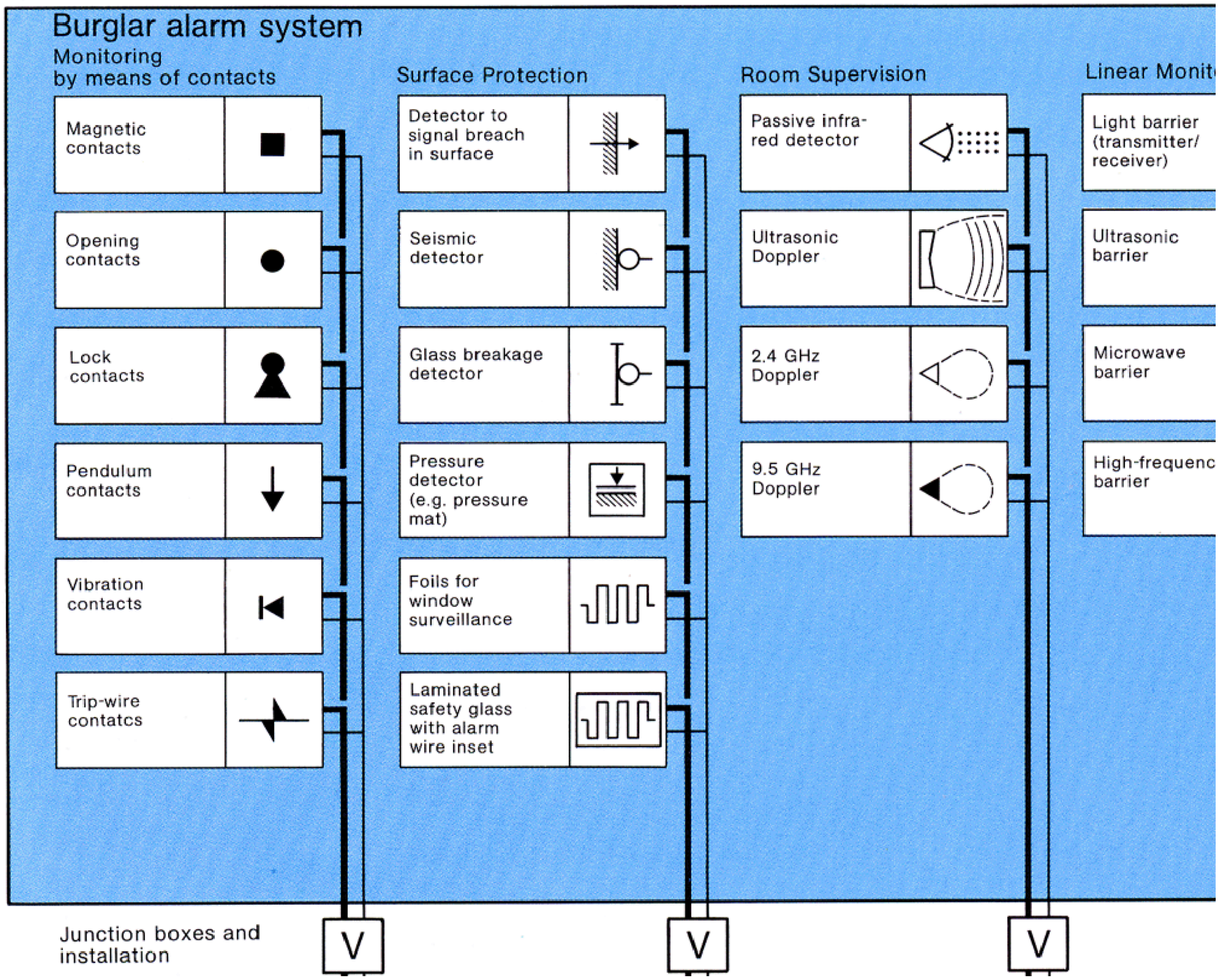
SENSOR TECHNOLOGIES

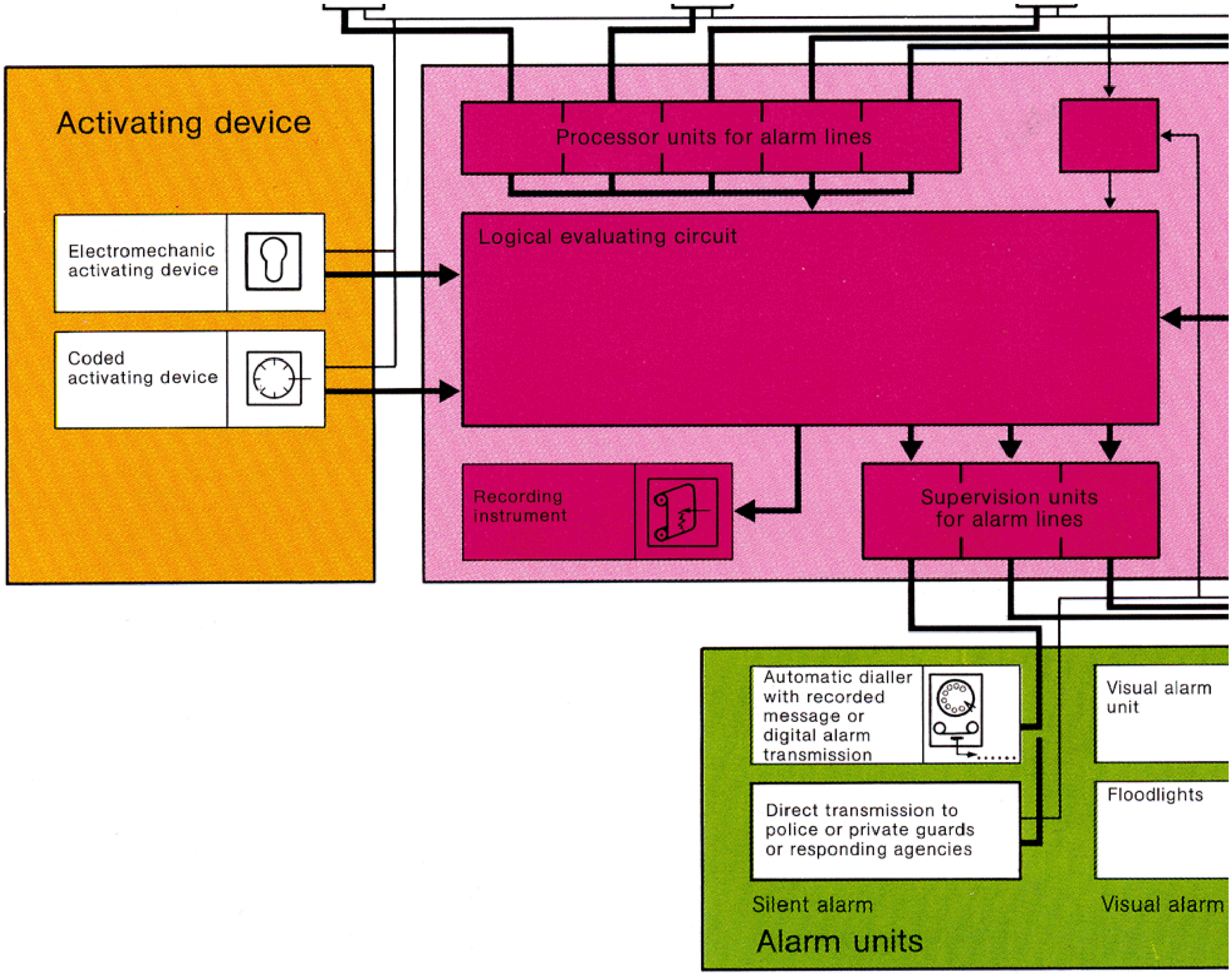
- **Active ultrasonic**
- **Acoustic detection (air turbulence)**
- **Audio sensors**
- **Balanced buried pressure**

- **Balanced magnetic switch**
- **Buried Geophone**
- **Capacitance and proximity**
- **Contact devices**
- **Continuity devices**
- **Dual technology passive IR/microwave**
- **Electric field**
- **Exterior active infrared**
- **Fence vibration**
- **Fiber optic fence**
- **Fiber optic wall**
- **Glass break detection**
- **In-ground fiber optic**
- **Interior active infrared**
- **Mechanical switch**
- **Magnetic switch**
- **Passive infrared**
- **Passive ultrasonic**
- **Photoelectric beam**
- **Ported coax buried line**
- **Radar**
- **Strain sensitive cable**
- **Taut wire**
- **Trip wire**
- **Video capture and motion detection**
- **Wall vibration**

40_3.0A Electronic Security Methodology

Electronic security is an intrusion detection system (IDS) installed to adequately protect valuable assets against adversaries who pose a threat to these assets. Electronic security systems (ESS) are used to alert responsible personnel, such as security guards, to intrusions at protected facilities. In some cases, the system may cause actuation of physical barriers to prohibit access. Electronic security systems can be placed into two categories: perimeter detection and interior detection.


Burglar alarm system
Monitoring
by means of contacts
Magnetic contacts
Opening contacts
Lock contacts
Pendulum contacts
Vibration contacts
Trip-wire contatcs
Surface Protection
Detector to signal breach in surface
Seismic detector
Glass breakage detector
Pressure detector (e.g. pressure mat)
Foils for window surveillance
Laminated safety glass with alarm wire inset
Room Supervision
Passive infra-red detector
Ultrasonic Doppler
2.4 GHz Doppler
9.5 GHz Doppler
Light barrier (transmitter/ receiver)
Ultrasonic barrier
Microwave barrier
barrier
Junction boxes and installation
V
V
V



Regardless of the type of sensor and its technology, three criteria must always be met:

- **The sensor must be capable of sensing and discriminating between an occurrence coming within the scope and purpose of the device and one that is irrelevant;**
- **The device must be reliable and impervious to artifacts that fall outside of preprogrammed parameters;**
- **The central processor must be capable of evaluating the information from the detector and initiating the proper response based upon the data.**

40_3.0A.1 Exterior Sensors

LSS403: DOE on layers exterior protection

Perimeter detection is used to prevent entry into a restricted area; the devices are usually located so as to protect the exterior premises.

- **Microwave detection** links are devices mounted on posts inside the fence line. Transmitters radiate amplitude modulated X-band energy, and receivers detect and process the received energy. Thus, an invisible RF energy envelope is produced that will detect an intruder.

- **Infrared detection** links are devices that are post-like and mounted inside the fence line. Transmitters radiate multiple beams of modulated infrared energy, and the receivers detect and process the energy. Penetration of the invisible infrared shield will cause an alarm.

- **E-field links** are transmitter and receiver wires that are strung horizontally from mounting posts located inside the fence or mounted on the fence. A radio-frequency energy field is generated around the wires. The intrusion by a person into the invisible field will "short" energy, creating an alarm.

- **Buried sensor links** are devices that sense seismic pressure or electromagnetic (EM) disturbances. A combination of theses sensors are buried inside the fence line.

- **Other systems** are available that can be used in combination with the previously mentioned sensors. The probability of detection by these outdoor devices depends on their application. Perimeter detection equipment must be applied with consideration of the environmental limitations of the device's technology.

There are many types of sensors specifically designed for exterior protection. The choice of modes of detection will determine the intruder's ability to define his method of attack. The generic categories of sensors that may be employed to protect perimeter and external areas are:

- **Active or passive;**

- **Overt or covert;**
- **Line of sight or terrain following;**
- **Volumetric or linear;**
- **Free standing, fence related or buried.**

Exterior sensors are employed to provide assurance that an intruder that crosses an established perimeter or boundary or enters a protected area will he detected. This, regardless of the type of movement and at any point in the detection zone under specified weight and speed criteria. The system must be capable of detecting:

- **Walking;**
- **Running;**
- **Jumping;**
- **Crawling;**
- **Rolling;**
- **Climbing.**

Exterior sensor zones must meet the following primary operational criteria:

- **Adequate coverage in all weather and light conditions**
- **Overlap to eliminate dead areas**
- **Wide enough to deter bridging**
- **Detection zones must not contain:**
    - **dips**
    - **high ground**
    - **obstructions that could provide a pathway for an individual to avoid detection.**

Sensors can be placed anywhere within their zone of protection. These devices are designed to withstand changes in environmental conditions including temperature, humidity, and dust, and will continue to function in harsh environments. Typically, exterior sensors will be less likely to detect a target, and can exhibit a higher false alarm rate than the more protected interior units, mainly due to factors that cannot be controlled that involve the environment, debris, animals, unanticipated human activity, as well as electrical and electronic interference. Multiple sensor technology is often utilized to minimize the problem.

In planning for the use of exterior sensors, there must be a

well-defined and isolated area of surveillance for an individual zone and corresponding sensor. This will result in a lower FAR. For example, a fence, wall, or other marker can be effective in dividing a perimeter into unique localized segments.

Exterior Intrusion Sensors

Applications Index

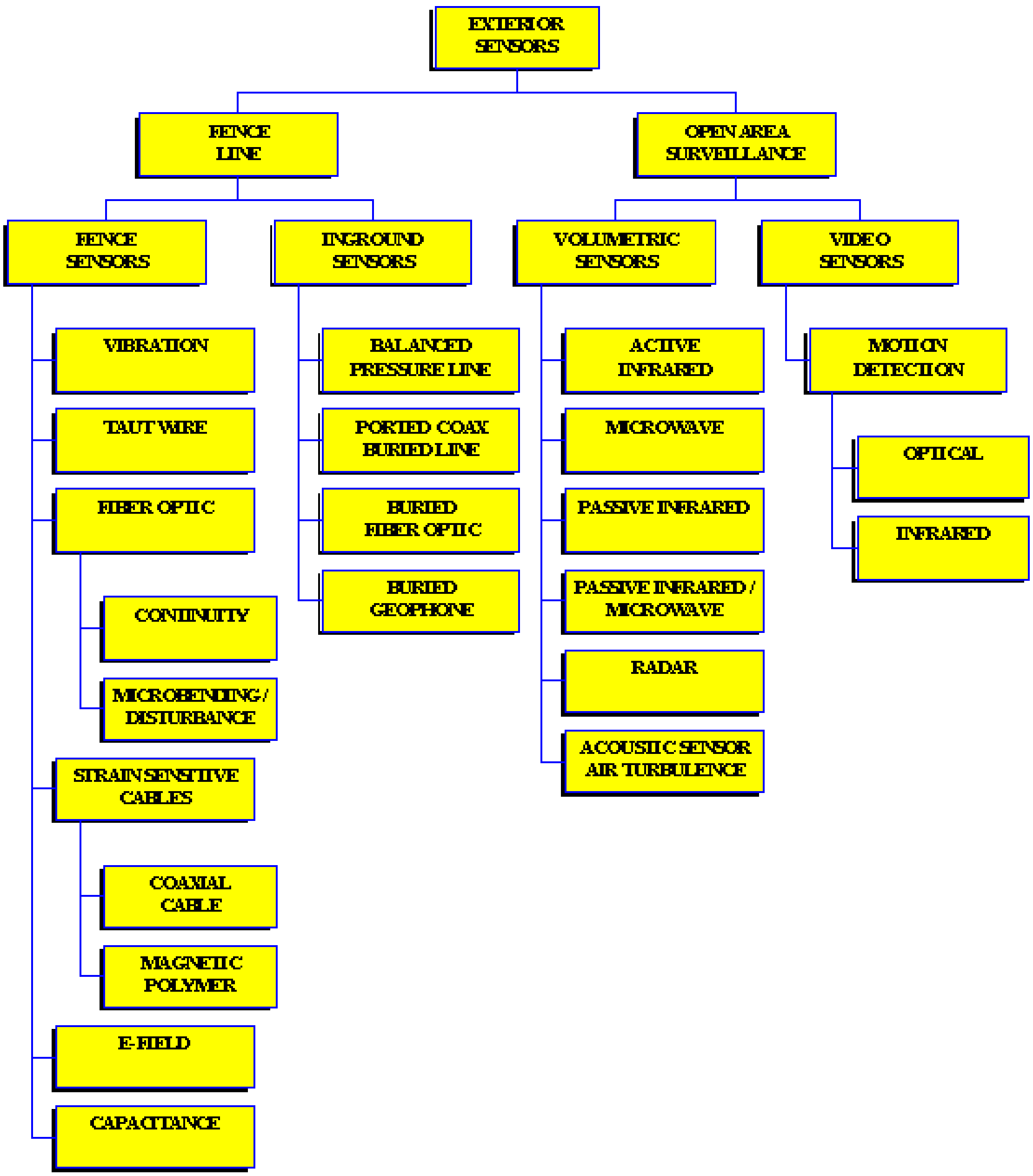


Figure LSS+4038 Exterior intrusion sensors take many forms.

Courtesy Perimeter Security Sensor Technologies Handbook.

EXTERIOR SENSOR APPLICATIONS MODEL

This example is typical of a secured facility employing various detection sensors.
The illustration shows how sensors can operate in conjunction with each other, and hypothetic
where sensors would be installed to enhance intrusion detection probability.

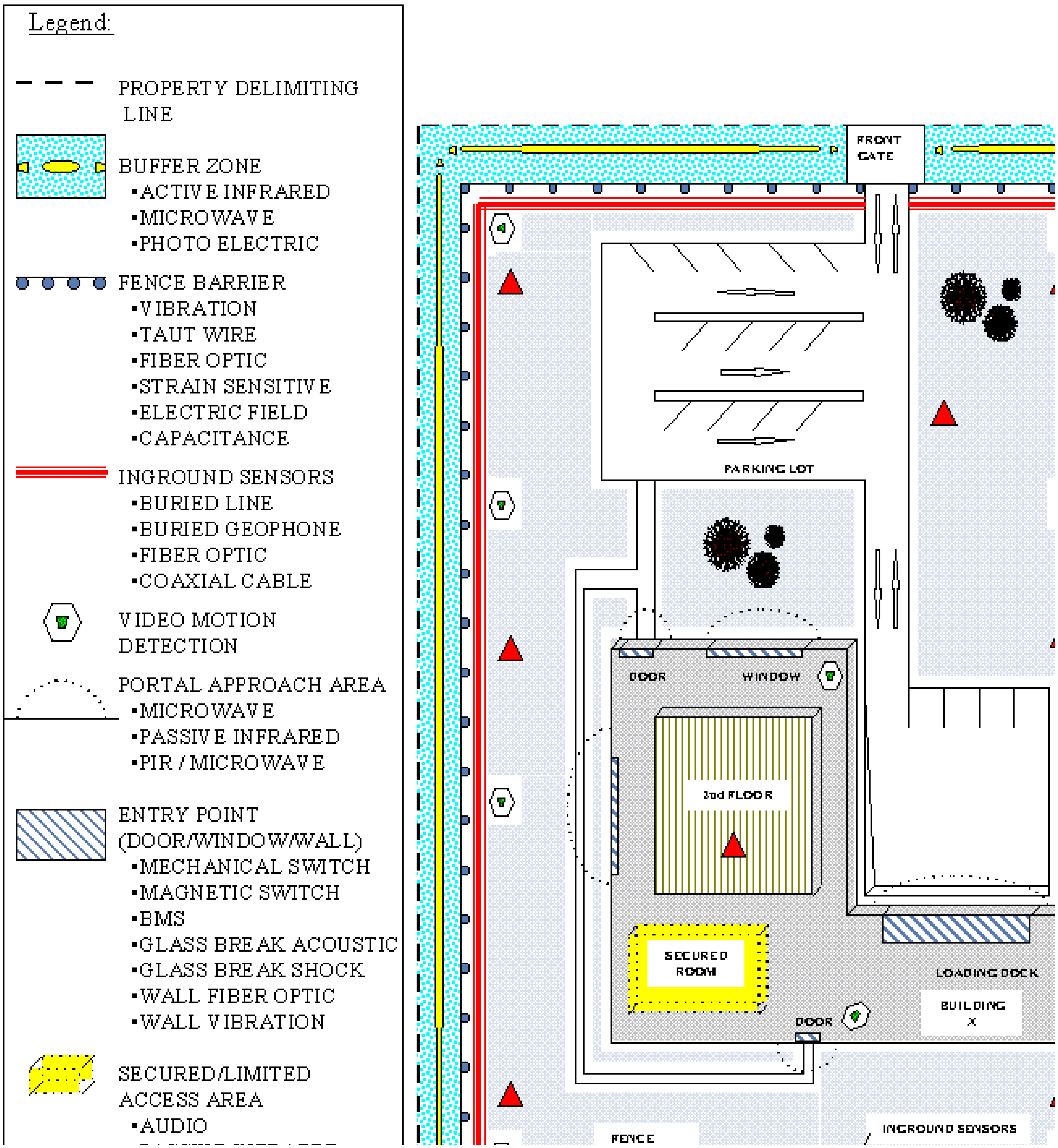


Figure LSS+4039 Diagram of typical exterior sensor application model. Courtesy Perimeter Security
Sensor Technologies Handbook.

40_3.0A.2 Interior Sensors

Interior intrusion detection systems are normally designed to protect specific security areas such as vaults, or vault-type rooms, or to detect intrusion into a building or facility. These systems employ various technologies (for example, the detection of physical movement, heat, movement related to time, cable tension, vibration, pressure, and capacitance). Many of these sensors are designed for indoor use only, and should not be exposed to weather elements.

If the intruder penetrates the perimeter detection, the protected area has been breached. The interior sensor then must be in place to prevent further entry into controlled or protected buildings.

- **Visual or closed-circuit television** surveillance may detect the intrude;

- **Entry into a building** is provided by the application of a balanced magnetic switch on doors and openings. This device uses an internal bias magnet to balance a delicate reed switch in the field of the external magnet attached to the door. Should the door be opened or should another magnet be introduced in an attempt to defeat it, the switch will change state and alarm;

- **Other devices** for detection of an intruder may be utilized inside the building, including microwave and infrared motion detection, photoelectric or laser beams, seismic, sound detection, and passive infrared.

Interior sensors perform specific functions:

- **Detection of an intruder approaching or penetrating a secured boundary, such as a door, wall, roof, floor, vent or window;**
- **Detection of a target that is moving within a secured area, such as a room or hallway;**
- **Detection of an intruder moving, lifting, or touching a particular object.**

INTERIOR SENSORS APPLICATIONS MODEL

The following example is a typical secured room employing various detection sensors. This illustration demonstrates how sensors operate in conjunction with each other, and where sensors can be installed to enhance security.

Legend:

1. **FIBER OPTIC WALL/CEILING SENSORS**
2. **VOLUMETRIC SENSORS**
   - **MICROWAVE**
   - **ACTIVE ULTRASONIC**
   - **ACTIVE INFRARED**
   - **PASSIVE INFRARED**
   - **PASSIVE ULTRASONIC**
   - **AUDIO**
3. **VIDEO MOTION DETECTION**
4. **VIBRATION WALL/CEILING SENSORS**
5. **DOOR/WINDOW CONTROL**
   - **MECHANICAL SWITCH**
   - **MAGNETIC SWITCH**
   - **BMS**
6. **GLASSBREAK SENSORS**
   - **ACOUSTIC**
   - **SHOCK**
7. **PHOTOELECTRIC BEAM**

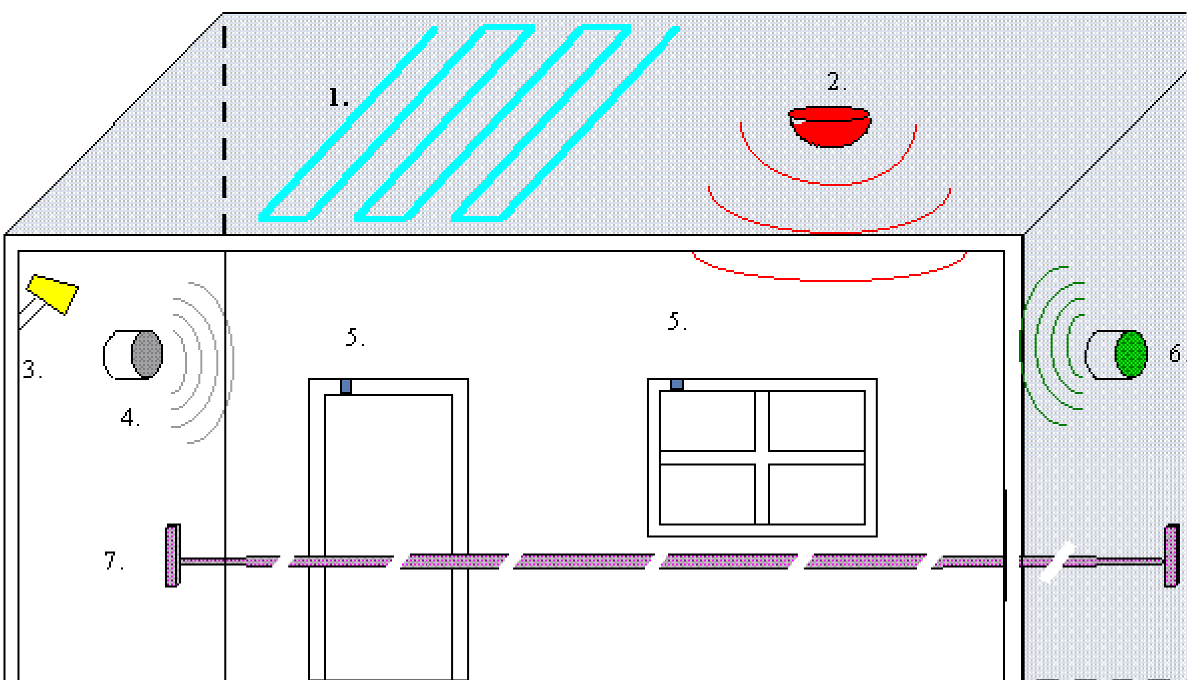


Figure LSS+4040 Interior sensor typical application.
Courtesy Perimeter Security Sensor Technologies Handbook.

Interior sensors are also susceptible to false and nuisance alarms, however not to the extent of their exterior counterparts. This is due to the more controlled nature of the environment in which the sensors are employed. However, they can also be affected by external factors including:

- **Machinery noise and/or vibrations;**
- **Air movement from fans or air conditioning/heating units;**
- **Changes in temperature.**

Interior Intrusion Sensors

Applications Index

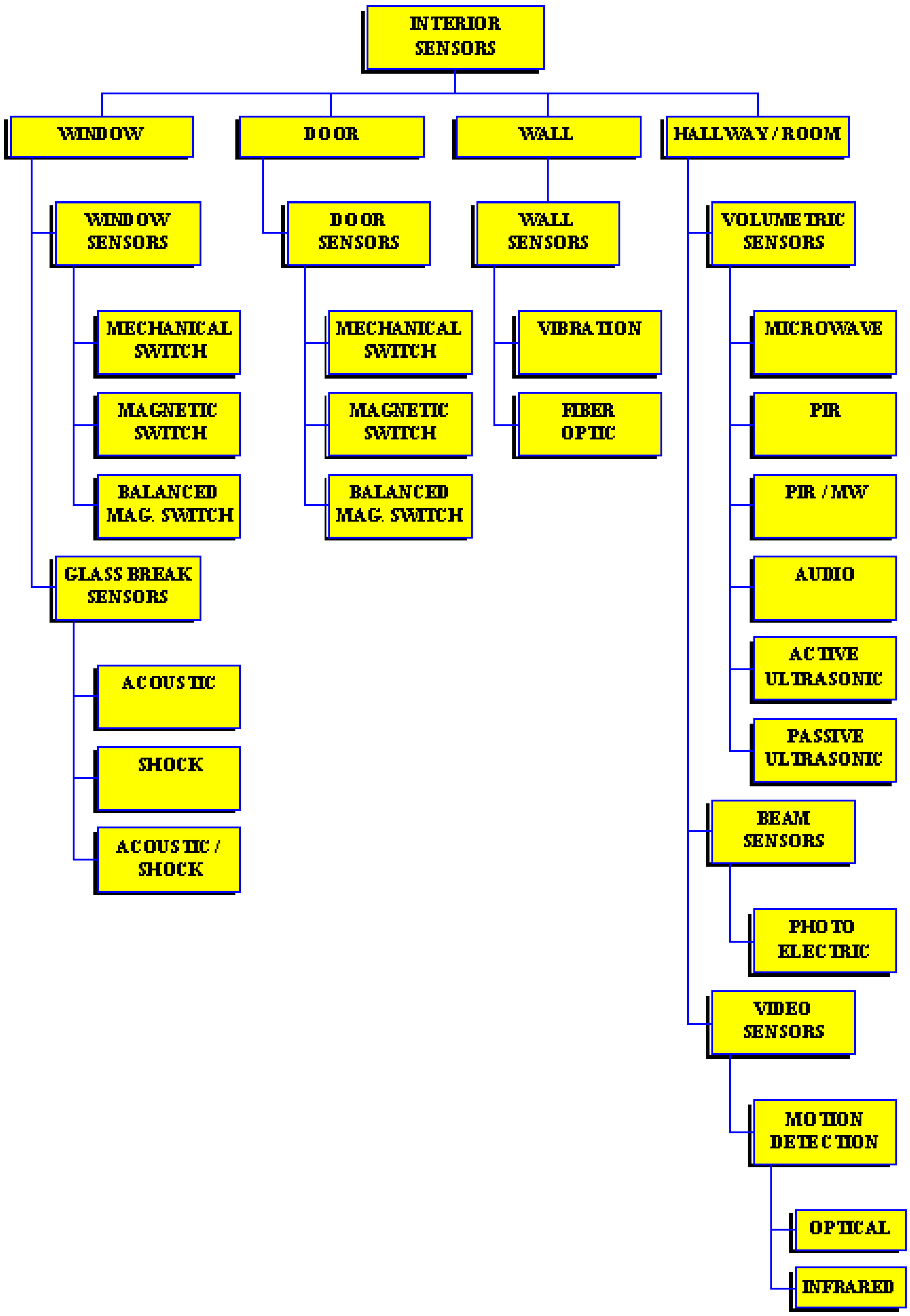


Figure LSS+4041 Interior intrusion sensor application

40_3.0A.3 Definitions

Certain definitions must be established in order to properly develop a Physical Security Plan, and to evaluate its implementation:

- **Alarm Zone.** A critical area alarm zone is a predesignated volume of space which is under surveillance of one or more sensors;

- **Detection Zone.** A detection zone is the volume of space under surveillance of a sensor that will create an alarm when the space is penetrated;

- **Self-Checkinq.** A feature to ensure secure operation. The system may periodically monitor the sensor transducer and signal processing circuits. Many systems require self-excitation of the sensor transducer (e.g., vibration, strain, pressure) while others monitor the signal level at the receiving transducer (e.g., microwave, infrared).

- **Standard Work Clothinq.** For evaluating CCTV motion detectors, standard work clothing is the equivalent of washed denim jeans and jacket. Such clothing should be a measure of intruder-to-background contrast.

- **Surface Protection Sensors.** Surface protection sensors are devices that detect penetration of the boundary of a secured volume rather than the presence or motion of an intruder within the secured volume. Surface protection devices are commonly used to detect the opening of doors and security cabinet drawers (portal-type detectors) or the attempted penetration of walls. Surface protection devices generally do not offer as high a degree of security as do volumetric intrusion detectors and therefore are often used to complement other sensors.

- **Tamper-Indicatinq.** A feature to detect tampering with or unauthorized manipulation of equipment components. The term includes line supervisory circuitry on data transmission lines, and switches used to sense the removal of equipment cover plates.

- **Volumetric Intrusion Sensors.** Volumetric intrusion sensor

systems are sensitive to the motion or presence of individuals within a specified volume. For the protection of rooms and large volumes, volumetric detection systems generally offer a higher degree of security than do surface protection systems. Various physical phenomena are employed in order to provide volumetric detection. These units offer a high degree of security if they are installed and operated in such a manner that they can detect movement by a small individual into the secured area at all rates between 6 and 180 meters (20 and 600 feet) per minute and in various crawling and walking postures within 1.5 meters (5 feet) from any direction.

40_3.0.1 Performance Characteristics and Criteria

In planning a comprehensive security system, individual sensor technology that is to be deployed must be analyzed in terms of three performance characteristics: **Probability of Detection (PD)**, **False Alarm Rate (FAR)**, and **Vulnerability to Defeat** (i.e. typical measures used to defeat or circumvent the sensor). The goal of any integrated Intrusion Detection System (IDS) design is to insure a low FAR and a high PD. Equally important: it is not subject to bypass or compromise.

Probability of Detection (PD): This criteria allows measurement of sensor performance in detecting a valid alarm condition in the area it is designed to protect. The characteristics of the sensor, environment, installation and adjustment, and the behavior of the target all must be taken into account. The sensitivity of a sensor is reduced due to numerous and/or excessive FAR or NAR. Pulse count and environmental adjustment circuitry, as well as automatic gain controls (AGC) can impact a sensors ability to increase PD. The industry emphasis is to reduce FAR and NAR and not to increase PD. The adversary takes advantage of this vulnerability.

False Alarm Rate (FAR) and Nuisance Alarm Rate (NAR): This measurement provides a projection as to the occurrence of false indication of activity within the protected area. Although false alarms and nuisance alarms are thought to be the same, they technically are not. A nuisance alarm may be a valid trip from an invalid target. For example, an animal, fan motor, or air turbulence may have activated the sensor. The problem is one of system design or unexpected occurrence rather than a true false alarm. In contrast, a real false alarm may indicate a possible intrusion attempt that cannot be verified, or an electronic failure. In either instance, the alarm must be responded to as if

valid. During the evaluation or inspection process, a review of all alarm logs and records should be made to determine false and nuisance alarm rates for a defined period of time. Any abnormally high alarm rate should be identified. The process should also insure that false alarms are correctly logged and reported, and that a correct definition has been established for false and nuisance alarm status, and that such definition is understood by alarm system operators. Obviously, the ability of operators to consistently make judgments as to whether alarms are considered false or nuisance will greatly affect false and nuisance alarm rate calculations.

Vulnerability to Defeat: This is yet another measure of the effectiveness of a sensor. Unfortunately, there are many classifications of sensors that can be used to protect a specific type of area; one type of technology may be optimum for a given environment. No sensor will reliably operate in all conditions; there is no universal detector. Each sensor is designed for low FAR for certain applications. Utilization of the proper sensor for a given task will insure that the potential for its defeat is low. Security can be enhanced by the use of multiple sensors and differing complementary technologies that overlap each other.

40_3.0.1.A System Performance Objectives

A facility can be protected in three ways: alarm systems, random patrols, and visual surveillance. Alarm and detection devices are fundamental components of any physical security system. To be effective, alarms must be clearly audible, and capable of immediate identification of the location and type of alarm by the operator.

To achieve an acceptable degree of assurance that the electronic monitoring and detection components of a security systems work properly, it is incumbent on facility management to provide adequate equipment, an effective testing and maintenance program, and a sufficient number of trained personnel to operate the alarm and assessment equipment.

Specific performance objectives should be established for an intrusion alarm systems:

- Detects attempts to gain unauthorized access to critical areas in conformance with the physical security plan (PSP);

- Whether critical area intrusion sensors meet the general

performance objectives, and are adequate and appropriate for their intended function;

- Whether the intrusion sensors are designed with sufficient redundancy and diversity to assure maintenance of their capability to meet the general performance objectives;

- Whether there is a system to detect unauthorized placement, movement, or removal of critical materials in conformance with the physical security plan and any regulatory requirements.

40_3.0.1.B Inspection Requirements

Each system must be carefully inspected to verify that each sensor is performing as required to insure proper intrustion detection, and detection system capability. The process must verify that:

- The location has intrusion detection systems capable of detecting attempts to gain unauthorized access to critical areas;

- That the system will detect the opening of all doors and emergency exits in all critical areas;

- That the location has detection systems and procedures to discover unauthorized activities and conditions, as defined by the PSP;

- That intrusion detection systems have sufficient redundancy and diversity to assure maintenance of their capability to meet the general performance objectives;

- That sensor detection systems are segmented into a sufficient number of overlapping alarm zones to provide adequate coverage of the areas under surveillance by the detection systems;

- For extremely critical areas, verify that the system protects unoccupied areas with intrusion detection systems that will alarm in all alarm stations upon entry of an individual into the areas, movement of an individual within the areas, and exit of an individual from the areas;

- For extremely critical areas, verify that the system has

detection capability and procedures to discover unauthorized placement and movement of materials within protected areas;

- For extremely critical areas, verify that the system protects designated locations with intrusion detection systems that will alarm upon entry of an individual into the location, movement of an individual within the location, and exit of an individual from the location;

- Verify that emergency exits from critical areas are alarmed to provide local alarm annunciation that is both visible and audible;

40_3.0.1.C Detection System Security and Performance

It is critical that detailed examinations be conducted to insure the integrity of all alarm sensors and associated systems. Verify that:

- Critical area sensors and associated systems, including transmission lines to their respective annunciators, are tamper-indicating and self-checking;

- Controls and switches that affect the sensitivity of any intrusion detection system are located within a tamper-alarmed container or housing;

- For extremely critical areas, verify that all intrusion detection systems and emergency exit alarms are provided with tamper-indicating alarms and line supervision;

- Alarms that annunciate in both the primary and secondary alarm centers indicate the type and location of the alarm source;

- All critical area intrusion detection systems are self-checking and annunciate equipment or component failure in all alarm centers, indicating the type and location of the alarm source;

Each sensor and zone must be evaluated to insure that they provide the requisite protection that is specified in the PSP. For maximum efficiency, the following performance tests of critical area sensors should be observed by at least two inspectors. The inspectors should be provided with handheld

radios that operate independently of the facility's radio frequencies. One inspector should be stationed in the alarm center to relay alarm response to the inspector that is observing the tests in the alarm zones. This inspector should verify that the alarms are annunciated audibly and visibly, and that there is an indication of the type and location of alarm.

Review the Physical Security Plan to determine that the system conforms with the goals of the PSP for detection parameters such as distance from detector, speed of approach, and height and weight of intruder for each type of sensor. Determine the type and locations of sensors that are used, the level of redundancy, the number and location of alarm zones, and the number and location of critical area doors and emergency exits.

To prevent the initiation of electrical fires, all components of detection sensors should meet the fire safety requirements of nationally recognized testing laboratories. Attachment of a label from Underwriters Laboratories (UL) or Factory Mutual (FM) to the equipment is acceptable as proof of meeting fire safety requirements.

Each sensor in each alarm zone should be tested in at least one sector of the alarm zone for its ability to detect penetration of, or activities within, the zone.

- **Volumetric Sensors.**

Ultrasonic and microwave sensors are most sensitive to movement directly toward or directly away from the detector, and are least sensitive to movement along an arc of equal radius from the detector. Conversely, passive infrared detectors are most sensitive to movement along an arc of equal radius from the detector, and are least sensitive to movement directly toward or directly away from the detector. These sensitivities to direction of movement must be considered when evaluating each type of volumetric sensors;

Volumetric sensors can be tested by crawling, walking, or running in several directions in each alarm zone under surveillance;

Verify through crawl, walk, or run tests near selected objects within sample alarm zones, that objects within the alarm zones do not prevent detection of movement or provide detection-free paths;

Verify through crawl, walk, or run tests through the intersections of adjacent alarm zones, that there is sufficient overlap of alarm zones to detect motion in any direction;

- **Surface Protection Sensors**

Infrared break-beam detection sensors can be tested by crawling, walking, or running through each detection zone;

Capacitance detectors can be tested by moving to within 15 cm (6 inches) of the protected object, or by touching the object while wearing a heavy insulated glove;

- **Critical area gates, doors, and turnstiles**

Open each critical area emergency exit door and gate, and rotate each emergency exit turnstile, verify that an alarm annunciates the opening or rotating (locally) by both visible and audible means and also annunciates in all alarm centers. The alarm should annunciate when the latch edge of the door is opened one inch and more;

Open each normally locked door and gate in a critical area and verify that an alarm annunciates the opening in all alarm centers;

- **Balanced Magnetic Switches**

Place one or more test magnets on selected samples of balanced magnetic switches so that the system alarms when the switch is subjected to additional magnetism;

- **Detector Tamper Alarms and Line Supervision**

Open the covers of selected samples of equipment cases, junction boxes, and conduit elbows to verify that the system will detect attempted tampering in both secure and access modes, and will annunciate the alarm type and location in all alarm centers. While the covers of the equipment cases and junction boxes are still open, disconnect a sample of alarm transmission wires at the terminal strips. The system should detect this form of tampering in both the secure and access modes;

- **False Alarm Rate**

Each critical area detection system should average not more than one false alarm and one nuisance alarm per alarm zone per week while maintaining design-performance detection capabilities. Assure that there has not been a reduction in sensor sensitivity levels to an unacceptable degree to reduce false alarms.

40_3.0.1.D Technical Considerations for Evaluating Sensors

Redundancy and diversity of critical area intrusion detection sensors is essential. This generally requires two or more independent intrusion sensors in each alarm zone that use different means to accomplish detection. Redundancy and diversity are good design concepts that should be considered. Any combination of the following commonly used intrusion sensors should be acceptable if properly implemented.

- **Acceptable Volumetric Intrusion Sensor Combinations for Redundancy:**

Ultrasonic motion detectors
Microwave motion detectors
Passive infrared detectors
CCTV motion detectors

- **Acceptable surface protection sensor combinations for redundancy include:**

Balanced magnetic switches
Infrared break-beam detectors
Capacitance detectors
Electric-field (E-field) sensors
Breakwire sensors

- **Unacceptable sensor redundancy includes the following:**

A guard or watchman monitoring critical areas using CCTV that is not the motion-detecting type is unacceptable as either the only detector or as a redundant detector of unauthorized access, activities, or conditions. Because the observation of seldom-varying scenes on CCTV monitors is monotonous, the probability of detecting unauthorized access, activities, or conditions using common CCTV and the human eye is unacceptably low.

- **Observation of Intrusion Detector Testing**

Test each critical area alarm zone. By appropriate sampling techniques, observe a sufficient number of tests to conclude that the tests are conducted properly, and that the equipment is performing as designed. Tests should include crawling, walking, and running in each alarm zone, unless problems are encountered. Simple go/no-go tests are sufficient to evaluate intrusion detectors.

- **Tamper Alarminq Conduit Elbows**

Although it is widely accepted that the physical protection standards require tamper alarming of all equipment housings and junction boxes in detection systems, many overlook the fact that the removable covers of conduit elbows must also be tamper alarmed. Specifications should require that all alarm devices, including transmission lines to annunciators, should be tamper indicating. The covers of all conduit elbows that house alarm-related wiring must either be tamper alarmed or they must be welded shut.

- **Test Magnets for Balanced Maqnetic Switch Detectors**

A test magnet kit consisting of two small bar magnets (such as Permag Sierra 22U17B, 3/8" x 3/8" x 7/8", Alnico 2) and two small horseshoe magnets (such as Little Giant #1022) can be used to verify that balanced magnetic switches will alarm when subjected to additional magnetism. The amount of additional magnetism needed to cause an alarm will vary among different manufacturers. However, a pair of either kind of magnets placed on opposite sides of the switch must cause an alarm.

40_3.0.1.E Lighting

Lighting is of primary importance in the operation of an effective alarm and detection system. Effective lighting provides a deterrent to adversary intrusion, assists the protective force in locating and assessing alarm initiations, and provides for effective use of CCTV as a surveillance and assessment tool. Lights are required to have a minimum specified luminescence at ground level for specific areas, a regular power source, and an emergency backup lighting capability.

In conjunction with alarm and video capture systems, lighting levels, reliability of lighting systems, and susceptibility to sabotage must be evaluated. Performance tests should be conducted to assess and verify:

- **Lighting levels at:**
  - Portals;
  - Security area perimeters;
  - Exterior and interior areas that rely upon CCTV;
  - Normal and emergency auxiliary supplies for lighting systems;
  - Procedures that are implemented in case of lighting failure;
  - Methods of monitoring lighting systems for failed equipment;
- **Observe lighting conditions and their adequacy during night time on both primary and backup power. Light meters may be utilized to check levels and contrast. Observe levels from different locations:**
  - Key visual assessment posts, such as towers;
  - Monitors in alarm centers;
  - Adequacy of lighting by observing individuals dressed in various clothing with different color contrasts;
  - Stand in different areas to check lighting via monitors;
  - Check lighting levels for low and high contrast ratios and glare or bright spots in images;
  - Look for blind spots;
  - Can animals and humans be distinguished for any location;
  - Lighting levels;
  - Light-dark contrast;
  - Glare;
  - Shadows;
  - Inoperative light bulbs;
- **Observe lighting for a variety of conditions:**
  - Clear weather;
  - Rain;

    - Fog;

- **Sabotage, vulnerability of:**

- Lighting circuits;
- Power supplies and critical components:

    - Switch yards;
    - Transformers;
    - Circuit breakers;
    - Power transmissions lines;
    - Generators and fuel supply;
    - Uninterruptible power supplies;
    - Lighting circuits and redundancy;

- **Vulnerability of power supplies to single point failure;**
- **Access control to critical areas that control power;**
- **Self-testing of all critical components;**
- **Backup systems for alarm assessment if power fails.**

40_3.0.1.F Power Systems

Auxiliary power sources, consisting of batteries and/or generators, must be be available with automatic and immediate transfer if the primary power supply fails. Generators should not be relied upon as the sole source of backup power; batteries should provide the initial energy until the generator can come on-line.

40_3.0.1.F.1 Tamper Protection for Power Sources

Often overlooked during planning and installation, the primary and backup power sources for intrusion detection systems are susceptible to tampering. Power switches, inverters, and generators must be protected. Exterior fuel tanks and filler points are especially vulnerable. An inoperable filler point or contaminated fuel tank, for example, may nullify all backup power sources.

40_3.0.1.G Improper Installation, Calibration

or Alignment

Improper installation, calibration, or alignment of sensors and other system components can degrade the effectiveness and reliability of an alarm system, generate false alarms, and potentially allow undetected intrusion. For example, if a microwave detector is not installed and aligned to system specifications, then an intruder may be able to take advantages of imprecise coverage and jump over or crawl under a beam at the crossover point where adjacent zones overlap.

40_3.0.1.G.1 Video Systems

Video motion and capture systems require continuous technical oversight to insure proper operation. This means maintenance, calibration, and verification of image quality. Specifically:

- Verify correct installation and alignment;
- Determine that there are no "holes" in coverage;
- Verify that the field of view is matched to the lens to insure that an intruder can be observed everywhere that the camera sees, and that motion detection technology properly responds to images to initiate an alarm or capture for instant playback.

40_3.0.1.H Testing and Maintenance

To ensure effective operation of alarms and detection devices, managers must provide for a regular test and maintenance protocol for both alarm devices and entry-control systems. Such a program must include the periodic testing and inspection of equipment and circuits. Most alarm system failures are the direct cause of an inadequate testing and maintenance program. The lack of maintenance and operation (testing) usually results in equipment failure. For this reason, the testing and maintenance program is one of the most important features of any protection system. An effective program will normally include provisions that require facility technicians, augmented by service representatives, to perform all tests, maintenance, calibrations, and repairs necessary to keep the detection and assessment systems operational. The surest way to incur a breach of security is to provide for inadequate testing and maintenance. Key indicators of such a condition include:

- **Frequent system failure;**
- **Cursory testing procedures;**

- **Inordinate number of items of equipment awaiting repair**

All test protocols should be well planned and the results documented. Such documentation must include:

- **Date of the test;**
- **Identification of access-control or entry-control system that was tested;**
- **Identification of alarm sensor and zone that was tested;**
- **Test type or protocol that was employed;**
- **Circuit number of other identifying characteristic, and type of test;**
- **Name of the person conducting the test;**
- **Results.**

40_3.0.2 Environmental Considerations

Each zone of protection has a unique environment that must be taken into account during system planning for sensor technology and installation. If the specific environment in which every trip will be operating is not taken into account, excessive false alarms and potential for bypass will be the result. Factors that must be considered will include:

- **Climate;**
- **Daily and hourly fluctuations in weather and environmental conditions;**
- **Random animal activity;**
- **Activity patterns;**
- **Electrical fields;**
- **Radio transmissions;**
- **Vehicle, truck, rail or air movement.**

40_3.0.3 Defeating Alarm Systems

Intrusion-detection systems consist of both an alarm and an assessment system, and are usually layered for both interior and exterior applications. Exterior systems are designed to provide the earliest possible detection of an unauthorized intrusion, as far away from the security interests as possible. The interior intrusion detection system may be even further divided into layers according to the configuration of security areas and the

required levels of protection.



**Figure LSS+4058 High security locations are protected by layers or concentric rings of perimeter sensors,
including fences, microwave, infrareds and buried detectors. Courtesy of DOE Office of Security and Safety Performance Assurance.**

LSS402 Defeat techniques for different sensor technologies

At critical facilities, various layers of protection are employed. The outermost layer of the exterior system is usually the **perimeter intrusion-detection and assessment system** (PIDAS). Exterior systems must he capable of withstanding the environmental conditions in which they are deployed.

Depending upon the operating environment and design parameters, systems will typically consist of multiple and complementary electronic sensors. Typically, the PIDAS also includes fixed-position CCTV coverage for timely assessment of alarms. PIDAS alarms normally annunciate in a monitoring station where the operator can acknowledge the alarm, assess its cause, and direct a response as necessary.

Exterior systems will often integrate the following technology, which are discussed in detail throughout this chapter:

- Microwave;
- Infrared;
- Electric field sensors;
- Fence disturbance detectors;
- Seismic sensors.

40_3.0.3A Physical Barriers

At most facilities, three barriers are utilized to form lines of defense to physically protect valuable assets. Perimeter barriers are normally found at the edge of the protected property and are considered to be the first line of defense. This may be a fence, wall, or a natural barrier, such as a river, lake, cliff, ravine, or other terrain that is difficult to traverse. The second line of defense is building exterior walls and roof. Interior building rooms, safes, and vaults make up the third line of defense. These physical barriers are mentioned because they establish areas where intrusion detection may be warranted.

Depending on the type, configuration, location, and other conditions of the protected area, applicable ESSs are selected from several different types. At property lines and large building walls, intrusion detectors covering large areas are required as opposed to a room within a building or a vault. Also, exterior applications require weatherproof enclosures and are sometimes subjected to a wide temperature range.

40_3.0.3B Detection Systems

There are many types of electronic security systems in use at military and other high security installations. All require frequent tests and checks, in some instances as often as once a day. The emphasis is on operational tests to ensure the continued functionality of the designed system, rather than on routine maintenance of component parts.

Before the advent of low-cost computer multiplexed hardware, security systems were simple hardwired alarm systems, providing a minimum level of intrusion detection. Today, the system may be a fully redundant computer-based system interfaced with a redundant looped time-division-multiplexed communication network for gathering alarm data from sensors and for sending commands to

release locked doors under the card-access control subsystem. The remote multiplexes may be microprocessor-based units, capable of data collection, communication with the host computer, and performing limited-access control functions.

The security system provides location information as well as delay time for the guards. By successive detections, the security force can track the intruder and relay location information to the responding guards. In turn, the guards can constantly inform the security force on the progress of their work or the need for additional assistance. The cameras, using various means of target intensification, can "see" better than the human eye. Guard patrols are also used to detect unusual activity.

Alarm systems provide another layer of protection in securing a facility or location. Throughout this chapter, defeat techniques or countermeasures are explored for various sensor technologies. In this section, general information is presented regarding adversary strategies, as well as defeat issues with regard to two-wire circuits, wireless equipment, and card access systems. A comparison between computer networks and physical intrusion detection is also examined because of the similarities in attack methodology. Transmission security, physical security of alarm panels, and closed circuit television systems are covered elsewhere in the chapter.

Regardless of the sensor type, there are three primary means for avoiding detection through a system's normal operation:

- **Deceit or Diversion:** Create false alarms to divert attention from an actual intrusion, or use false pretenses to incapacitate or bypass the sensor;

- **Employ force in combination with a rapid attack to avoid intervention:** This mode assumes that the response time to an alarm would exceed the ability of an intruder to reach its target. This technique presumes that detection and response is imminent;

- **Stealth and evasion methods:** There are several techniques that can be employed, including denial of service, alarm stacking, spoofing, camouflage, speed, and brute force. Exploit other pathways that may exist, such as over, under, through or around sensor detection patterns. Use sensor walk-test lights to determine a detection path. Alarm stacking takes advantage of the conditioning of the responder or monitoring personnel, and

assumes that the alarms are false and are being caused by environment factors or a defective sensor. Alarm stacking requires that several sensors be triggered simultaneously, or that one or more sensors report multiple detections. Both of these conditions will be seen as irregular by monitoring staff and may create a delay or a total disregard of the report. Intruders may also attempt to bypass sensors by extremely slow and stealthy movements into the detection path which would not materially change the threshold trigger levels of sensors. Bypass of passive infrared devices is an excellent example. Walking at an extremely slow pace toward a sensor will generally not be detected.

40_3.0.3C Comparison Between Computer Networks and Physical Alarm Systems

Network intrusion detection systems offer many parallels to physical intrusion detection alarm systems and sensors. NIDS are becoming quite prevalent in safeguarding computer systems and supplementing their security. Such systems provide security in the digital world, just as the burglar alarm does in the physical environment. Digital systems have vulnerabilities that can be exploited by an attacker, much the same as does a physical intrusion detection system. The author believes that lessons can be learned by comparing attacks on computer systems with attacks on physical facilities. Although the domains are different, the attack methodology can be quite similar in concept.

An intruder will try to evade detection by determining the weaknesses or design deficiencies in a system and attempt to exploit them. Each security system has different components, and thus, potential for bypass. Computer networks and alarm systems look for intruders in two ways: signature matching or abnormality detection. Each alarm sensor is looking for certain parameters that are considered normal for its environment. An IR detector, for example, is evaluating a range of temperature within its zone of coverage. Any deviation from what it expects to see will create a signature that it recognizes as an alarm condition.

The detection of an abnormality would include a sensor failure, tamper detection, failure to detect the expected signature, multiple hits, or the detection of an out of range parameter. Abnormality may also indicate that there is a problem with the system, in terms of transmission links, central processors, visual or audible indicators, or the normal baseline response of

a system, indicating a problem with overall integrity. The role of alarm assessment and the guidelines that have been established to define what is "normal" in terms of system performance, is critical to the determination of what constitutes an abnormality. It is therefore essential that those responsible for system design and evaluation carefully consider the range of events that are defined as normal with respect to a given facility. If the tolerance for events is too high, then the system may be easily exploited. If the tolerance is set too low, then a high number of false alarms may result.

False Positive and False Alarm

An alarm is received that is not valid and does not denote an intruder. It is the result of a faulty signature that the sensor is looking for.

False Negative

Failure to alert when a valid detection of intrusion is received.

Obfuscation

In the computer world, this concept relates to the manipulation of data to change its content without being detected. With regard to alarms, it means that signals may be interrupted from a detection device to the central processor, or from the processor to the alarm center, but such interruption or tampering would not be detected as an anomaly. This procedure may also be known as spoofing. In its simplest form, obfuscation might mean the jumping of contacts on a trip, the insertion of an end-of-line resistor near the circuit termination point, or the blinding of a video camera with an infrared laser. In the more complicated form, it might require the flooding of a photoelectric receiver with light that is modulated at the same frequency as that which is transmitted by the system. Likewise, in an ultrasonic motion detection system, it might require the generation of the transmitted frequency at high energy levels, thus minimizing the Doppler shift detection by the receiver. This method of attack can take many forms and is perhaps the most dangerous.

Fragmentation

Within the digital environment, this attack refers to breaking a system by sending multiple fragmented packets that cannot be properly processed. It can be roughly approximated to alarm

stacking, where multiple signals from individual devices are received, causing an alarm condition to occur that may be improperly interpreted as a system failure, or due to causes that do not constitute a condition of intrusion (such as adverse weather conditions).

Encryption

Transmission links should always be encrypted between a central processor and alarm monitoring center. However, much like the computer world, the use of encrypted virtual private networks (VPN) can also cause problems, because the networks may not detect encrypted traffic that is not authorized, but is intended to directly access host servers.

Denial of Service (DoS)

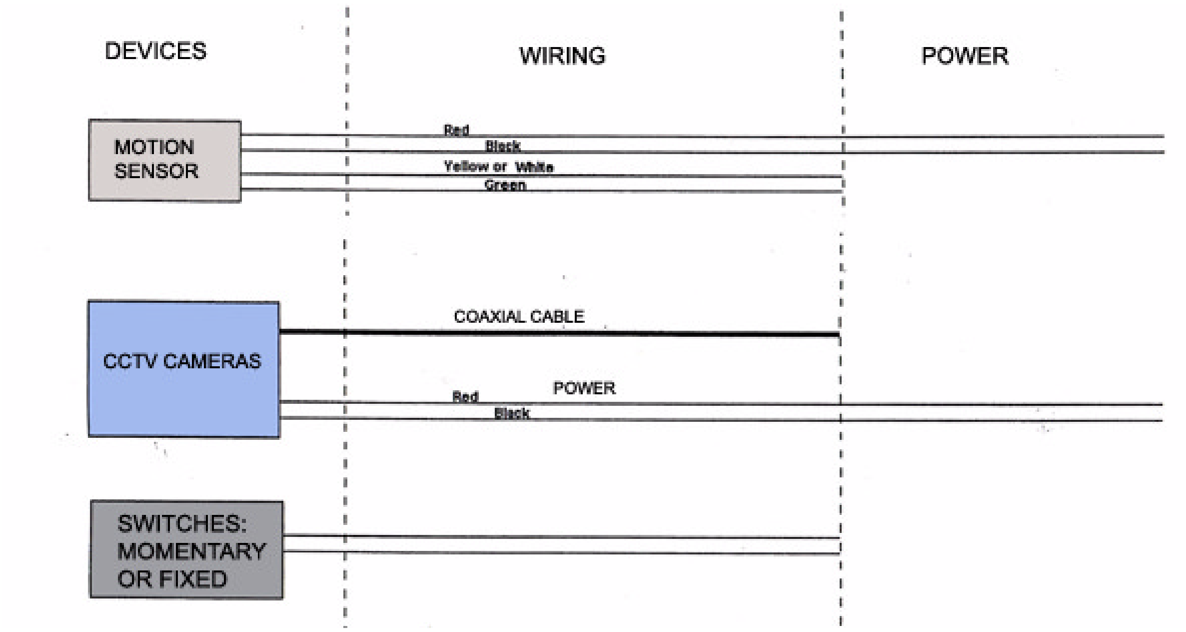
A denial of service attack can be compared to alarm stacking, and is a method to overload processing capability. This form of attack can take many forms, ranging from multiple alarms from one or more devices within a specific facility, to causing the receipt of thousands of alarms from different premises throughout a community. Such attacks have been employed in major cities to mask burglaries of drug stores, jewelry outlets, and banks. In one particular attack, a major feeder trunk was cut outside of a telephone central office, taking thousands of telephones and alarm reporting circuits out of service for an extended period. The overflow of alarms into all monitoring centers made it impossible to assess the validity of any particular alarm, and allowed the burglars to proceed without detection.

Application Hijacking

This method of attack involves the interception of a session between the alarm monitoring center and local facility central processor. The hijacker is able to assume the legitimate credentials from the local facility. Once this occurs, the local system is taken off line, so that there is no reporting to the monitoring center. There are variants of this method. One allows the attacker to steal the client's session token that permits it to communicate with the host. In another, the "man in the middle" attack is involves the hijacker pretending to be the legitimate user to the server and pretends to the server to be the legitimate user.

40_3.0.3.1 Two-wire devices

Switches, continuity devices, and sensors that utilize a single pair of wires to signal continuity or a normal condition are all subject to bypass.



Vulnerabilities that exist with regard to sensors, wiring, and power include:

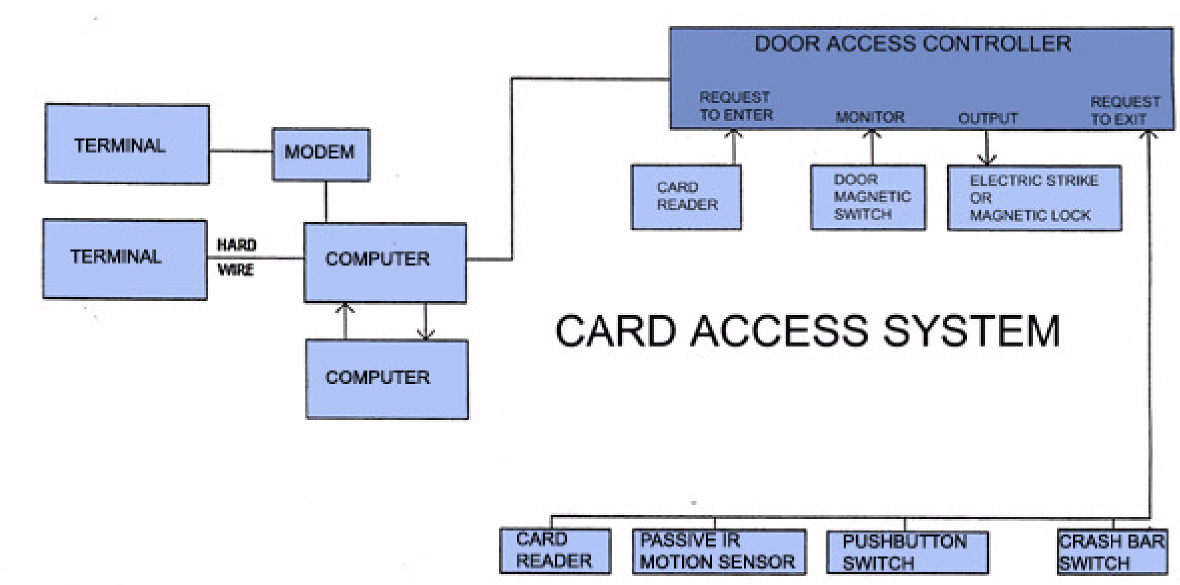
- **Walk test lights that are not disabled;**
- **Shielding of sensor before the intrusion occurs;**
- **Shielding during the intrusion;**
- **Mounting boxes that are accesible from the rear of the sensor;**
- **Two-wire trips are either opened or shorted to bypass;**
- **Wiring may be compromised when it is accesible and recognizable as to color coding or function;**
- **Bypass of wiring to control electric strikes;**
- **Power loss may cause a system to fail or go into alarm.**

40_3.0.3.2 Card Access Systems

There are a number of vulnerabilities that can be exploited with regard to card access system components. Such systems can be compromised in the following manner:

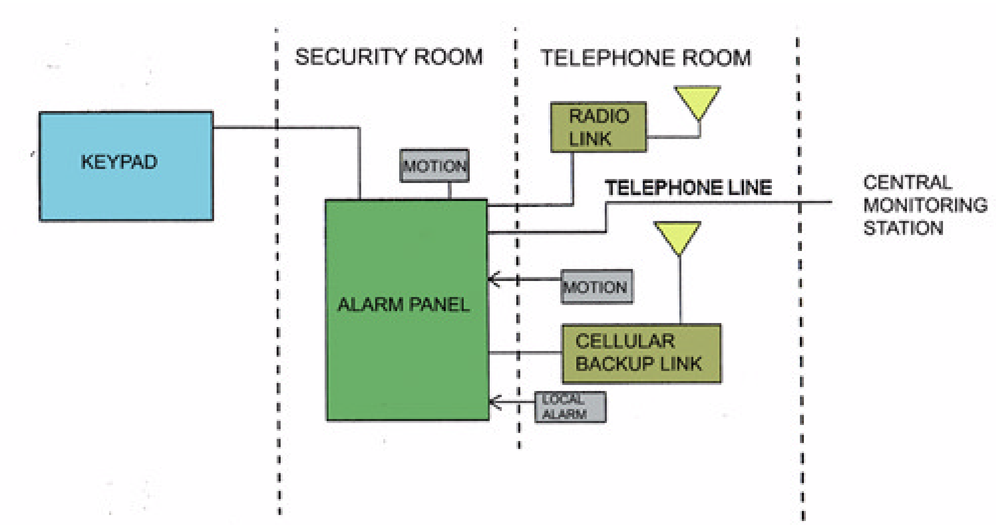
- **Computer terminals unattended while the user is logged onto the system;**

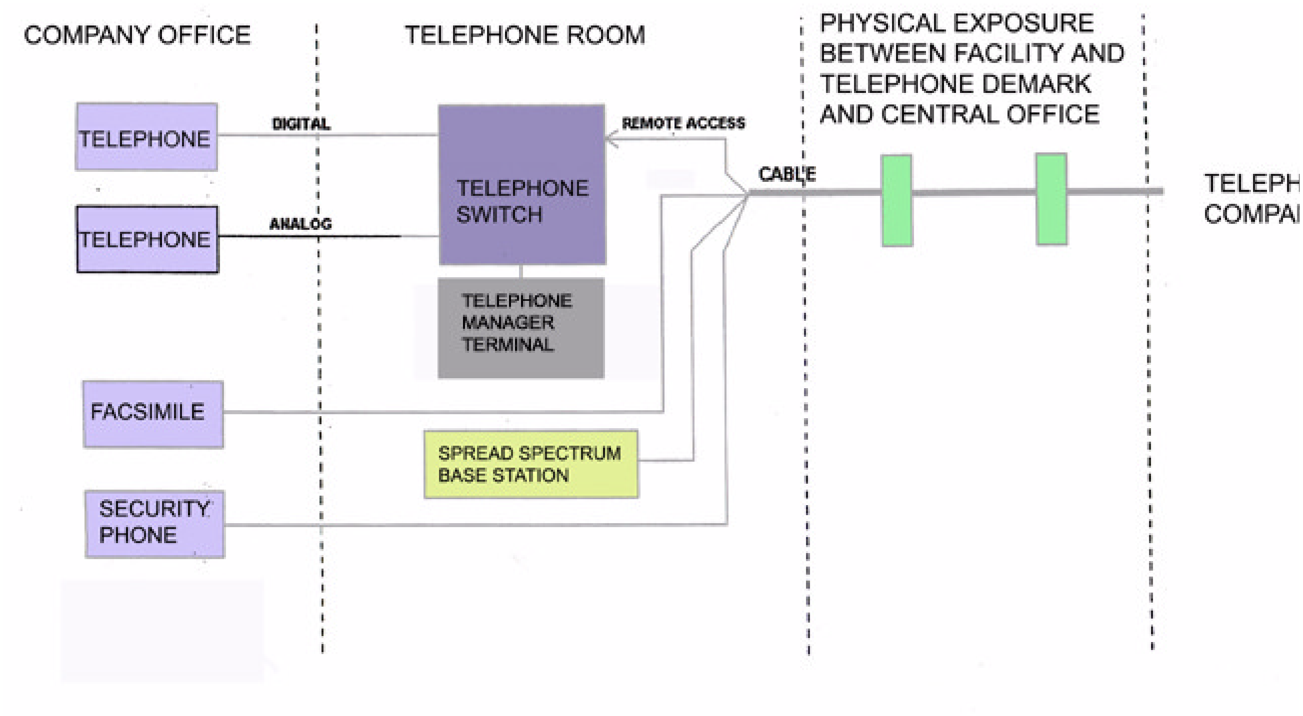
- Inadequate or not enforced security procedures;
- Shared passwords;
- Failure to change default password;
- Failure to monitor and implement a password procedure for selection and changing;
- Failure of physical security measures, such as a compromise of the master key system that allows access to secured areas;
- Stolen or borrowed cards from users;
- Failure to delete inoperative, lost, stolen, or former employee cards;
- Failure to implement a card technology that cannot be hacked or copied;
- Failure to implement proper controls on card programming access or information within the database of cardholders;
- Failure to adequately encrypt the cardholder database;
- Failure to restrict use of cards by time of day and day of week, as well as access only to areas within the employee's authority;
- Failure to properly vet janitorial or maintenance staff;
- Compromise of computer control system;
- Failure to monitor the system for access violations, or invalid attempts at access;
- Failure to implement independent card inventory control;



40_3.0.3.3 Hardware Room and Telephone Room Security

It is essential that security be maintained in the area designated for the location of the alarm central processing equipment to insure its uninterrupted and secure operation. Likewise, the location of telephone and wireless link equipment that ties the alarm system to a central station, remote monitoring facility, or response agency be secure against all forms of attack. Note that this area should not be on the top level master key. See **chapter 31**.





Each component of the security system input, output, and control hardware has specific vulnerabilities. These are summarized below.

Keypad

- Codes may be easily viewed by others as they are input;
- Failure to maintain a log of all entry and access attempts;
- Failure to review access logs;
- Sharing pass codes, thereby preventing individual accountability;
- Insufficient pass codes, requiring that they be shared among employees;
- No duress code;

Alarm Panel

- Keys left in the panel door or near the panel. This can allow unauthorized access to reprogram or defeat the alarm panel;
- Original lock has not been replaced with a high security cylinder, such as Medeco cam lock;
- Factory original keys will open the alarm panel. These keys are available to virtually anyone;
- Alarm identification is visible to an intruder;

- Security room is unlocked;
- Security room is unprotected with alarm sensors. There should be a magnetic trip on the door, and motion sensor to protect the area around the alarm panel;
- The room that contains the alarm panel is a shared use area, allowing janitorial, maintenance, other staff, or unauthorized individuals to access the panel;
- The security room is on the top level master key, allowing potential compromise;
- Individuals that have access to the alarm panel are unsupervised;
- Inadequate fire walls and protection for the security room;
- Alarm panel serial numbers are visible. This may provide information with regard to passwords or encryption keys;

Transmission Lines

- Transmission lines can be cut, if a dial-up circuit is utilized;
- Leased lines to a central station can be compromised if they are not supervised properly;
- Telephone room is kept unlocked;
- Telephone room is on the top level master key;
- A lock box is utilized to store the key to the telephone room. Unless proper security is maintained over the lock box, this is also easily compromised;
- The telephone room is not properly alarmed;
- No security clearance is required for individuals to access the telephone room;
- No covert CCTV camera is installed in the telephone room;
- There are inadequate fire walls in the telephone room;
- No written records are maintained with regard to all circuits that terminate in the phone room;
- Telephone circuits are not tagged and properly identified;

Central Monitoring Station

- Doors left open or unlocked for convenience or ventilation;
- Design of central station structure is not compliant with UL standards. There is no outer building shell;
- Owner/operators of central station facility do not follow proper procedures in order to accommodate clients;
- Improper response upon receipt of an alarm;

Telephone Rooms and Circuits

- Telephone circuits easily accesible and subject to intercept;
- Cordless telephone does not utilize spread spectrum and can be intercepted;
- Telephone wiring is accesible;
- Telecomm manager terminal is not protected from unauthorized programming or access;
- Remote access ports into telephone switch;
- Analog outputs from digital ports;
- Telephone room easily accesible;
- Punch blocks within telephone rooms are not properly documented and secured;

Exposure Between Facility and Telephone Company

- Surface pedestal with underground cable is subject to compromise. The buried cable pedestals are not under the user's physical control or supervision;
- Aerial splice containers with above ground cables are subject to compromise;

Telephone Central Office

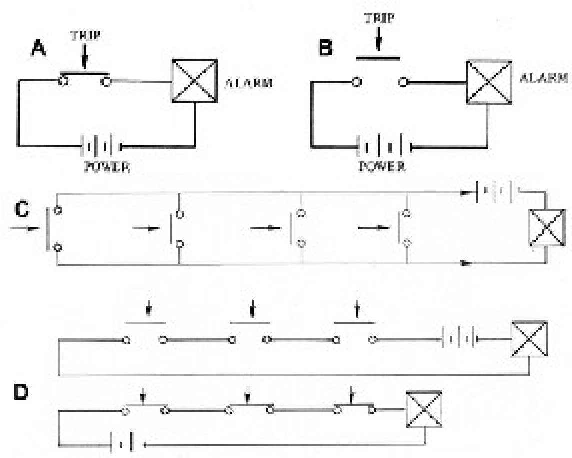
- Legal wiretaps are non-detectable;
- Illegal wiretaps;
- Lack of security in central office;
- Failure to protect trunks that feed the central office.

40_3.1 Contact and Continuity Devices

Mechanical switches are used to detect the opening of a protected door or window. Contact switches depend on direct physical operation/disturbance of the sensor to generate an alarm. They are the simplest in theory and operation, and perhaps in a limited sense, the most stable and reliable. When an intrusion or other defined action occurs, the contact trip will make or break an electrical circuit.

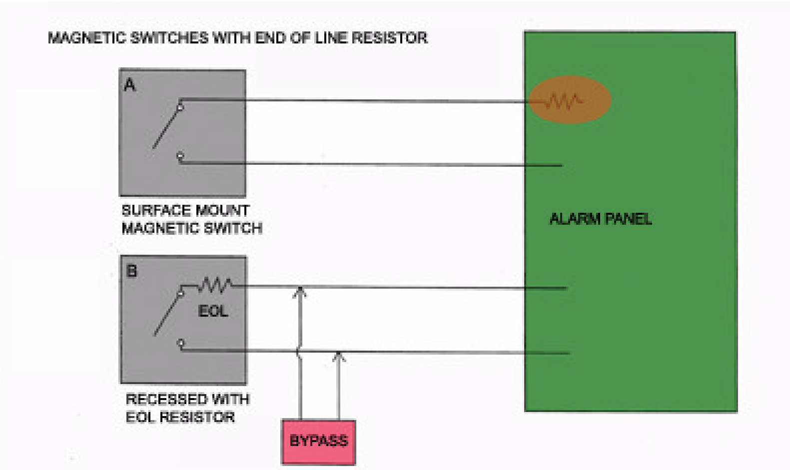
The most common types of contact sensors are the magnetic trip, window foil, pressure floor mat, foot switch, holdup buttons, micro switch, level-switch, and taut-wire trips. All of these devices function on the same basic principle: circuit continuity is completed or broken upon activation. These mechanical switches are usually spring-loaded or plunger operated; they are activated when the contacts are moved to an open or closed position.

Contacts can be series wired within a loop if every device is in a “normally closed” condition. Otherwise, trips may be wired in parallel using one pair of wires, so long as all devices are “normally open” until an activation occurs.



Sensors can be mounted in almost any configuration: on doors, windows, drawers, cabinets, trap doors and any other item that must be moved. They are generally complemented by other protection technologies such as microwave or infrared. In order to operate reliably, trips must be properly mounted on secure and stable fixtures that are not loose fitting or subject to random movement.

End-of-line resistors are utilized to protect sensors from bypass, as shown in the diagram below. If the resistors are not placed at the trip, then they can be easily circumvented. Magnetic (and other types) switches can be defeated by presenting a short circuit to the switch contacts or anywhere along the circuit, unless protected by a properly placed EOL resistor. The use of a magnet to simulate a normal condition will also defeat standard magnetic reed switches. Note that if the EOL is improperly placed within the circuit, then a simulation of the correct resistance can be inserted between the trip and the alarm panel. If the tamper device is later removed, there will be no evidence of such bypass. The switch (A) is a standard magnetic contact device. The end-of-line resistor is placed at the alarm panel, rather than at the switch and can easily be circumvented. The recessed switch (B) has the EOL properly placed, but can still be bypassed, as shown.



Nuisance alarms can be caused by:

- **Poor fitting or improperly mounted doors or windows;**
- **Extreme weather conditions (wind and storms);**
- **Seasonal fluctuations in the external and/or internal environment (heating versus air conditioning).**

40_3.1.0 Defeat of Mechanical Contacts

Switch type sensors are subject to simple bypass in a variety of ways. These include:

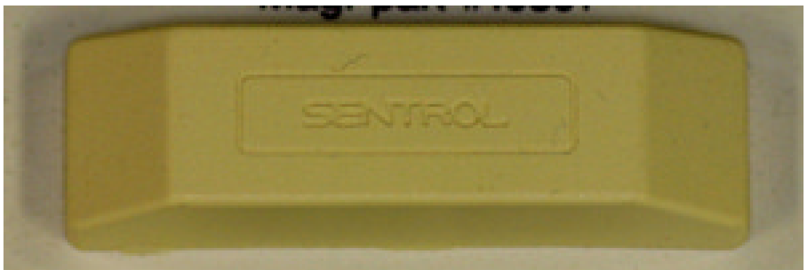
- **Holding the switch in the "normally closed" position while opening the door or windows;**
- **Use of a small piece of metal that prevents the switch from triggering;**
- **Taping the switch in the "closed" position during daytime operations;**
- **Placing a short-circuit across the terminals of the switch so that it shows its normal state in any condition;**
- **Cutting a circuit that is normally open;**
- **Bypassing end-of-line resistors;**
- **Release of a switch from an external location through the use of a stiff wire or other mechanical bypass;**
- **Shimming by forcing a small thin piece of material (metal or plastic) between the switch and protected area (door edge or object) to hold the switch depressed;**
- **Wedging an object into the switch to hold it closed during a**

disarmed period. Use of a toothpick, super glue or other material is typical;

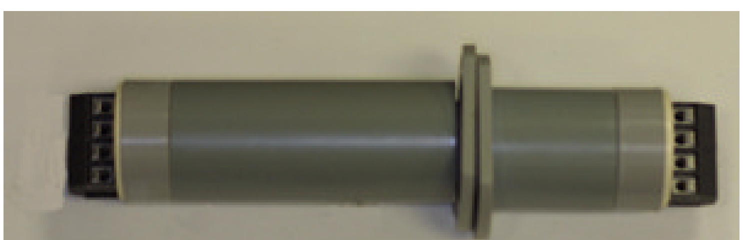
- **Bridging of exposed or internal switch contacts or at a splice point (jump-out).**

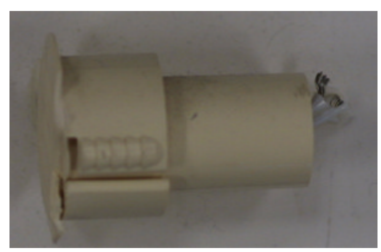
40_3.1.1 Magnetic Contact Sensors

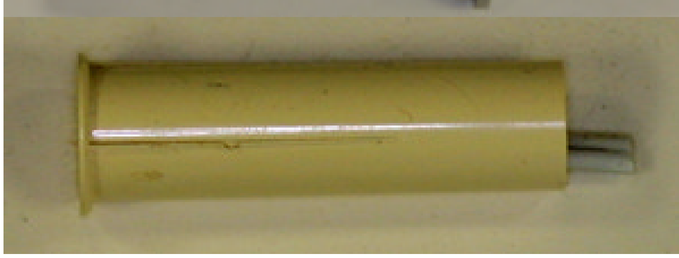
LSS401: Alarm contact devices, including magnetic switches











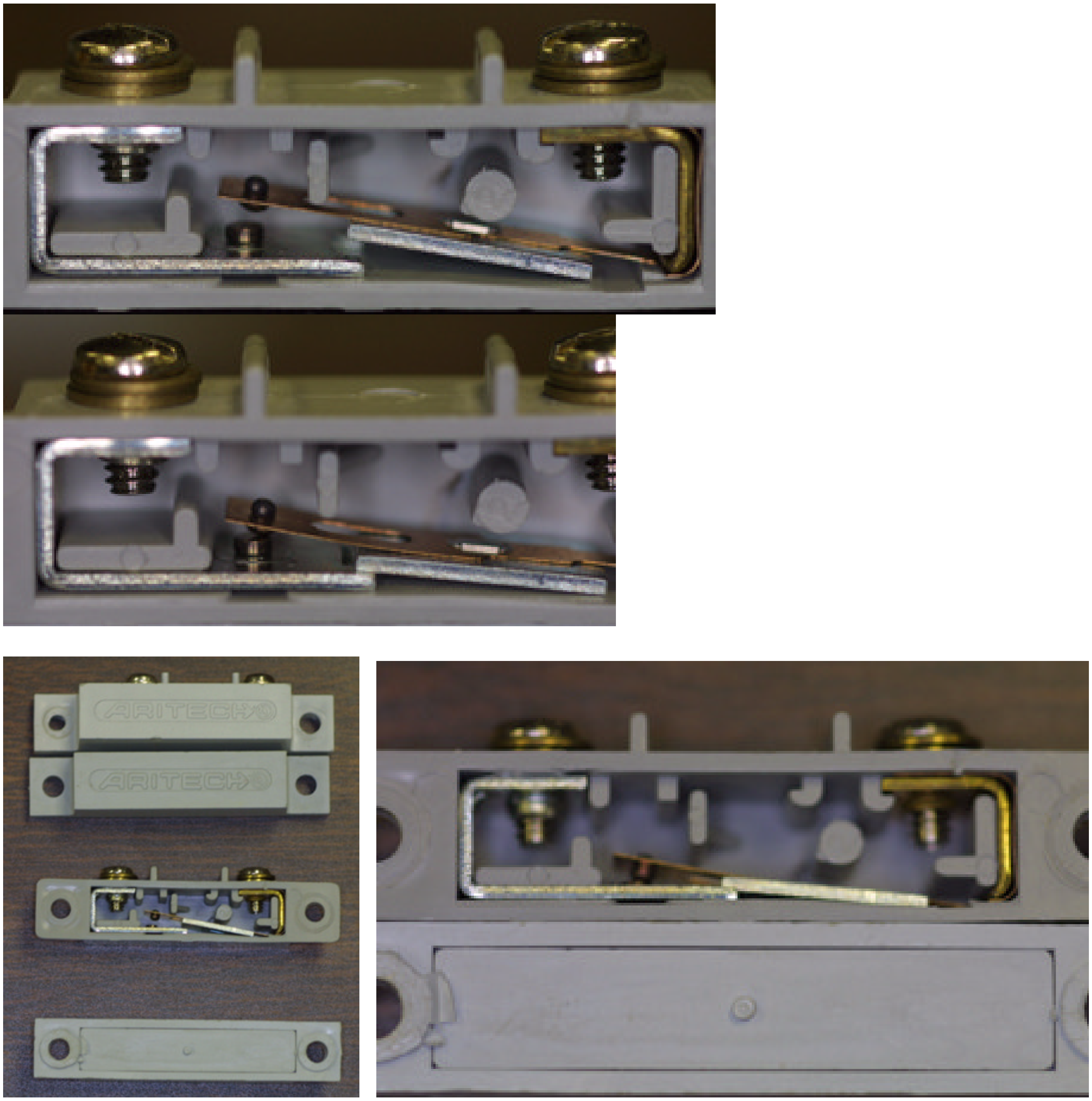
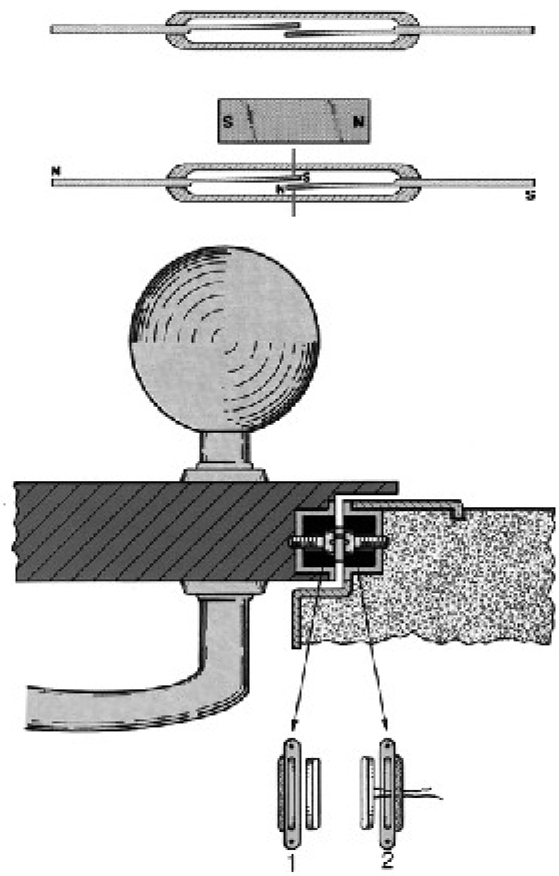


Figure LSS+4043 A variety of magnetic contact switches are available. The photographs show the switches in normal open and closed states. The magnet biases the contact, shown in the bottom photograph, so that the circuit is completed.

Magnetic contacts are utilized to protect doors, windows, drawers, paintings, statues, safes, and other objects that can be moved. They are produced in a variety of configurations and can be secreted in virtually any location. Their operation depends upon direct physical operation of the sensor by the target object. In high value items, other trips should be utilized to

afford overlapping protection. Trips utilize a fixed magnet and some form of magnetically sensitive switch. When the field is in close proximity to the sensor, the switch closes (or opens). When the field is removed, the status of the contacts is reversed.

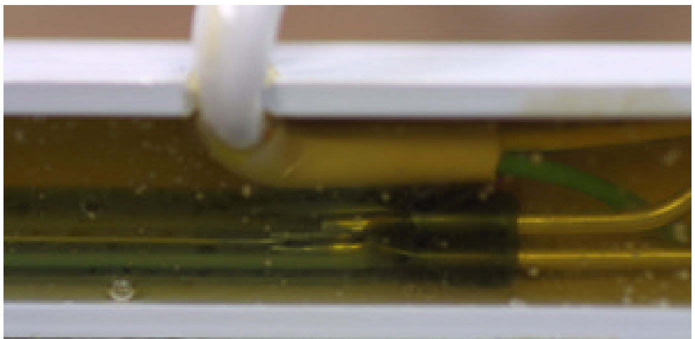


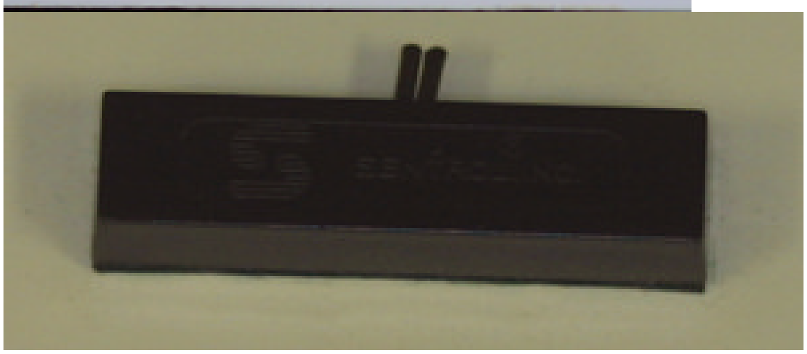
There are generally two parts: a magnetic switch that is mounted on the fixed object, and a magnet mounted on the moveable component. Most magnetic trips utilize sealed reed switches in plastic or glass tubes filled with an inert gas. A thin contact strip at each end of the vial is positioned so that the tips are parallel and overlap without touching. When a magnet is brought in close proximity to the reed, they are drawn together.

Reeds are constructed with ferromagnetic metal leads. This metal becomes magnetic in a magnetic field. When this happens, each lead assumes opposite magnetic polarity. The leads attract one another and when the field strength is sufficient to overcome mechanical lead stiffness, the leads make contact, thus making electrical continuity. This action happens in as little as

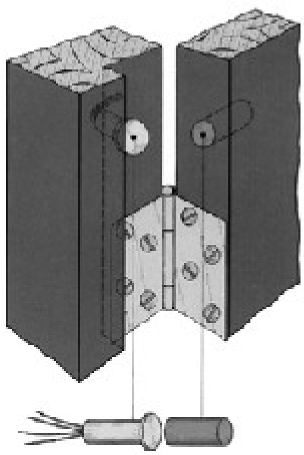
0.5ms.

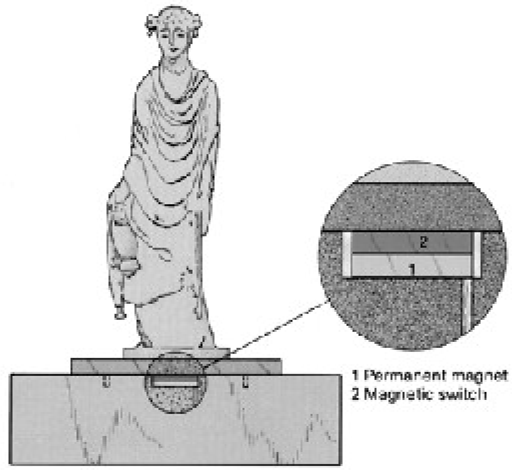
Reed sensitivity is determined by the manufacturer, that specifies the gauss level of the magnetic field required to close the reed blades. Magnetic field strength is measured in Gauss and reed sensitivity is measured in Ampere-Turns. These units are not mathematically related, but can be matched empirically.





Unreliable operation will result if there is excessive movement of the mounting surface, such as poor-fitting doors, windows, access panels, or frames, as described in the preceding section. Extreme weather conditions can cause excessive movement of mounting surfaces.





40_3.1.1.1 Defeat Techniques for Mechanical Magnetic and Reed Switches

Traditional magnetic switches that do **not** employ reeds can often be easily bypassed through a variety of techniques. These include:

- Avoidance: cut through an opening;
- Capture with external magnets;
- Bridging of external or exposed switch contacts or at splice point (Jump out);
- Tape or glue a magnet to the switch during alarm-off mode;
- Alarm stacking with the application of shock from a non-secure side (use of a ball pene hammer);
- Liquid solder on exposed contacts.

During the past thirty years, the single element reed switch has been the primary magnetic switch component for perimeter protection of doors and windows. Almost all reed-based devices suffer from significant vulnerabilities in terms of bypass, mechanical reliability from external energy sources, and environmental issues. The traditional alternative to the single element reed switch is the balanced magnetic switch (BMS) which utilized multiple reed segments. Other technologies are available that can provide high security perimeter protection. These are discussed in later sections of this text, and in the accompanying video on magnetic switch defeat techniques.

Specific defeat techniques include:

• **Application of magnetic fields**

The traditional reed switch can be defeated with a strong magnetic field because of its inherent design characteristic that require that its active contact blades be equally magnetic in all planes. Any magnetic field that is within close proximity will temporarily magnetize the blades, causing them to be attracted to each other. This can result in a closed circuit condition. The remedy is to utilize a switch that has two sets of contacts, one of which will trigger upon the presence of a second field. Another method of bypass involves bridging of the contacts, resulting in permanent continuity. Access to the door or window without affecting the status of the trip will also allow bypass the alarm system. The position of the switch should not be easily observed or accessed.

• **Strong electrical fields**

Contacts can be permanently welded closed from a high voltage lightning or power surge, or through the use of a Taser gun. In addition, proper operation can be affected from the application or proximity to strong electro-magnetic interference (EMI) that is generated from nearby power lines and cables or large appliances. Remember that the wiring that connects such devices to the remote alarm panel can act as an antenna. Large voltage spikes will cause a permanent closed-circuit condition, rendering the sensor inoperative.

• **Physical reliability**

Sensors contain two parallel metallic blades that are encased in a glass envelope. The enclosure can be broken from shock or rough handling prior to or during installation. Sensors can also be damaged as the result of swelling of enclosures that can be caused by changes in temperature or humidity. Thermal expansion of materials can pose a serious problem.

40_3.1.1.A Balanced Magnetic Switch (BMS)

LSS403: Defeat of magnetic switches, including BMS

A balanced magnetic switch consists of an assembly with an array of five internal magnet that is usually mounted on the door or window frame and a balancing (or external) magnet mounted on the

moveable door or window. The switch is usually balanced in one position between the biasing magnets and external magnetic fields. A disturbance of the fields caused by movement of the external magnet will cause the state to change. In the normally closed state, the biasing magnet interacts with the fields generated by the external switch magnets.

Generally, there are three reeds that respond to the external magnet array. These three magnets are set to north-south-north or south-north-south with regard to polarity. The bias magnets match the polarity of the external fields. Any attempt to introduce a magnetic field to bypass the normal operation of the switch will result in one or more reeds changing state, and an alarm. There is also a separate anti-magnetic tamper reed to sense the introduction of stray magnetic fields. A magnet in the base of the BMS provides anti-pry protection. Although certain manufacturers represent that actuating magnets are matched to specific sensors, they are in fact interchangeable. A magnetic array may also be placed on the front of the switch to defeat its operation.

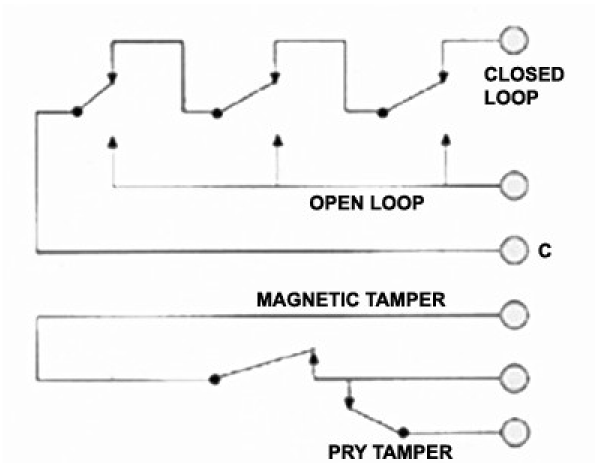
These sensors offer a higher level of security than traditional magnetic switches. They are also available for hazardous areas where there is an explosion potential. Typical tolerance is a movement from about one-half to one inch from the door to frame. For added security, supplementary devices should be utilized. As with other switch sensors, erratic operation will result from excessive movement in the mounting surfaces caused by mechanical design, wear, extreme weather variances, or improper installation.

40_3.1.1A.0 Defeat Techniques for Balanced Magnetic Switch

The BMS is a high security sensor that contains one or more internal biased magnets and reed switches. Unlike the conventional mechanical or reed switch, it is significantly more resistant to tampering or bypass through the application of an external magnetic field. Remember, the reed switch will react to the greater magnetic field. However, these switches are biased, so a precise field with the correct strength and polarity is required for activation.

In the photographs below, a triple balanced magnetic switch is shown. This device, manufactured by Sentrol (Model 2707) contains three reeds that are mounted at an angle, and another reed switch

to detect tampering through the use of an external magnet. A fifth reed provides an alarm in the event that the base is pryed loose. In normal operation, the switch must be mounted a specified distance from the actuating magnet, or it will not set up properly. A nominal gap of .4"-8" is recommended. The circuit is shown below for both normally open and normally closed loops.



This switch can be defeated, as shown in the photographs, by applying three magnets of the proper strength and polarity directly against the reed switches but separated by a metallic mounting plate. The author has utilized **Neodymium magnets** (NeFeB) consisting of neodymium, iron, and boron. A nominal strenth of 67 gauss is required at each of the reeds. As shown, the reeds can be located by reading the magnetic signature on the actuating magnet with a magnetic film, such as visimag, than transposing their position onto a piece of plastic, paper, or metal which is then affixed to the base of the switch. The location of the reeds can also be determined by applying material around each of the reeds to locate the bias magnets.

If done properly, the bypass magnets will not be visible during normal daytime operation. They will not affect how the switch works, but will maintain circuit continuity when the door is opened. Magnetized needles can also be utilized to pinpoint the center of each magnetic field, as shown.

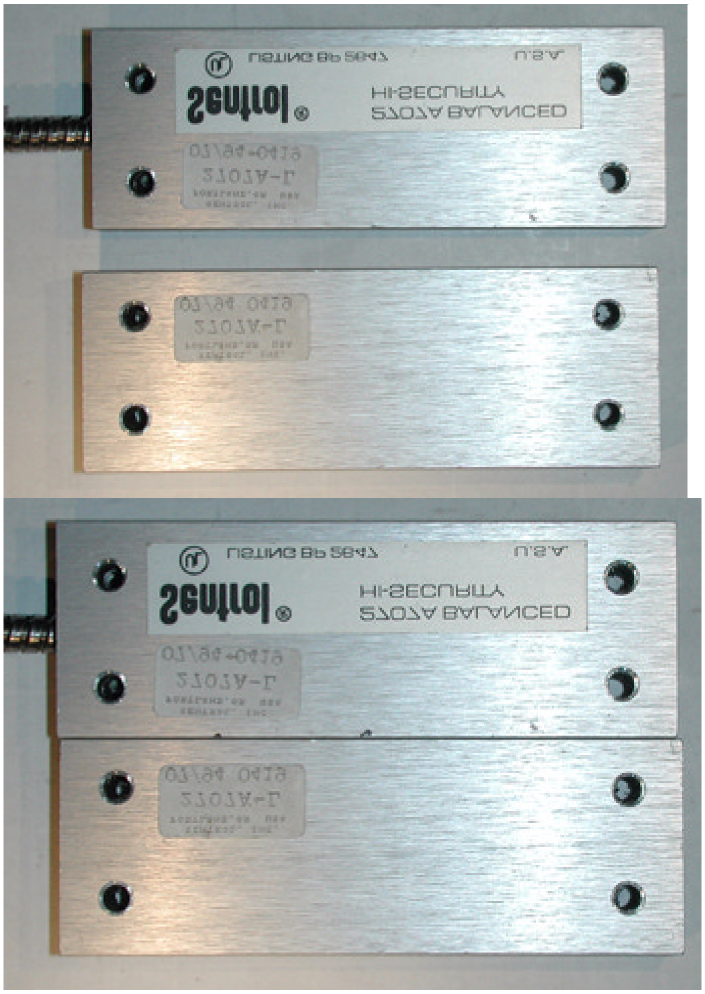
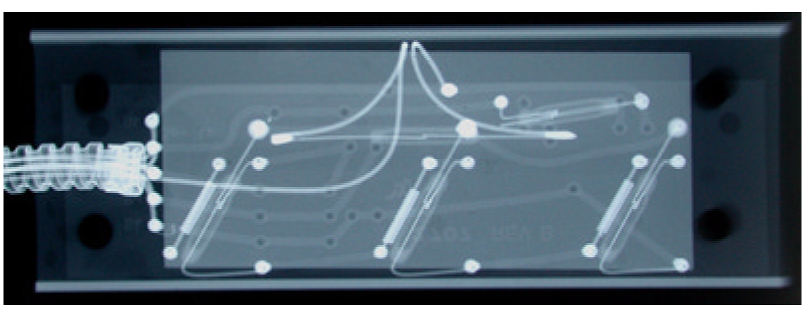


Figure LSS+4067. A Sentrol 2707A high security balanced magnetic switch (left) with the proper spacing between magnet and reed elements, and (right) the switch will go into alarm because the reqired gap is not present.



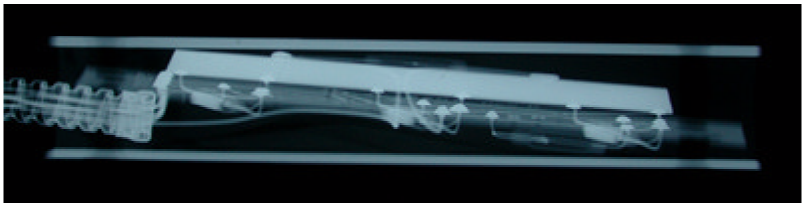
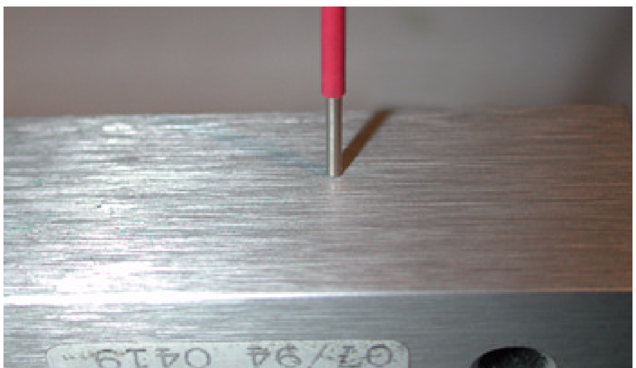


Figure LSS+4068. An x-ray view of the Sentrol 2707B BMS, shown above. Note the three reed switches that have been placed at an angle to the base of the switch. Note also the biasing magnets next to each reed. The reed switch that is parallel to the base detects the presence of the mounting plate and provides anti-pry indication. The reed that is located at an angle at the upper right corner detects magnetic tampering with an external field. The side view (right photo) shows the orientation of the switch to the magnetic array that would be located so as to create a .4" to .8" gap.





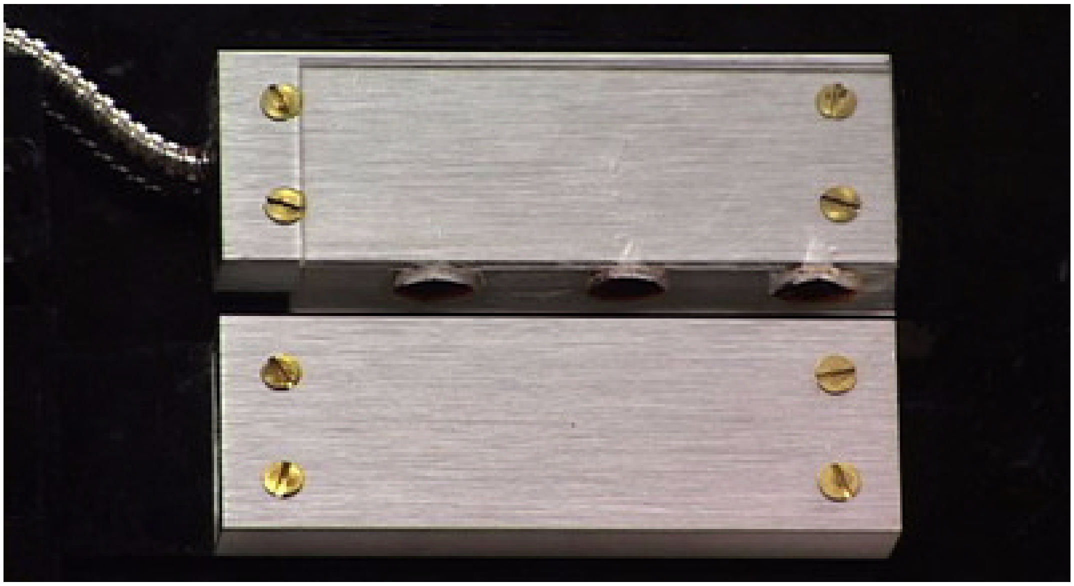


Figure LSS+4069. A balanced magnetic switch that contains three reeds can be bypassed with magnets attached as shown. Magnetized needles and visimag material can be utilized to determine the precise location of magnetic fields. Rare earth magnets can then be placed against the active portion of the switch. In the above photograph, a piece of plastic is utilized to support the magnets to demonstrate the principle. In a real bypass, the system shown below would be more likely to go undetected.

Another technique to defeat the BMS would be to embed three magnets within a plastic base upon which the sensor array is normally mounted (for anti-pry feature). If the magnets are oriented properly with reference to the three reed switches shown in the x-ray view above, then the device would always show a normally closed state, regardless of whether the door was opened or closed. Security staff should pay close attention to the base plate for the 2707 BMS because of the potential for substitution and subsequent defeat of the trip.

Generic methods to defeat this type of sensor include:

- Avoidance by cutting through or around the door or window;
- Alarm stacking with shock from the non-secure side;
- Jump-out the alarm circuit cables;
- Capture with external magnets of a single-bias BMS;
- Tape or glue one or more magnets to the switch during access to area.

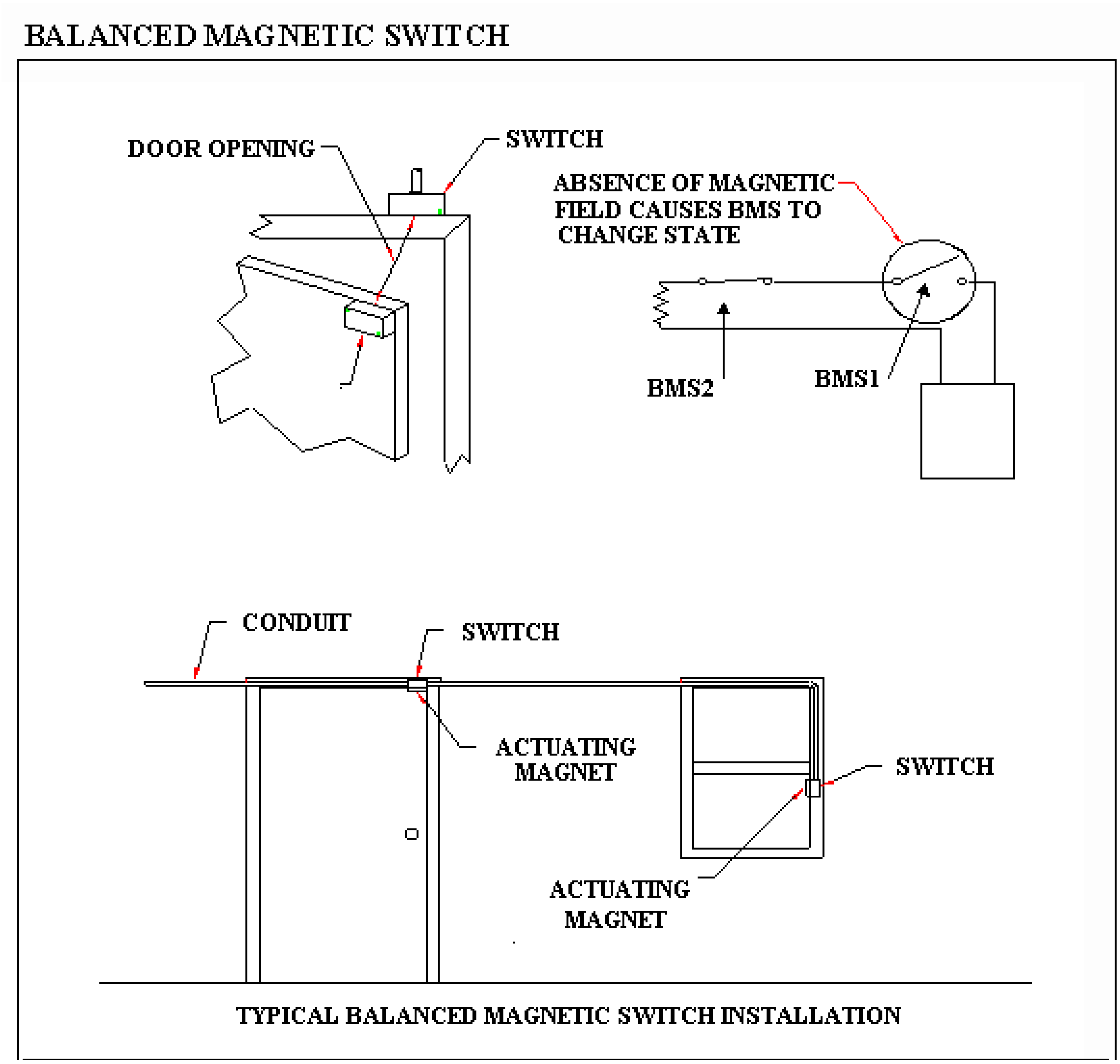


Figure LSS+4001 Typical balanced magnetic switch installation

40_3.1.1A.1 Magnasphere Magnetic Switch

 **LSS403: Magnasphere technology**

The Magnasphere high security contact was designed specifically to eliminate certain vulnerabilities that are inherent in the reed switch. The design relies upon a tiny magnetic ball floating freely inside a small metal housing with two protruding wires. The switch remains closed only when a magnet is directly under the switch so it can pull the magnetic ball into electrical contact with the case and electrode, thereby completing the

circuit. The presence of a strong magnetic field near the switch has the opposite effect of the reed switch; the magnetic force dislodges the ball and breaks the circuit. This design eliminates the possibility of magnetic bypass.

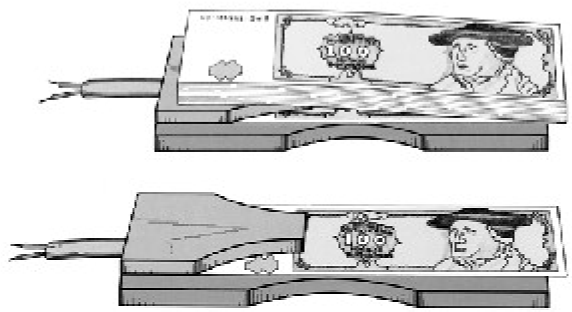
In contrast to the balanced magnetic switch, which is a 4" x 2" aluminum box containing three reed switches and armored cable. The Magnasphere high security switch can be packaged for surface mount in a 3/8" x 3/8" cube. The switch is suitable for installations where the sensors are less than ½" apart.

Exposure to high voltage will generally not result in contact welding, as can be experienced with traditional reed switches. False contact closure is virtually eliminated with the floating ball design. In the event that the ball contact sticks, normal door or window movement (with attached magnets) attracts the ball contact. This "torques" the contact to open the circuit. Other environmental issues, such as swelling and shifting of doors and windows and temperature extremes will not affect the switch. End-of-line resistors can also be incorporated directly into the switch wiring.

40_3.1.2 Bank Note Contacts

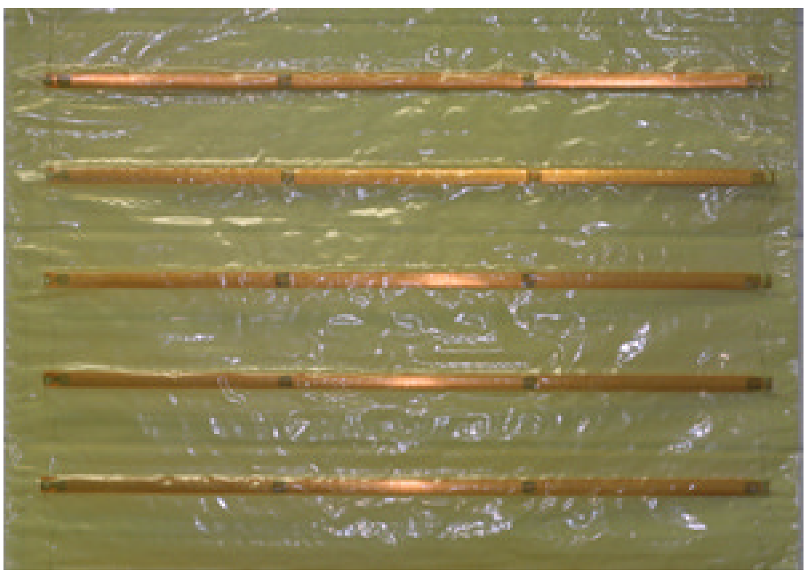
Special bundles of bank notes are provided to tellers for use in case of a robbery. When money is removed from the package or the entire group of bills is handed to the robber, a micro switch contact signals an alarm. Usually two spring-biased conductive surfaces are insulated from each other by several bills. When the currency is withdrawn, they are allowed to touch in order to complete the circuit. The contacts can be likened to a clothesline clip separated by an insulating material.

Such an alarm is automatic as long as the teller utilizes the bait money during a holdup. However, once the money is removed, it is obvious that an alarm device was attached to the bills and has been triggered. False alarms are also more likely with this arrangement.



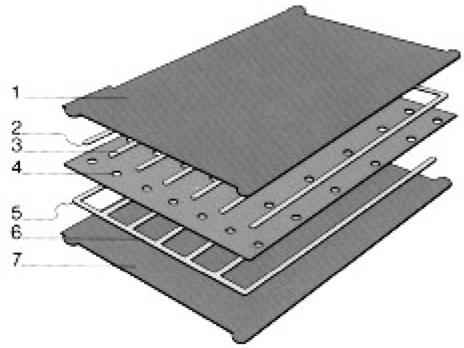
40_3.1.3 Pressure Mats

LSS401: Discussion regarding pressure mats



Sensors utilized in pressure mats are usually quite simple in design and are often constructed as two thin metal strips that are electrically insulated. So long as a specified amount of pressure is not applied, the strips will not touch each other. Usually, the strips are configured as a "normally open" device; they will not complete the circuit in the absence of pressure.





Mats are available in various sizes or as rolls that are cut to the required shape. They are placed under carpets, carpet runners, pads and the like. When someone steps onto them and applies the requisite amount of force, a signal will be sent to the central processor, based upon circuit completion. The sensors should be placed in locations that are likely to be traversed by a burglar during the course of committing the crime. Such places might include:

- **In front of windows;**
- **In front of doors;**
- **In front of safes;**
- **At the top or the bottom of a flight of stairs;**
- **In front of valuable objects.**

40_3.1.3.1 Guidelines for the Placement of Mats

Erratic operation and failures can result if certain precautions are not observed. The following guidelines apply to installation:

- **The protective layer of the mat should be watertight because a damp environment can alter the circuit impedance and lead to a false alarm;**
- **Small stones and other hard objects can become embedded into the surface layer of carpet and the pressure mat, causing a false alarm;**
- **The location of the mat should be evaluated in terms of visibility. Mats are generally between 5 - 10 mm thick. If they are observable under a carpet, then they can be easily bypassed.**

40_3.1.3.2 Defeat of Pressure Mat Sensors

Pressure mats can be bypassed easily, by:

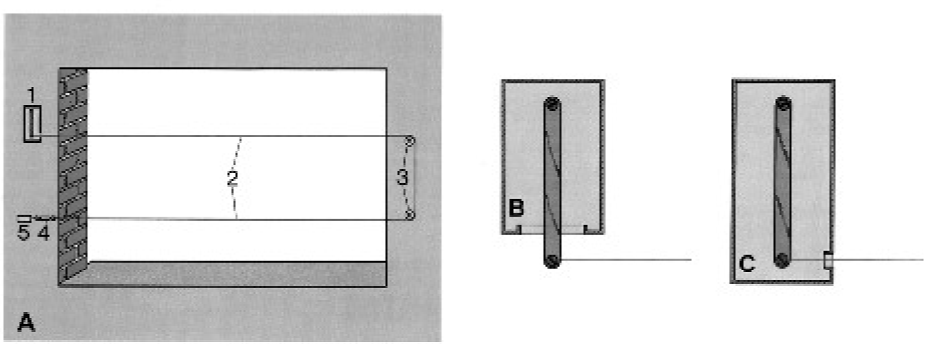
- **Avoidance of mat, stepping over or around;**
- **Bridging the electronic detection circuit;**
- **Running a tack or staple through the mat, thereby causing a fault condition which will require it to be taken out of service.**

40_3.1.4 Trip Wire Contacts

LSS402: Trip wires in alarm systems

Trip wire or taut-wire sensors are another form of inexpensive contact device. They are comprised of a length of cord that is connected to the lever arm of a micro switch, together with a tightening device and deflection pulley. Sensors are used to monitor openings in walls, windows, doors, ventilation shafts, light domes, and skylights.

Typically, switch assemblies are designed to enclose the entire contact lever within a casing to protect it from tampering.



In operation, the wire maintains the contact lever in a neutral position. If there is any change in tension because of the cord being torn, cut, or pulled taut, the switch will be activated, causing an electrical change in the circuit.

40_3.1.4.1 Guidelines for the Installation of Trip Wires

- **Trip wires can monitor gross movement within an opening; they are not sensitive to small variations. Thus, when an intruder crawls through an air duct, the wire is sure to be disturbed. When the same intruder pushes a hand through the opening, there is much less likelihood of touching the wire. The sensor should be utilized to monitor spaces, based upon the likelihood of an intruder tripping the device;**
- **Suitable wires, threads, and cords should be utilized. These must not stretch when subjected to hot or humid conditions. The dimensions of long trip wires can change from extreme environmental factors;**
- **Deflection pulleys, terminal clamps and switches must be mounted so that they cannot be reached by an intruder. The entire switch and lid contacts should be incorporated within the housing to prevent bypass.**

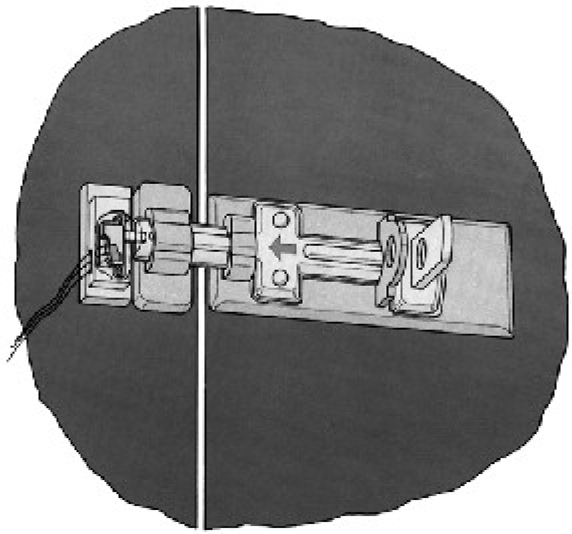
40_3.1.4.2 Defeat of Trip Wire Systems

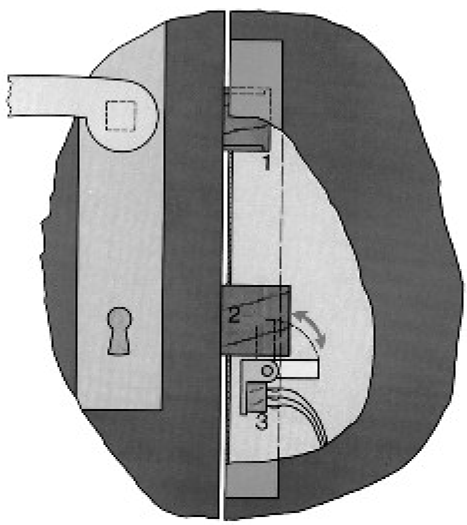
Trip wire detection systems can be easily defeated by:

- **Avoidance of the trip zone;**
- **Clamp and cut, thus bypassing the trip wire.**

40_3.1.5 Bolt Contacts

Bolt contacts supervise door and window latches to insure that they are fully extended or locked when an alarm is set. They consist of small switches that are activated by spring contact, lever, push button, or similar arrangement.





40_3.1.6 Foil and Embedded Wires in Glass or Screen

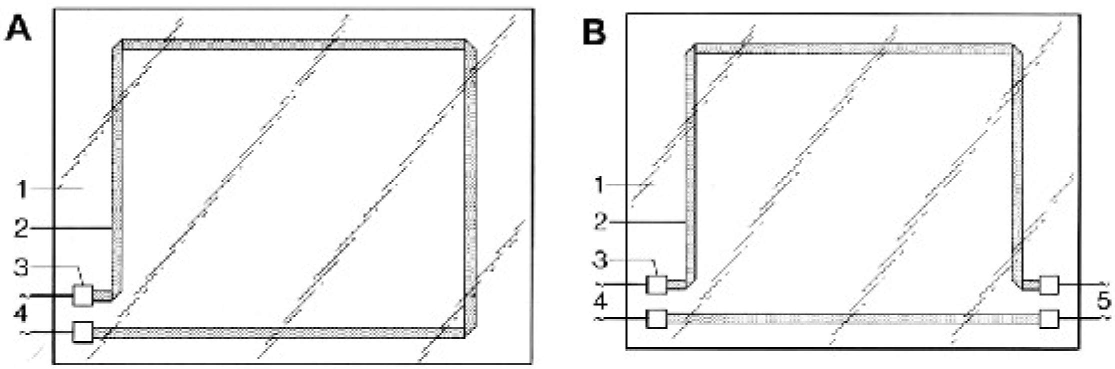
LSS401: Alarm foil

LSS401: Grid wires in alarm systems

LSS401: Ribbon switch material as a sensor

Electrically conductive lead foil or tape, ¼" to 3/8" wide, is used for the surveillance and monitoring of glass. Alarm foil is nothing more than a continuous wire through which an electric current is passed. Fine wires can also be embedded within a glass

panel or screens during manufacture.



Foil is affixed to the glass surface by self-adhesive bonding or with a thin coating of lacquer material. It is usually run completely around the pane or close to critical access points near the edge. Once it is bonded to the surface, any fracture of the pane will sever or tear the foil and interrupt circuit continuity.

Although foil has been utilized for at least seventy-five years, it is not particularly reliable. It is subject to fracture from expansion and contraction that is caused by changes in weather conditions. It can easily be sabotaged with a knife or sharp instrument and is prone to intermittent failure.



Foil is usually integrated with other trips within one loop. For example, foil and a magnetic door contact may be wired in series, so that a failure of either will result in loss of continuity.

The use of foil offers several advantages and disadvantages:

Advantages:

- **Visible deterrent;**
- **Low cost;**
- **Simple installation.**

Disadvantages:

- **Low rate of response: breakage or fracture of the glass may not necessarily tear the foil;**
- **High risk of sabotage, damage or bypass;**
- **Conspicuous and unattractive;**
- **Trips can be easily bridged.**

40_3.1.6.1 Defeat of Foil Glass-Break Material

Foil as a glass-break sensor is subject to compromise through a variety of techniques, including:

- **Avoidance;**
- **Cut and break. This technique requires that a circle be cut in the glass with a glass cutter. Use modelling clay to adhere to the glass prior to breaking it after being scribed by the diamond glass cutter. A wet newspaper can be used to hit the glass in order to dampen the sound;**
- **Use of an acid to physically remove glass within the internal perimeter of the foil protection;**
- **Use of adhesive material, such as duct tape, to protect the foil from fracture while the glass is broken;**
- **Bypass or jump-out of the circuit when the system is disarmed, or while the system is armed if the contacts that interconnect the foil can be accessed and bridged.**
- **Drill small lhole near take-offs and short circuit the contacts;**
- **Slice and break the foil during business hours to take the**

system out of service.

40_3.1.6.2 Defeat of Embedded Wires and Ribbon Switches

Wires embedded in screens and other materials are subject to bypass using a variety of techniques.

Grid Wires

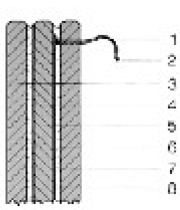
- Bypass or jump-out one or more of the grid wires while they are accessible;
- Avoidance of area that contains wires;
- Intentionally disable grid wire by damaging it;
- Folding back the grid wire mounting grill. This will only work if wire traps are not installed;

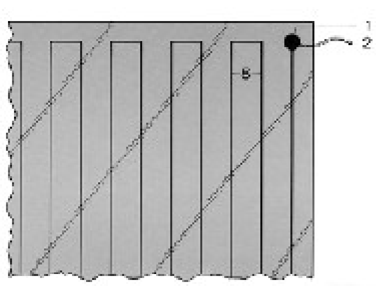
Screen

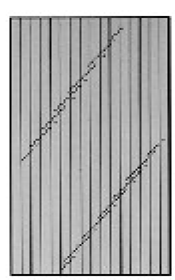
- Bypass or jump-out the alarm circuit while system is disarmed;
- Punch the screen and disable it, allowing intrusion during repair period or while the sensor is out of service;

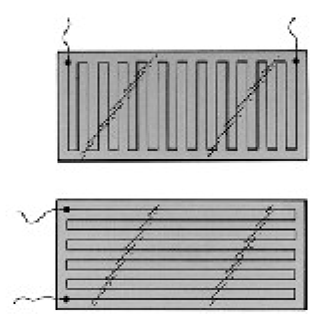
Ribbon Switch

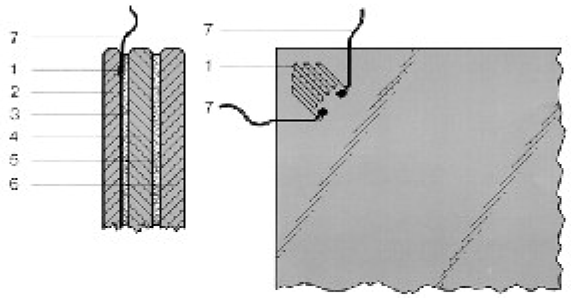
Avoidance, bridging over ribbon switch.











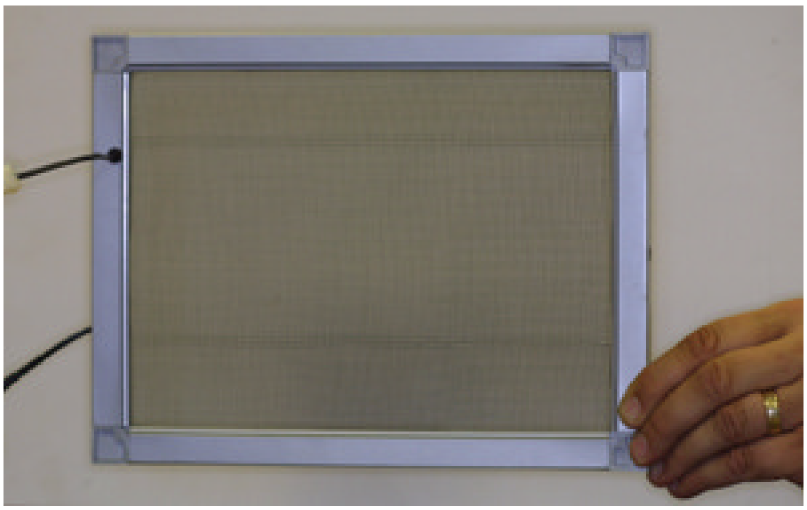
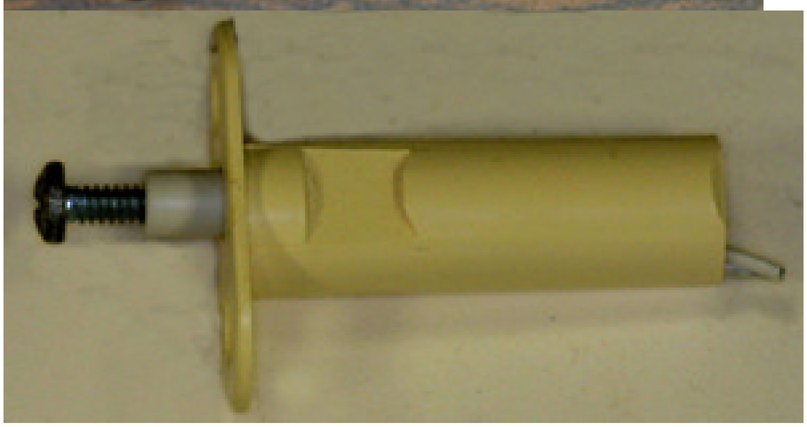


Figure LSS+4044 fine wires can be embedded in window screens during the manufacturing process. The photograph shows two individual wires that are interconnected to form a continuous circuit.

LSS401: Embedded screen wires

40_3.1.7 Foot Switches, Micro switches and Level-Switches







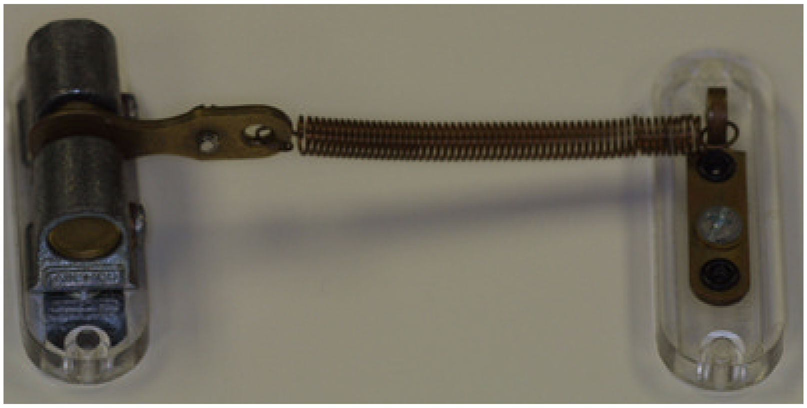


Figure LSS+4045 there are many different types of contact switches that depend upon a circuit being broken or completed.

Switches can be configured to sense a condition or status and change their electrical characteristics when a predefined event occurs. They can also be used for manual signaling of an event, such as a holdup. All switches are designed to complete (normally open) or break (normally closed) a circuit upon activation. Micro switches come in a variety of sizes, contact arrangements, and operating parameters. They can be installed in hard-to-reach areas and are quite effective as backup trip devices in drawers, on safes and safe locks, doors, cabinets and show cases.

Level-switches usually consist of a sealed glass tube that contains two metal contacts and a small amount of mercury. When tilted to a certain angle, the mercury will flow to or away from the contacts, completing or breaking the circuit. Mercury level-switches are well suited to specialized sensing applications. In one instance, the author placed a level-switch in a car that was supposed to be stripped in a salvage lot. When the auto was jacked up, the mercury flowed against the contacts to trigger a wireless alarm.

40_3.1.7.1 Defeat of Mercury Level Switches

Defeat of mercury level or tilt switches generally requires an avoidance of the device to which it is attached. Cutting and punching techniques will allow the circuit to be bypassed. Another popular method is to bypass the exposed contacts during a time when the system is disarmed. Spoofing will also defeat these switches.

40_3.1.8 Taut Wire



Figure LSS+4061 Taut wire systems can be defeated by spreading the wires, as shown, to create a gap for an intruder of up to fourteen inches.

Taut wire sensors, perhaps the most expensive fence sensing technology, are utilized with perimeter barbed wire fencing to detect changes in tension on the fence web through the integration of micro switches. Taut wire sensors do not detect vibration or stress; nor are they triggered by disturbance. The system is comprised of many micro switches that are a part of tensioned barbed wire placed at the top of a chain link fence, or actually installed as part of the fence. Installation is difficult and the system has a high maintenance requirement. The detectors are very reliable, provide a high probability of detection and very low false alarm rate. This type of sensor is employed at high security facilities.

The micro switch is constructed with a moveable center rod that is suspended within a metallic conductor. Normally, the rod stays within the center and does not make contact with the outer ring. The sensors are placed about six inches apart, vertically spaced and oriented inside of a tamper-proof enclosure that is mounted on a post near the middle of the zone to be protected. The enclosure runs the full height of the fence and protects the webbing and any outriggers. Individual strands of wire are tensioned and can be attached to the switch. Any change in tension caused by movement, climbing, spreading or cutting will cause the sensor rod to make contact with its outer ring. This will close the circuit and cause an alarm.

The switch housing is supported by a pliable, plastic support. The switch will always maintain a neutral position against gradual external force that is based upon settling movement or freeze-thaw cycles, thereby minimizing any affects upon sensitivity. Wind should not trip a sensor; a firm pull-force or exertion is required. Nor do small animals present a problem, because sensors are set for about a thirty-five pound force. Many sensors are placed on a fence line so that only one incident is required to trip the system. It is critical that regular tensioning maintenance be accomplished to insure the integrity of the system.

Sensors are mounted on top of a fence, or within the fence webbing itself. Outriggers may be added to protect top mounted sensors from climbers. Top mounted devices will not reliably detect cutting of the webbing in the lower fence. Thus, a vibration sensor should also be utilized to detect such cutting attempts or raising of the fence fabric to gain entry.

If the sensors are mounted as part of the fence fabric, strands of barbed wire within a single zone are supported at each fence post, (except the switch assembly post), by a supporting bar. The strands are loosely supported by the bars, allowing them to move freely, thereby activating the taut wire switches. If these two types of configurations are utilized, then an integrated barrier is presented to an intruder to detect cutting, climbing or raising of the fabric. High reliability, low FAR and low NAR will result.

A system can be enhanced by the installation of in-ground sensors within the protected fence line, thereby detecting tunneling or bridging. Volumetric motion detection such as microwave or infrared can be utilized along the perimeter. This, of course, depends upon the environment, terrain and length of the fence line. Video motion detection may also be utilized to increase the potential for detection.

The taut wire technology is extremely reliable and is less susceptible to environmental variables and small animals. It does have a high level of maintenance to insure proper functioning. If sensors are improperly tensioned, then unreliable detection will result. Medium to large animals that push the fence while grazing or nesting can be a problem and may result in false alarms.

Taut wire systems can be defeated by tunneling at mid-point between fence posts, or bridging the fence. Bridging can occur

anywhere along the fence line. Obviously, such an attempt would likely occur where there is a lack of observation.

40_3.1.8.1 Defeat of Taut Wire Systems

Taut wire systems can be defeated by:

- **Tunneling under the sensor. The optimum location is at the midpoint;**
- **Bridging, two-man or pole vaulting over the sensor coverage;**
- **Avoidance by attacking poor or non-existent sensor coverage at buildings and other obstructions. Look for gaps in coverage;**
- **Clamping the sensor wires to a stable frame, then cutting the sensor wires within the frame;**
- **Spreading the wires to create a gap through which an intruder can crawl;**
- **Alarm stacking.**

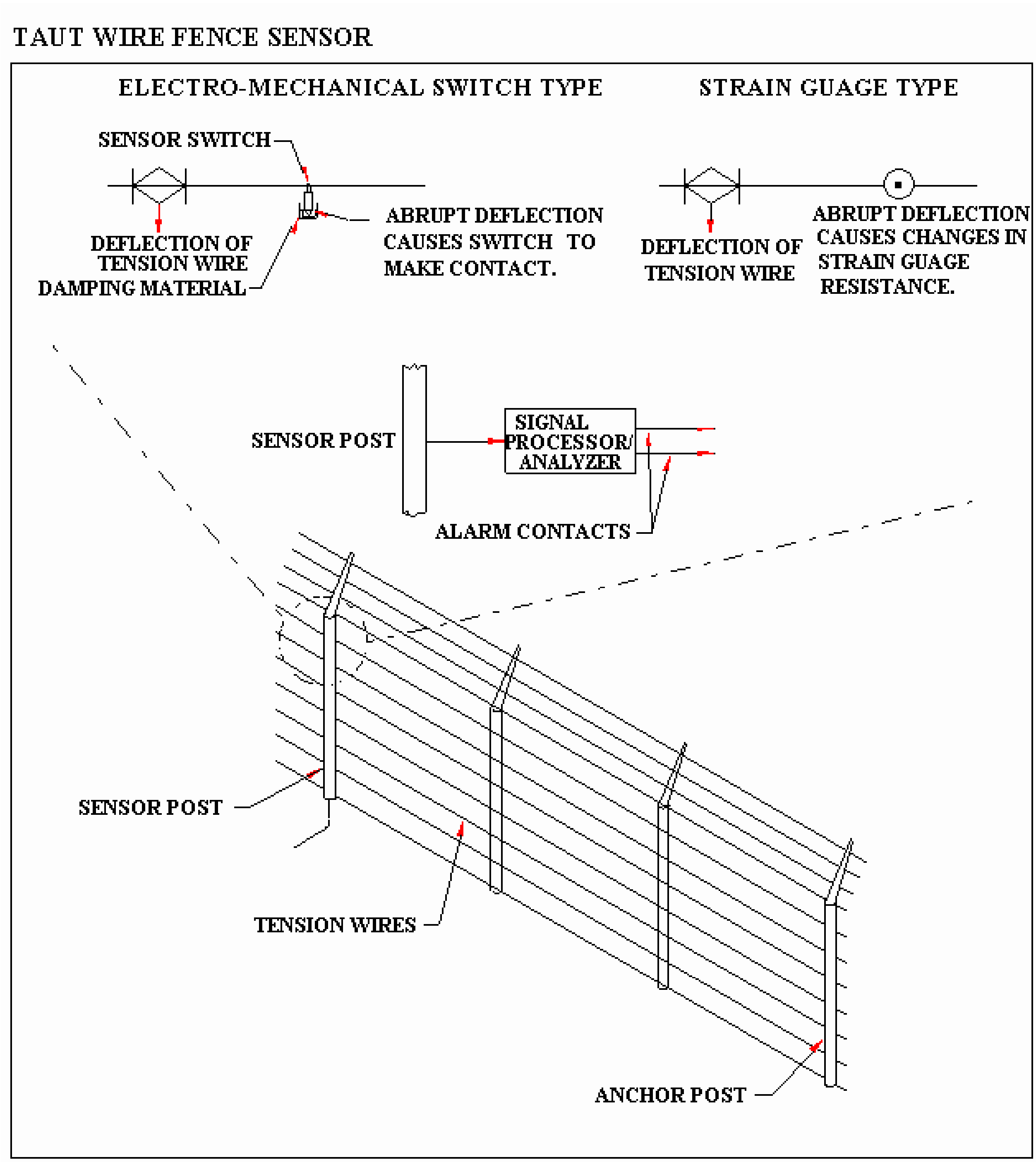


Figure LSS+4027 Taut wire fence sensor

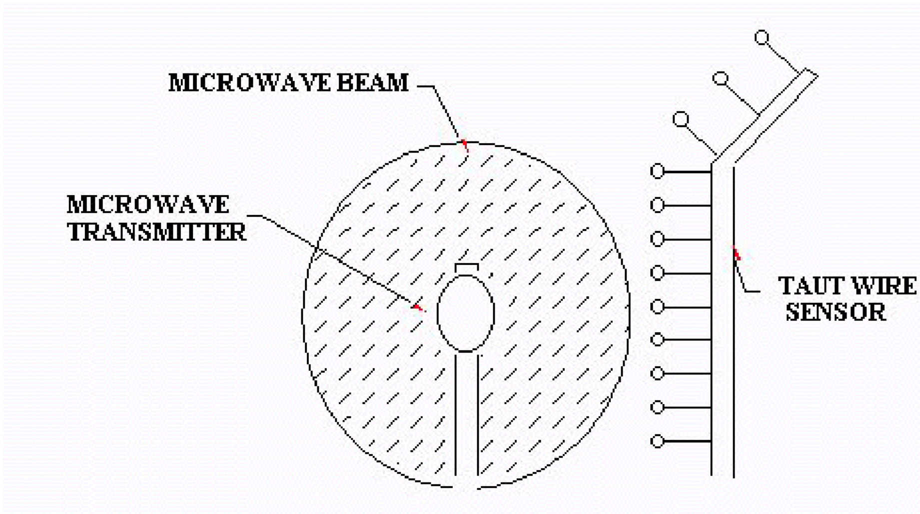


Figure LSS+4028 Microwave and taut wire sensor combination

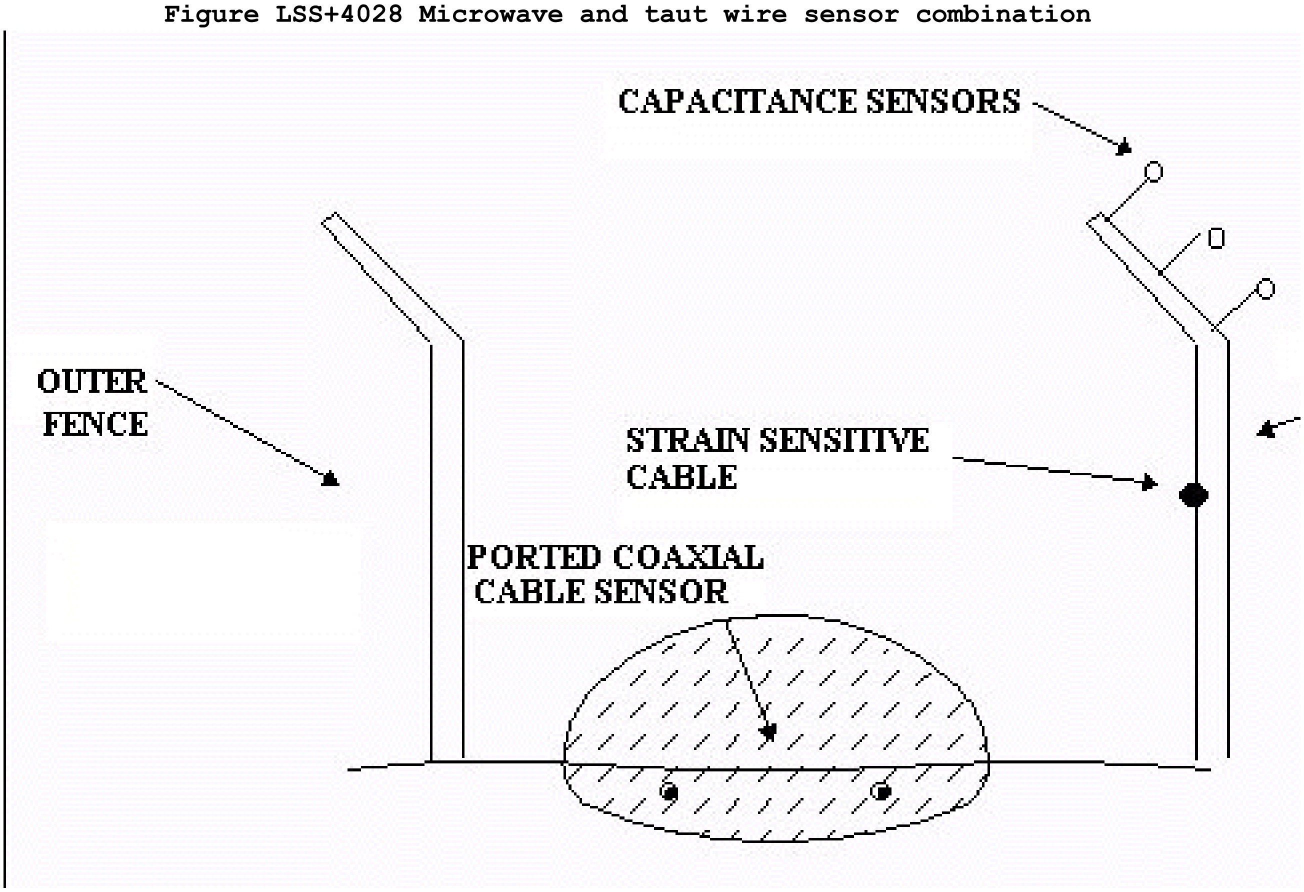


Figure LSS+4029 Ported coaxial cable and fence sensor combinations

40_3.2 Sensors that Respond to Pressure Changes: Audio, Shock, and Vibration

An array of devices have been designed to respond to different forms of atmospheric pressure. These are employed to protect glass, walls, doors, floors, open ground, and enclosed spaces.

40_3.2.1 Noise Source

Audio sensors require some form of excitation at a threshold noise level to initiate an alarm. The units can be used in both large and small areas to signal the presence of intruders. They are particularly well suited for use in detecting break-ins and eliminating false alarms because most systems allow remote monitoring to validate the signal.

The sensor usually consists of a microphone, contact pickup, transducer, or some form of piezoelectric device to detect pressure changes. They can be designed to respond to a wide range of noise that has a broad frequency spectrum, or they can operate in a narrow frequency range to detect a very precise audio wave signature. Glass-break sensors, for example, are designed to respond to certain precise frequency bands.

Audio devices must be carefully placed and tested to insure immunity from false trips and for reliable operation. If they are set with a low threshold noise level or too broad of a response to a spectrum of frequencies, they can be triggered from heating and cooling equipment, cars, telephones, and other noises. If the threshold is too high, then an intruder may bypass the system. These sensors must be calibrated to avoid common background noises that can cause nuisance alarms.

40_3.2.2 Glass-Breakage Detectors

LSS402: Shock sensors for glass break detection

LSS402: Other types of shock detection sensors

LSS402: Glass break sensors and how they work

Glass windows constitute one of the weakest points of entry for any building and thus require constant surveillance. Panes can be monitored with conductive window foil or electronic breakage

sensors. There are three primary types of sensors: **acoustic**, **shock**, and **dual technology** (shock and acoustic). Coverage does not generally exceed one hundred square feet of glass surface. Newer devices are sensitive to the band of frequencies that are generated when glass is fractured or broken.

There are two versions of electronic detectors: **passive** and **active**. Although each of these are designed to function in a slightly different manner, they both can receive and interpret the wide spectrum of solid-body oscillations that are generated when the surface tension of the glass is altered. The sensors utilize a microphone to listen to specific frequency bands, with processor filters to reduce all unwanted frequencies and only allow certain ranges of sound to be received.

Older sensor technology relied upon the use of a form of mercury level-switch that was affixed to the glass. If oriented properly, any vibration or shock would cause the conductive liquid to touch a set of contacts to complete an electrical circuit. Modern sensors are located in a single unit that is mounted on an internal wall or ceiling, facing the glass surface to be protected.

Acoustic Sensors: These detect high frequencies that are typically created upon initial shattering impact of glass. Waves travel away from the point of impact to the outer edges of the glass.

Shock Sensors: This sensor "feels" the 5 KHz (nominal) shock wave that is generated upon the breaking of glass. There are two types of "shock" transducers: electric piezo, and non-electric piezo. In the non-electric design, the crystal substance bends when it is pressured by the shock wave, and has a very low false alarm rate.

Dual Technology Acoustic/Shock Sensors: This technology links acoustic and shock devices to operate in complementary fashion to provide for a low FAR. Generally, the two sensors are packaged together and are ANDED electronically. A microphone detects signature frequencies and if they match glass-breaking characteristics, then the output is fed to the AND gate which is also connected to the shock detector. If there is a coincidence of signals, then an alarm is sent to the central processor. The dual technology sensors have a very low incidence of false alarms caused by background noise, RFI, and ambient noise created by telephones and office machines.

Acoustic devices are often mounted on the window, window frame, wall or ceiling. If they are placed on the glass, it should be located in the corner, approximately two inches from the edge of the frame. Glass mounting is not recommended because of temperature variables that can affect adhesive materials. Such materials should be able to withstand long exposure to heat and cold, as well as condensation. Remember, glass can reach 150°F in the summer, and -30°F in the winter.

If mounted on the wall or ceiling, the sensor should be installed opposite the window. Supplementary devices such as magnetic trips and microwave should always be used with glass break technology to insure reliability of operation. If microwave or infrared is employed, it should be positioned so as to look toward the window.

There are several factors that can cause unreliable or erratic operation:

- **Mismatching of sensor range capacity to the window size;**
- **Poor location of sensor, causing it to be out of range;**
- **Failure to account for the acoustic characteristics of the room. This can include "soft" rooms with carpet or drapery that absorb vibration, or attempting to make a "hard" area softer by adding wooden shutters, blinds, draperies, or rugs after the sensor has been installed and optimized. All windows should be checked for cracks prior to installation to insure that a valid frequency is generated upon fracture.**
- **Improper calibration or installation;**
- **RF interference;**
- **Sharp impact noise;**
- **Improper application or placement of the sensor;**
- **Background noise.**

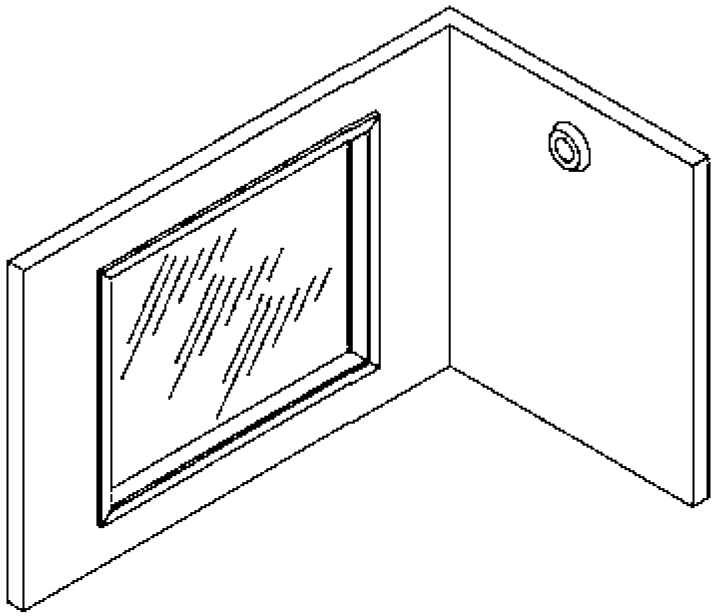


Figure LSS+4002 Typical glass-break sensor installation

40_3.2.2.0 Defeat Techniques for Glass Break Sensors

Sensors can be defeated by a variety of measures:

- **Detaching or cutting of an opening in the window;**
- **Removal of the window pane with or without a sensor attached to it;**
- **Distortion of the break frequency by muffling or masking the sound of breaking glass.**

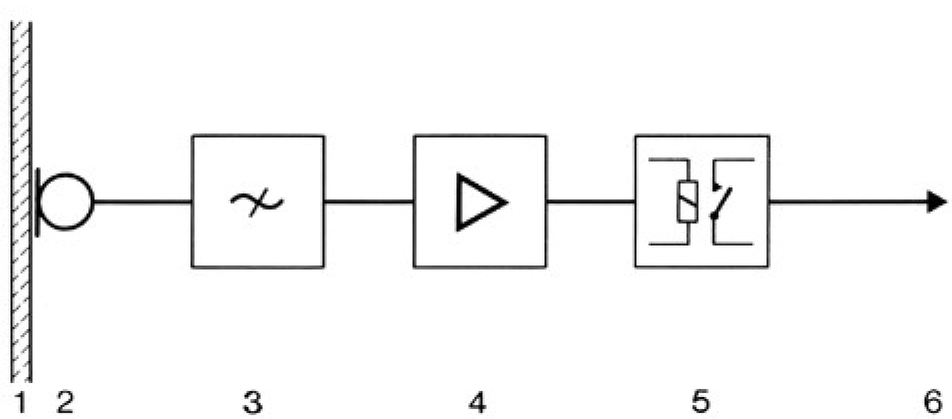
Generally, all glass break sensors can be bypassed by any entry means that does not involve the breaking of glass to which a detector is attached or that is within close proximity (audio sensors). In other words, avoidance of the detection systems or mode of attack that does not disturb the protected surface can bypass the sensor. These devices can also be circumvented by methodically cutting the glass without involving actual fracture. Passive audio systems can be defeated by the utilization of sound and shock absorbing materials that dampens the signature of breaking of the glass. Additionally, any blocking or muffling of the transducer or microphone will have the same affect.

Inertia sensors (Window Bug) that rely upon the detection of a

shock can be bypassed if the area to which they are attached is not disturbed. Sensors that rely upon pulse counts that correlate to shock, and which have high settings as their threshold can be circumvented by explosions, because such shock does not trigger threshold levels. Slow penetration, spoofing, and alarm stacking can also be utilized as techniques to bypass such devices.

40_3.2.2.1 Passive Glass-Breakage Sensors

A passive detector utilizes a piezoceramic converter (microphone) in conjunction with a frequency filter, amplifier, and evaluation switch or microprocessor. These components will translate information from the converter, selectively filter it, and evaluate the resulting data. Normal ambient noise is ignored, and only oscillations that are generated when glass is broken are fed to the processor. Glass-breakage sensors can monitor a radius of up to two meters (six feet) of glass.



As should be expected, the use of such detectors offers advantages and disadvantages.

Advantages

- **Detectors are packaged in a small, inconspicuous shape;**
- **Relatively inexpensive;**
- **More reliable than vibration contacts.**

Disadvantages:

- **Detectors are not supervised: they only respond to**

oscillations and bands of frequencies that are generated when the glass is broken. Inoperative sensors cannot be detected;

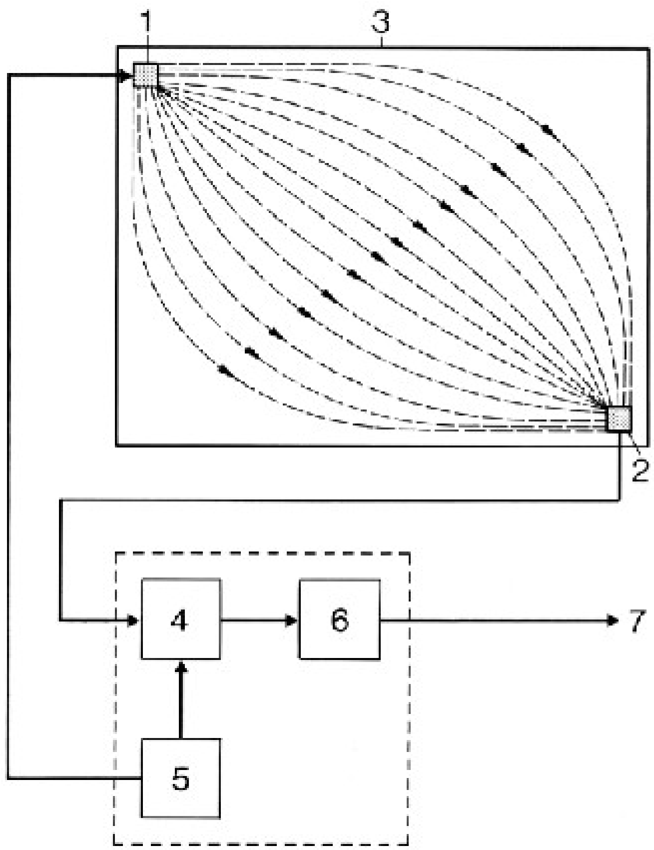
- **There is no way of knowing if a detector will properly respond to a break;**
- **The propagation of frequencies is dependent upon at least three critical factors:**
  - **Type of glass;**
  - **Type of frame and mounting of glass;**
  - **Temperature.**
- **The sensitivity of the detector is proportional to the risk of false alarm;**
- **The sensor may receive validated information from external effects that do not result in breakage. Certain objects can generate solid-body oscillations within the valid band of frequencies that trigger a false alarm;**
- **There is a significant risk of sabotage from the outside surface of the glass;**
- **A detector can become loose if the adhesive surface fails. Such a detector is usually impossible to monitor;**
- **Detectors should only be affixed to insulation glass or second (interior) panes;**
- **Sensors should only be used on surfaces that are not directly linked to outside panes due to the potential for false alarms;**
- **Detectors cannot be used on multi-pane laminated glass or single-pane security glass;**
- **Detectors cannot be used on surfaces with posters, plastic, or anti-splinter foils because their operation is unreliable;**
- **Detectors should be used in conjunction with other monitoring devices that cover the same area;**
- **Detectors must be affixed to the glass surface and checked at periodic intervals.**

40_3.2.2.2 Active Glass-Breakage Sensors

These devices utilize a transmitter, receiver and processor to evaluate signals transmitted **across** the glass. The transmitter and receiver may be located in single or separate housings. The

purpose of the processor is to constantly evaluate the signal that is transmitted, using the glass as a medium.

A transducer that emits ultrasonic signals is attached to the glass. The band of frequencies is spread over the complete surface of the pane and is used to excite the piezoceramic converter within the receiver. Any fractures, cracks, or holes in the glass will alter or interrupt the transmission characteristics. These changes are sensed by the evaluation unit.



There are several advantages to the use of active devices. These include:

Advantages

- **Active sensors are supervised, in that a failure in the transmitter or detachment of a sensor will result in an alarm;**

- **Sensors are very reliable in their response to fractures and breaks;**
- **Sensors are resistant to sabotage and exclusion of artifacts;**
- **Active sensors can monitor larger areas of glass than the passive sensors.**

Disadvantages

- **Although active detectors can be affixed to multi-pane laminated glass, the transmission characteristics of such materials may preclude reliable operation. It is necessary that measurements be made to determine attenuation of signals across the surface;**
- **Glass-breakage detectors, either active or passive, should not be used on plastic surfaces, due to the difference in propagation characteristics.**

40_3.2.3 Seismic Detectors

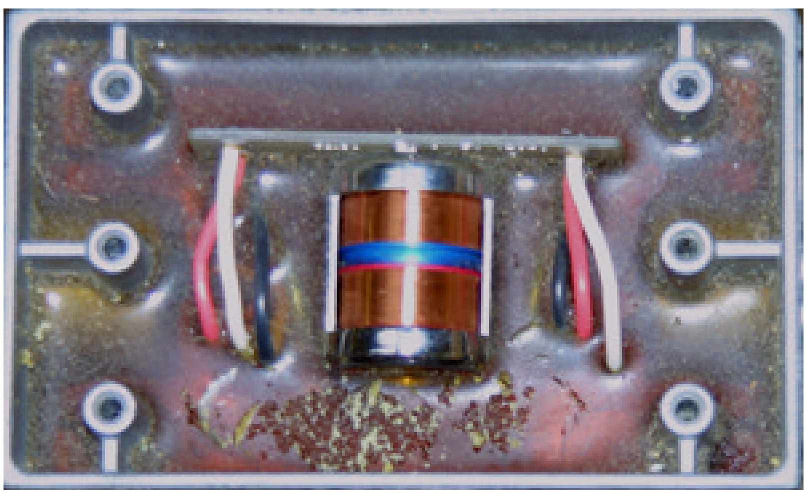
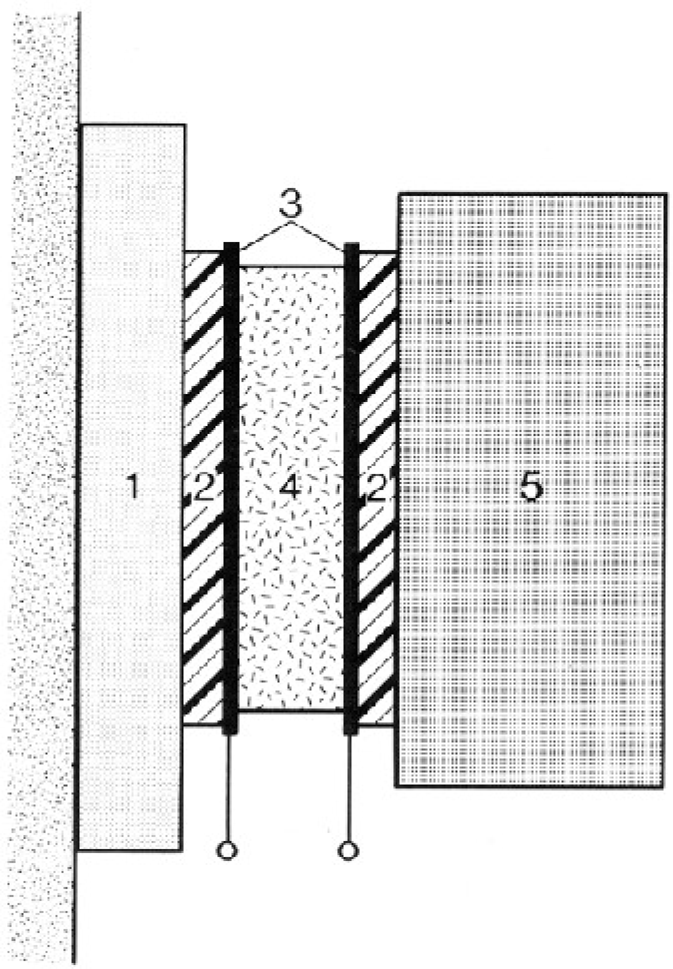


Figure LSS+4046 A seismic detector senses shock, vibration, or pressure in three planes. Generally, a cylinder, ball, or other object is suspended within a cylinder or enclosure. Any movement will cause it to make contact with its outer barrier.

Seismic detectors are particularly effective for monitoring safes and strong rooms, because sensors can be permanently mounted on walls, floors, ceilings, and doors, or in the ground. They may

also be temporarily placed in certain locations to provide additional protection. A seismic detector is classified as a passive device. The range of a sensor is dependent upon many factors. These include:

- **Design, construction, and materials of the structure to be monitored;**
- **Joints and cracks can reduce the overall effectiveness of a sensor;**
- **Propagation characteristics of sound waves in the monitored materials will determine placement and number of sensors.**



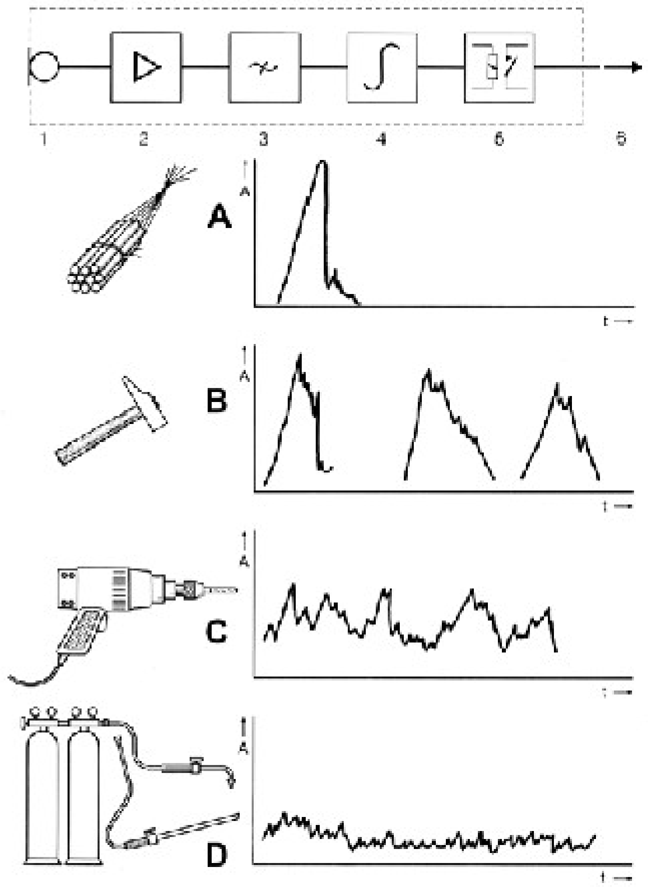
Seismic detectors are sensitive to a broad range of events.

Sensors that are mounted internally are responsive to vibrations from power tools, mechanical striking, drilling, and forced-entry techniques that create shock waves. They are impervious to environmental interference. Internal detectors may be attached to night safes and cash dispensers, although normal noise and vibration may cause false alarms. They are better suited to large safes and vaults. Seismic sensors that are mounted in the ground may produce nuisance alarms if installed too near fences, power poles, guy wires, or roads where vehicles generate heavy ground vibration.

40_3.2.3.1 System Components

Detection systems are comprised of a piezoelectric microphone, amplifier, frequency filter, integrator, processor, and output interface. The use of sophisticated processors can reduce the likelihood of false alarms caused by ambient noise, shock, and vibration. A microphone is usually constructed with a ceramic element between two metal foils and mounted directly on a monitored object. Its function is to detect sound waves in solid bodies without being sensitive to ambient noise.

Seismic sensors are not supervised. Therefore, remote testing must be utilized to monitor system performance, components, and the mounting integrity of the detector. Sensors cannot send a signal in case of failure.



40_3.2.3.2 Guidelines for Installation

- **Detectors should be mounted on inside surfaces of rooms under surveillance. This will protect the system against sabotage;**
- **Placement of detectors must afford complete coverage without dead zones;**
- **Remove existing interior furnishings prior to installation;**
- **Individual sensors should be mounted on each door;**
- **Sensors should be placed close to or over the lock or keyhole in a strong room.**

40_3.2.3.3 Defeat of Vibration and Audio Discrimination Sensors: General Issues

Vibration sensors are subject to a number of defeat techniques. These include;

- **Avoidance by using an entry method which does nor require contact with the protected area;**
- **Muffling or dampening of the low frequency energy;**
- **Explosive penetration using limited force;**
- **Slow penetration to avoid meeting the threshhold of pulse count and accumulator circuits;**
- **Spoofing and alarm stacking.**

Audio discriminator sensors can be defeated by:

- **Avoidance, muffling the noises associated with forced entry;**
- **Substitution of taped normal background noise to spoof the sensor;**
- **Bypass the sensor circuit while the system is disarmed;**
- **Mask the sensor microphone.**

40_3.2.3A Fence Vibration Sensor

LSS401: Fence alarm system

LSS403: Shock sensors utilized to protect fences



Figure LSS+4047 There are several different sensor technologies that are utilizes to protect fences, including strain, vibration, and noise detection.

Higher frequency disturbances and greater amplitudes of events associated with sawing, cutting, climbing or lifting of the fence fabric generate mechanical vibrations or stress that can be differentiated from normal changes that occur from routine environmental activity. Fence vibration detectors are mounted directly on the fence webbing to detect these vibrations through electro-mechanical or piezoelectric transducers. The frequency characteristics for typical intrusion-type activity is filtered and processed and matched with known signatures.

Electro-mechanical sensors incorporate a signal processor that has a pulse accumulation circuit that recognizes momentary contact openings of electromechanical switches. Piezoelectric sensors have a signal processor that responds to the amplitude, duration, and frequency of the transmitted signal.

The Electromechanical Sensors use either **mechanical inertia switches** or **mercury switches** to detect fence vibration or stress. Mechanical-inertia switches consist of a vibration sensitive mass that rests on two or three electric contacts that create a closed-circuit. The mass is moveable and reacts to minute changes in the vibrations (frequencies) that are generated in the fence

during a penetration attempt. These vibrations disturb the mass, causing it to be moved or separated from one or more of the contact points, thereby momentarily opening the circuit and creating an alarm. In some sensor designs, the mass is intentionally constrained or restricted by an internal guide in order to ensure that only a significant vibration will cause movement, break the circuit and activate the alarm.

Mercury switches, as described elsewhere in this chapter, consist of a glass vial containing a small amount of mercury with a set of normally "open" electrical contacts that are located in close proximity, but not touching or immersed in the mercury. An impact or disturbance of the fence fabric causes the mercury to be displaced from its normal resting position. This will result in a momentary contact between the mercury (a conductor), and the electrical contacts.

A piezoelectric sensor is much like the old crystal microphone: it has the ability to convert the mechanical impact forces into an analog electrical output. Its output distinguishes it from the electro-mechanical sensor which can only generate an open or closed signal. The piezoelectric detector's output varies in proportion to the amplitude of the event. The signal is processed and filtered to match against known signatures.

For optimum performance, fence vibration sensors are mounted directly to the fence fabric. Each detector is connected in series along the fence with a common cable to form a single zone of protection. A zone length can have a recommended range of up to 300 feet. The vibration sensors are the most economical in their class and the easiest to install. They have a high probability of detecting intrusion and work well in protecting properly installed and maintained fence lines. Additional protection against tunneling and careful climbing can be achieved with the installation of in-ground vibration (seismic) sensors that are placed adjacent to the perimeter fence (in a controlled zone within the overall protected area).

Fine tuning of these systems is enhanced by adding information to the processor about current weather conditions to increase or decrease the detection sensitivity. A weather sensor station can be mounted on the fence line to feed information to a field processor, which then adjusts vibration alarm sensitivity, based upon weather data input.

Additional reliability can be obtained by placing the appropriate

volumetric motion detection devices (microwave, active infrared) along the perimeter of the fence. Which volumetric device to employ will depend upon the environment, terrain, and length of the fence line.

Vibration detectors are designed to sense many different variations and thus, can become confused and subject to false indication of an alarm status. In order to reduce the FAR, a pulse count accumulator may be added to the circuitry. This will require a threshold of pulses generated by individual trips in order to show a valid alarm status. A pulse is a measurable amount of activity (amplitude) based upon stress or vibration to the fence, caused by cutting or climbing.

Reliable operation of sensors is based upon their proper installation, and utilization on quality fencing material. Poor quality fencing with loose webbing can create "noise" from flexing, sagging or swaying that translates to false alarms and unreliable detection. Difficult weather conditions can add to the problem. Shrubbery, tree branches, and animals can also cause the fence to vibrate, thus triggering sensors. If fences are located in areas of high wind or numerous animal interactions, vibration sensors are not recommended. Remember, fence vibration detectors are designed for one specific function: to detect vibration. If they are located in areas with inherently high vibration, such as from railroad yards or tracks, construction sites, or heavy highway traffic, then they are not a suitable means of protection.

These detectors can be defeated by bridging the fence and thereby avoiding contact altogether. Use of overhanging trees and structures can assist in this regard, as can cars, trucks or other platforms. Deep tunneling is also a preferred method. Fence corners can be a particularly difficult problem because of the increased bracing of the fence posts and more solid foundations typically used at a corner or turn-point. Detectors will be less sensitive to input at these points because of the damping effect of the corner structures.

40_3.2.3A.1 Defeating Fence Vibration Sensors



Figure LSS+4056 A fence vibration sensor will trip from the use of hooks or a climber. Courtesy of DOE Office of Security and Safety Performance Assurance

Electromechanical/vibration fence sensors can be defeated in a number of ways. These include:

- **Tunneling under the fence or barrier;**
- **Bridging, two-man or pole vaulting over the detection zone;**
- **Use a vehicle that is positioned next to the fence as a platform for jumping or bridging over the barrier;**
- **Injection of a dampening material into the sensor;**
- **Removal of the sensor from the fence, thereby preventing contact with the barrier;**
- **Alarm stacking.**

VIBRATION FENCE SENSOR

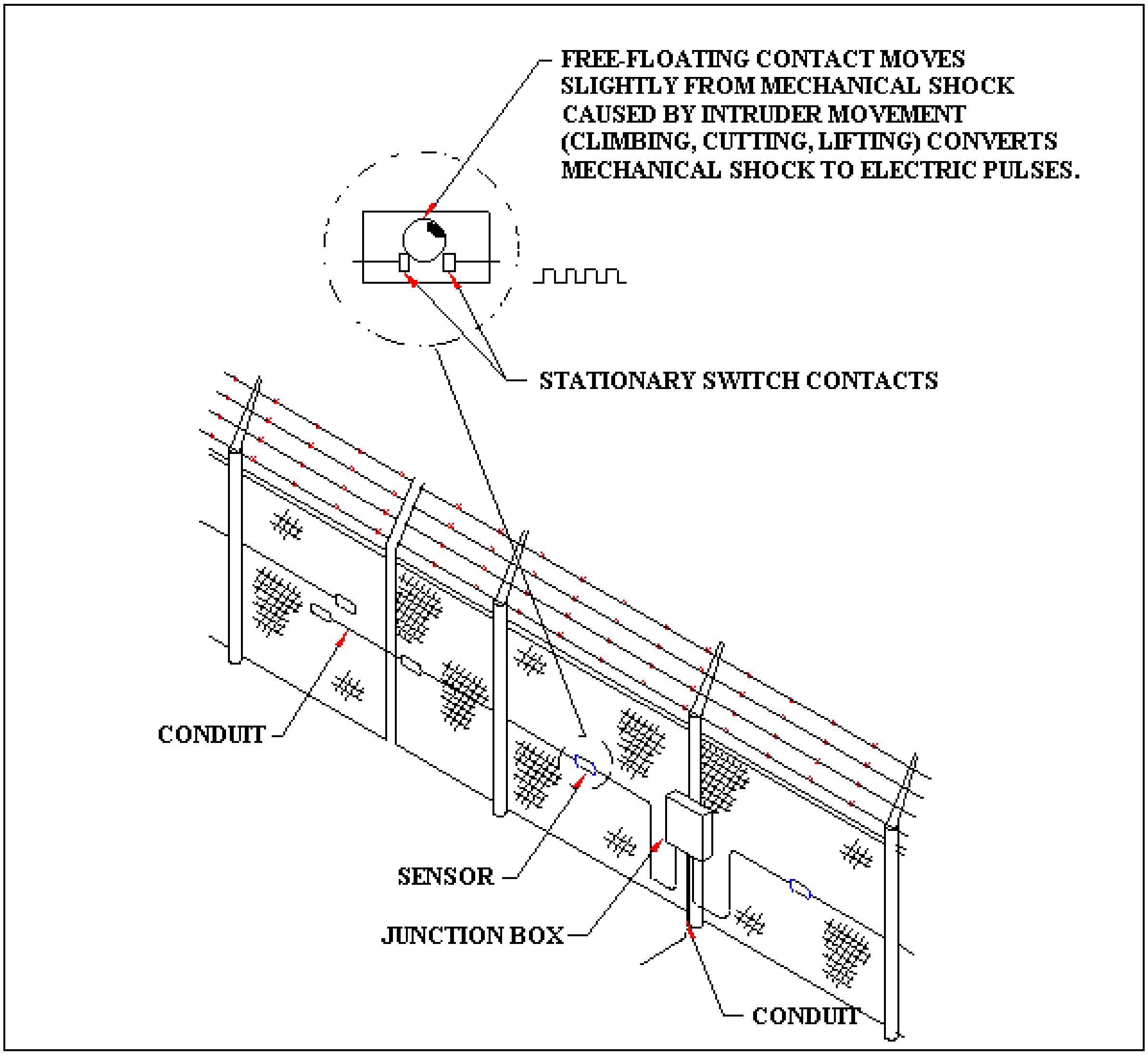


Figure LSS+4020 Vibration fence sensor

40_3.2.3B Strain Sensitive Cable

Strain sensitive cables are line sensors that use electric energy as both a transmission and detection medium. They maintain constant sensitivity across the entire length of the circuit. Supervision against cutting, short circuit or removal of wire is maintained along the cable from the processor to an end-of-line resistor.

In operation, the cable is mounted on the fence. When it is subjected to mechanical vibrations that are caused by attempts to cut, climb or raise the fence fabric, electrical signals will be induced that are proportional (analog) to the exerted force, from which a signature analysis can be performed by the processor. The cable acts like a microphone.

There are two basic categories of strain sensitive cables: **coaxial** and **magnetic polymer**. The coaxial cable is a specially sensitized conductor in which the center conductor carries a permanent electrostatic charge.

The "coaxial" cable that is sensitive to strain related stresses conducts a permanent electric charge along its center conductor, which is then insulated and covered with a braided shield. The cable is designed for outside use, being coated with a UV resistant material to withstand direct sunlight. In operation, the cable is constantly electrically biased. When stresses occur based upon vibration, electrical signals are produced in proportion to the force exerted, and analyzed for specific signatures. The cable can act as a contact microphone to allow human analysis to evaluate a processor decision on alarm status. These detectors are extremely sensitive to EMI (electro-magnetic interference) caused by power substations and to radio frequency interference (RFI). Care should thus be exercised in the location of such sensors.

The magnetic polymer utilizes two semicircular magnetic polymer conductors that are separated by an air gap containing two noninsulated wires, resembling the design of a capacitor. Strain sensitive sensors function as poles of a linear magnet; two semicircular magnetic polymer conductors are paired and separated by an air gap. Two insulated wires run between the polymers. Parallel to these wires are two noninsulated wires free to move in the air gap between the magnetic field created by the polymer conductors.

Vibration and stress can cause the noninsulated wires (active conductors) to move within the air gap, generating minute electric signals to the signal processor. Smart processors are available that "learn" from normal fence fluctuations and revise the data, thus minimizing false alarms and enhancing the performance of the system.

The "magnetic polymers" multiple conductors form a symmetrical and balanced pair configuration that makes this type of sensor

virtually impervious to both EMI and RFI. Its low impedance creates higher signal-to-noise ratios that can offer more finite signal processing. The sensor also functions as a transducer microphone that can provide a "listening" function for human override and analysis.

Cables should be installed using ties halfway between the bottom and the top of the fence. Also, stainless steel wire ties, as opposed to plastic ties, should be utilized to prevent silent removal by burning or ultraviolet decay. Sensor zone lengths can be extended to 1,000 feet, with the requirement of a quality fence and stable installation of both the sensors and fence line. Supplemental protection should be implemented. Volumetric motion detection devices, video motion detection, and electric field detectors can add reliability and redundancy to a system.

Nuisance and false alarms can be caused can be caused by severe weather conditions and animals. This problem can be minimized with proper calibration and installation, and the use of a listening device to analyze signals. Countermeasures for this type of sensor are the same as for other fence line protection systems discussed above.

40_3.2.3B.1 Defeat of Strain Sensitive Cables

Strain sensitive cable sensors can be defeated by a variety of methods, including:

- **Tunneling or trenching under the sensor. An alarm will not be initiated unless there is contact with the fence;**
- **Pole or two-man vaulting or bridging;**
Avoidance of protected area;
- **Bridging of protected area with board, ladder, or other structure;**
- **Bypass the sensor circuit while the system is disarmed;**
- **Creating small holes in the cable jacket (with pins or other sharp object) to allow water or moisture to enter and desensitize the cable. This is a long-term method of defeat and will require several days or months to accomplish;**
- **Remove the cable from the fence by gently severing or melting the wire ties, and then lowering the cable to the ground. This technique is accomplished over a period of time and takes advantage of poor fence inspections;**
- **Alarm stacking.**

STRAIN - SENSITIVE CABLE (COAXIAL)

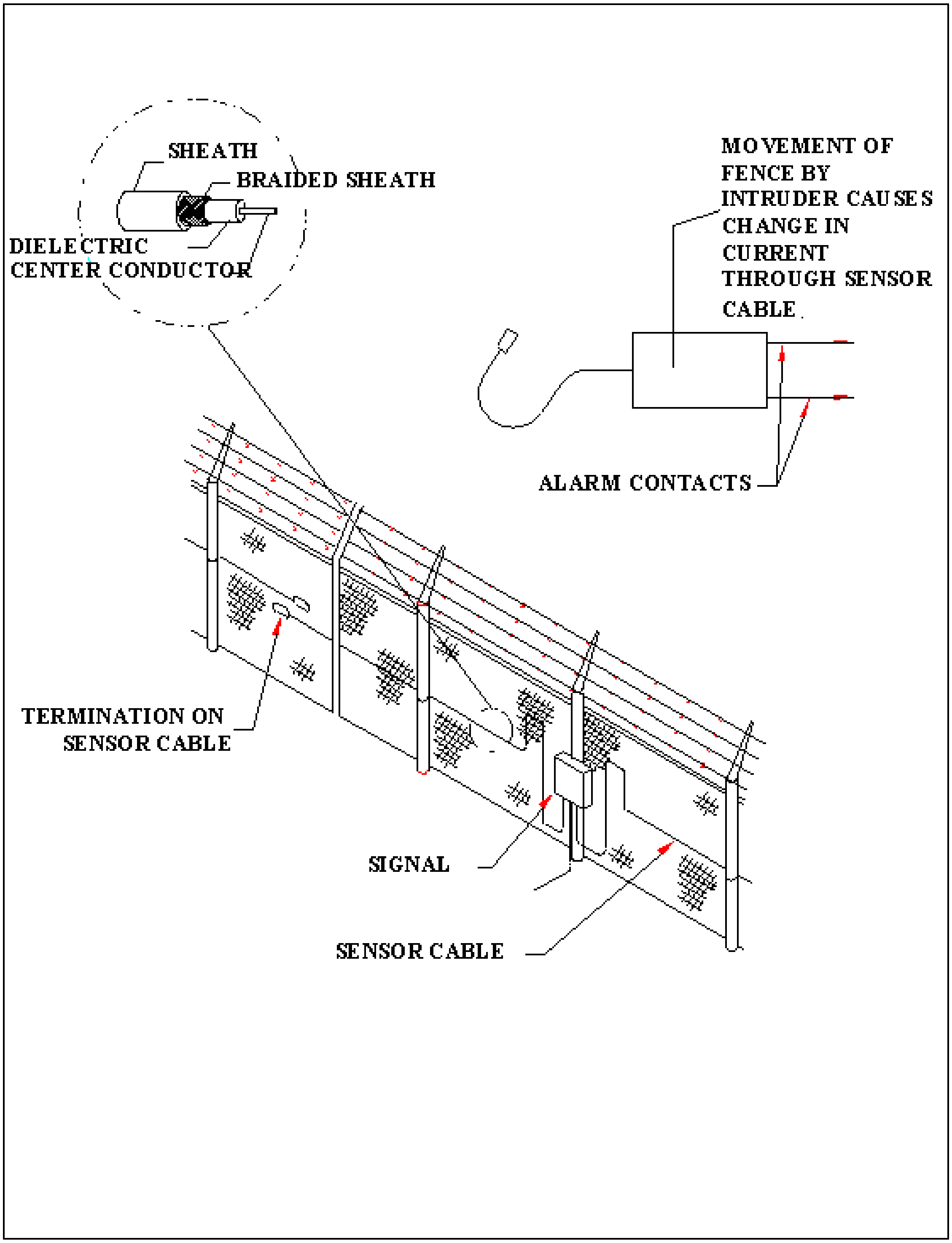


Figure LSS+4023 Strain-sensitive cable (coaxial)

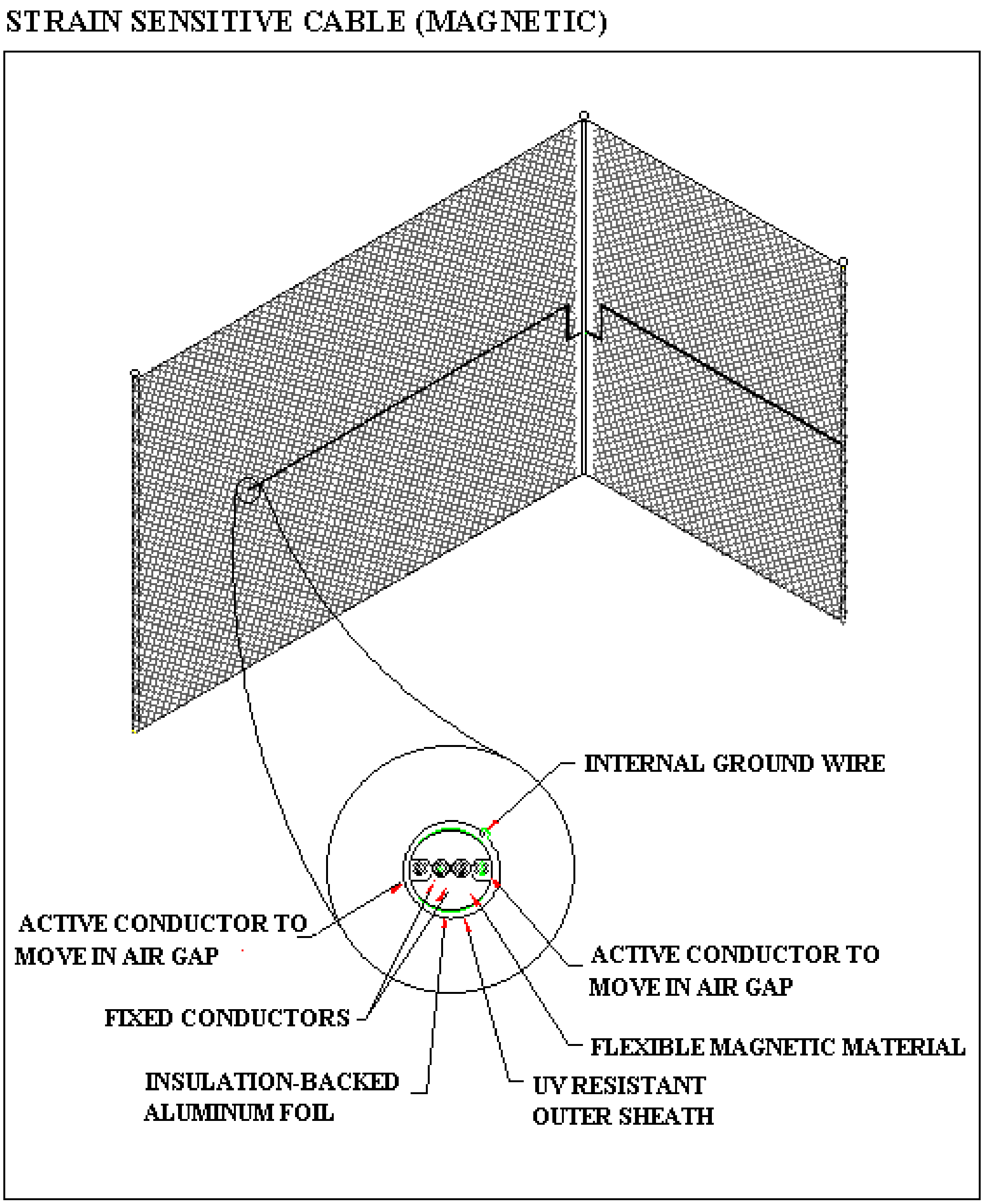


Figure LSS+4024 Strain cable (magnetic)

STRAIN - SENSITIVE CABLE (APPLICATIONS)

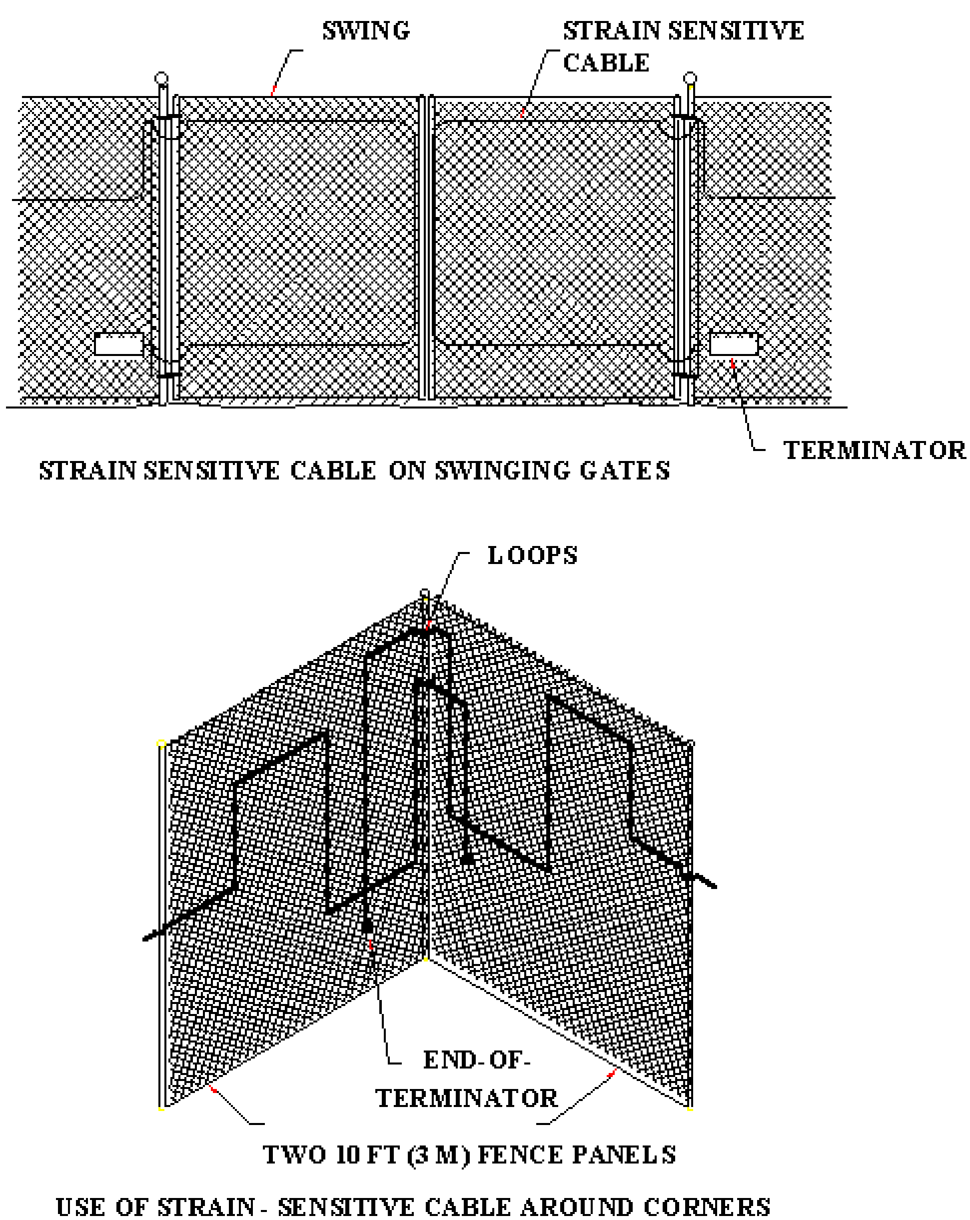


Figure LSS+4025 Strain-sensitive cable (applications)

40_3.2.3C Fiber Optic Fence Sensors

LSS403: Fiber optic fence sensors

Fiber optic sensors use light rather than electricity as a carrier for transmission and detection. Fiber optic cable can be easily incorporation into existing fences, or it can be used as stand alone fencing.

The construction of an optical fiber is a thin strong strand of glass or other optical medium, often referred to as a wave guide because the optical fiber guides light waves from a light source to a detector at the terminating end of the fiber. Pulses of light replace their equivalent electrical impulses in a wire. There are many advantages over other conductive medium, including:

- **Immunity to electrical interference and Electrical Magnetic Interference (EMI) disruption;**
- **Intrinsically safe;**
- **High reliability due to the stability of the electronics;**
- **Greater transmission distances as compared to metallic carriers. Light has a very low attenuation factor through glass. There is approximately a 3db light loss (absorption) per kilometer.**

Based upon the signal processor, there are two primary types of fiber optic sensors: **continuity** and **microbending.**

The fiber optic continuity sensor requires the glass strand to be broken in order to initiate an alarm, and can be compared to a closed loop device. The transmission of light is monitored from source to receiver; a break in energy is detected as an alarm. A composite strand sensor can be combined with a continuity sensor contained within a barbed steel tape. An installed system is similar to a taut wire installation; the difference being that it does not require the mechanical activation of switches. This makes preventive maintenance and repair of the system more affordable. The tape can be used as a free standing fence or can be applied to an existing fence, or attached to walls and buildings.

The fiber optic microbending detects alterations in the light

pattern caused by movement of the cable, generally as the result of bending or distorted to affect the wave guide characteristics of transmission. This correlates to stress on the fence webbing. The cable is actually the sensor when it is integrated into the fence fabric. An LED provides the light source. A threshold of change in the transmission of light will provide an alarm.

In order to insure maximum reliability, sensors should be mounted directly on, or woven into, the fence fabric. As with all other fence line detectors, a quality and stable installation of the fence is necessary for reliable detection. The fence should be free of rattles, clanks, knocking sounds, and vibration and stress activity. This will maximizes line sensor quality. If there is significant ambient noise on or around the fence, the lower the sensitivity setting will be for the system, with the correlation that it will be less likely to detect an intruder. Supplementary sensors, such as in-ground, can add another level of protection. Volumetric sensors and video motion detection can also increase redundancy and security.

Unreliable detection will result from poor fence quality (stability). Loose fence fabric and poor stability cause the sensitivity setting for the fence to be calibrated lower than preferred, making the system less likely to detect an intruder. When properly installed on a good quality, stable fence or installed in a taut wire-like configuration, the system is very stable and reliable.

Nuisance and false alarms can be caused by extreme weather turbulence that damages or disturbs the fiber, or by animals. The system will not respond or be affected by transient voltage or lightning strikes, but can be affected by RFI, EMI, and extreme changes in temperature and blowing debris.

40_3.2.3C.1 Defeating Fiber Optic In-Ground or Fence Mounted Systems

Fence protection systems that utilize fiber optic sensors, either mounted on the fence itself or in the ground, can be defeated. Techniques include:

- **Bridging;**
- **Tunneling under a barrier-mounted system;**
- **Careful and assisted climbing over a rigid turn or corner points in a coverage zone. In such cases, sensor coverage will**

generally not be as sensitive on a fence-mounted systems;
- **Alarm stacking.**

FIBER OPTIC CABLE

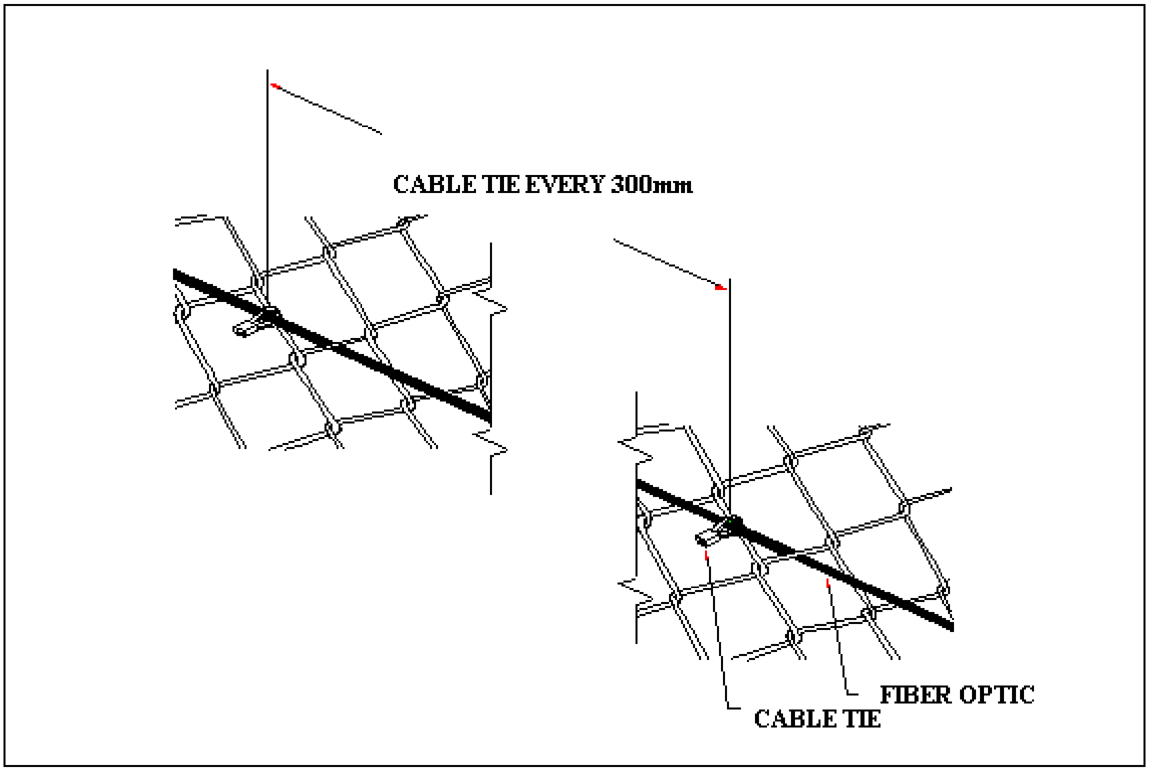


Figure LSS+4026 Fiber optic cable

40_3.2.3D Defeat Techniques for Perimeter Fence Lines

LSS403: DOE on perimeter sensors and their defeat

Perimeter fence lines can provide the first barrier to entry by an intruder, although other sensors may detect a violation before the fence is reached. There are four recognized techniques for compromising fence lines and other perimeter sensors: **crawling, clinmbing, jumping, and bridging.**

40_3.2.3D.1 Bridging

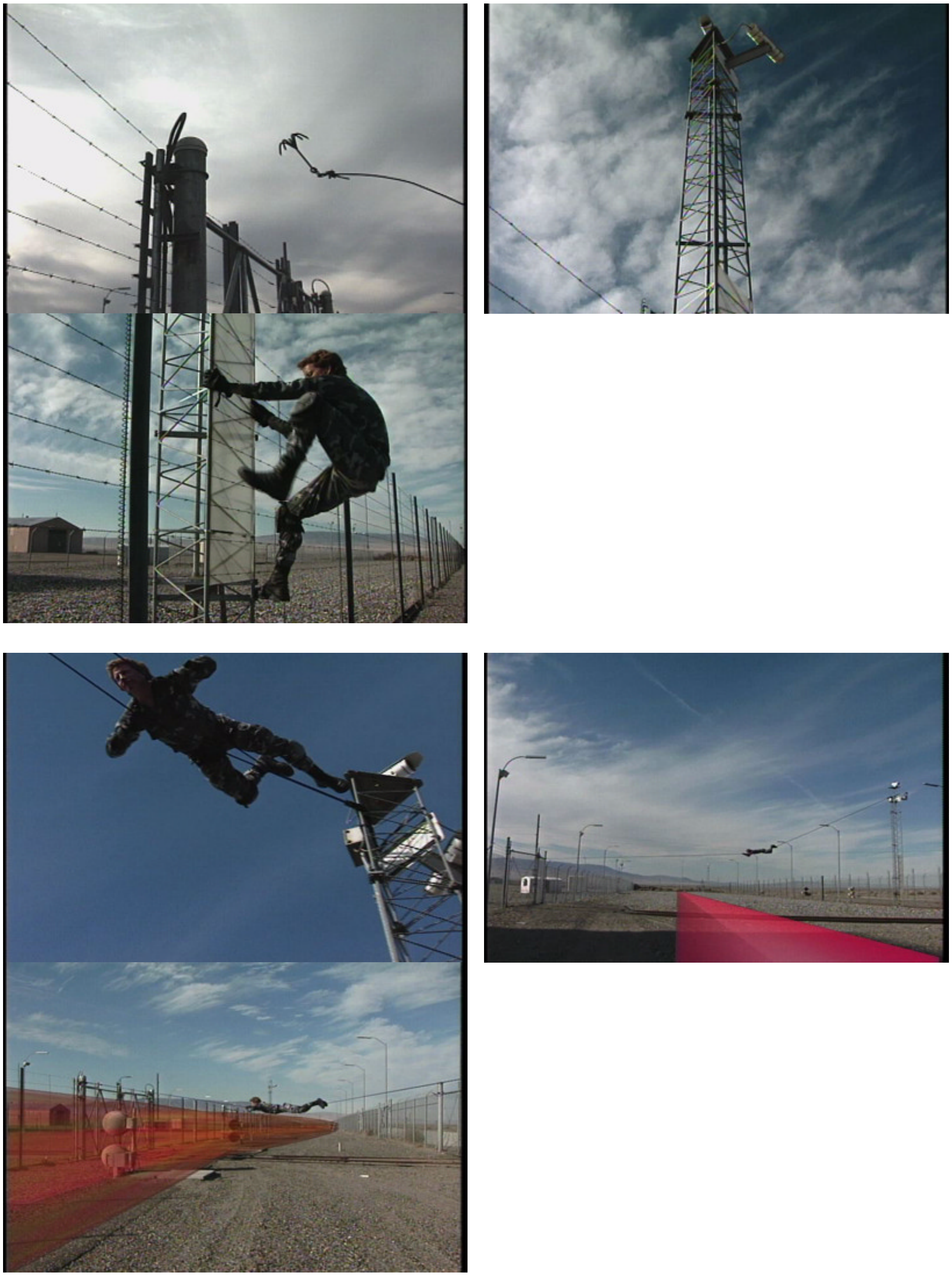
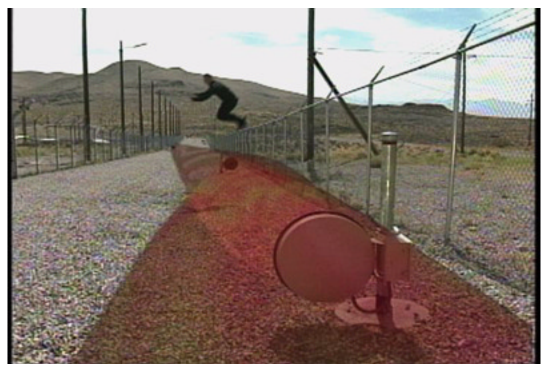


Figure LSS+4062 Bridging of the sensor is a popular method of bypass. In these photographs,
simulation of a microwave path is shown in rad. The intruder is able to bridge across and

over the RF pattern, avoiding detection. Courtesy of DOE Office of Security and Safety Performance Assurance

40_3.2.3D.2 Jumping



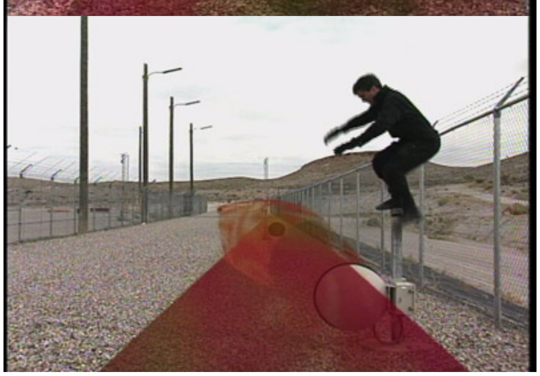










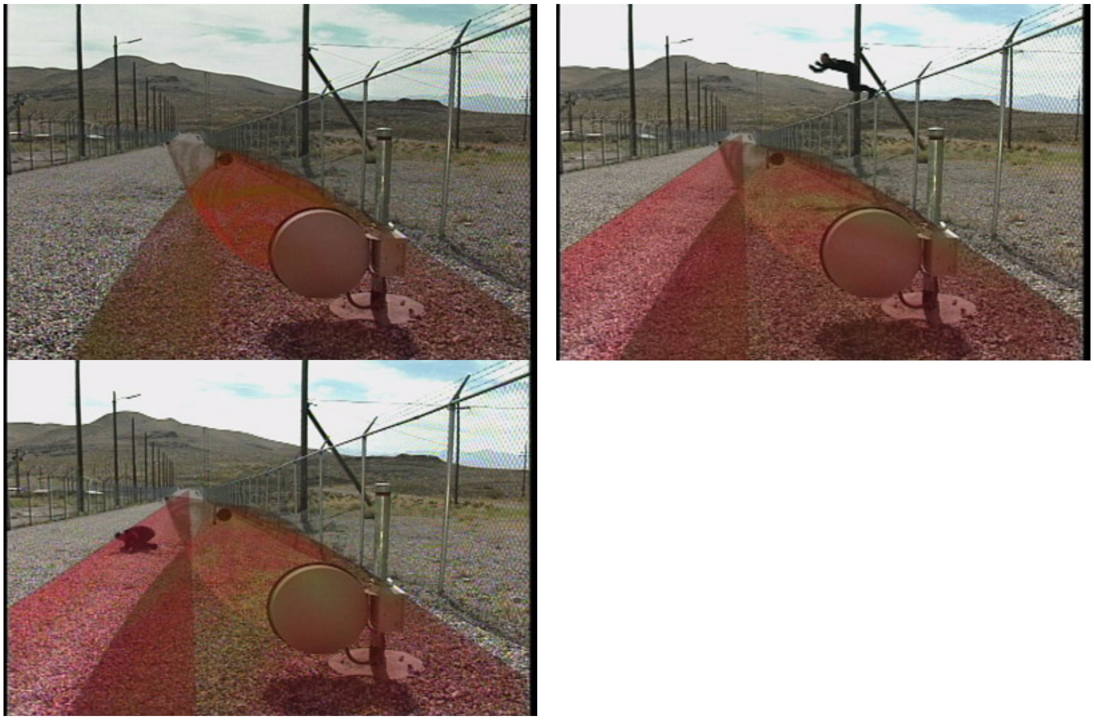


Figure LSS+4063 An intruder is able to successfully jump over a monostatic microwave pattern,
but not for a bistatic system. Note the overlapping coverage that catches the inruder. Courtesy of DOE
Office of Security and Safety Performance Assurance

40_3.2.3D.3 Climbing

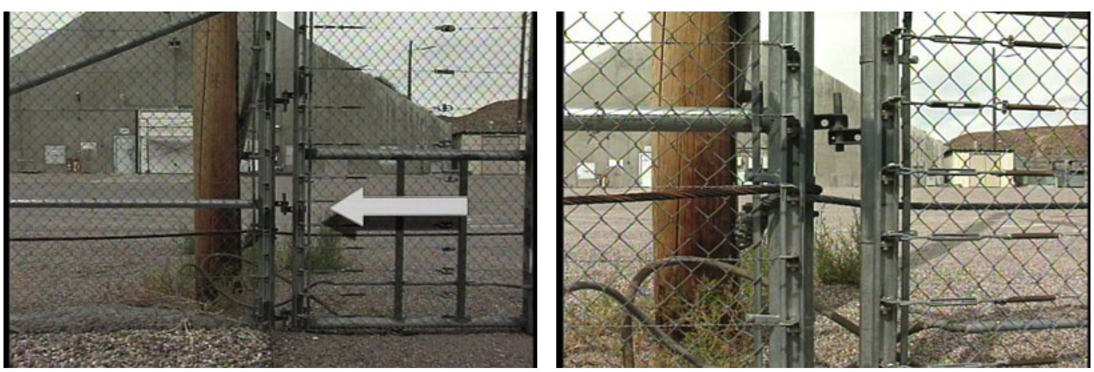




Figure LSS+4064 A climber is able to scale a fence by gaining a foothold. This is poor design.



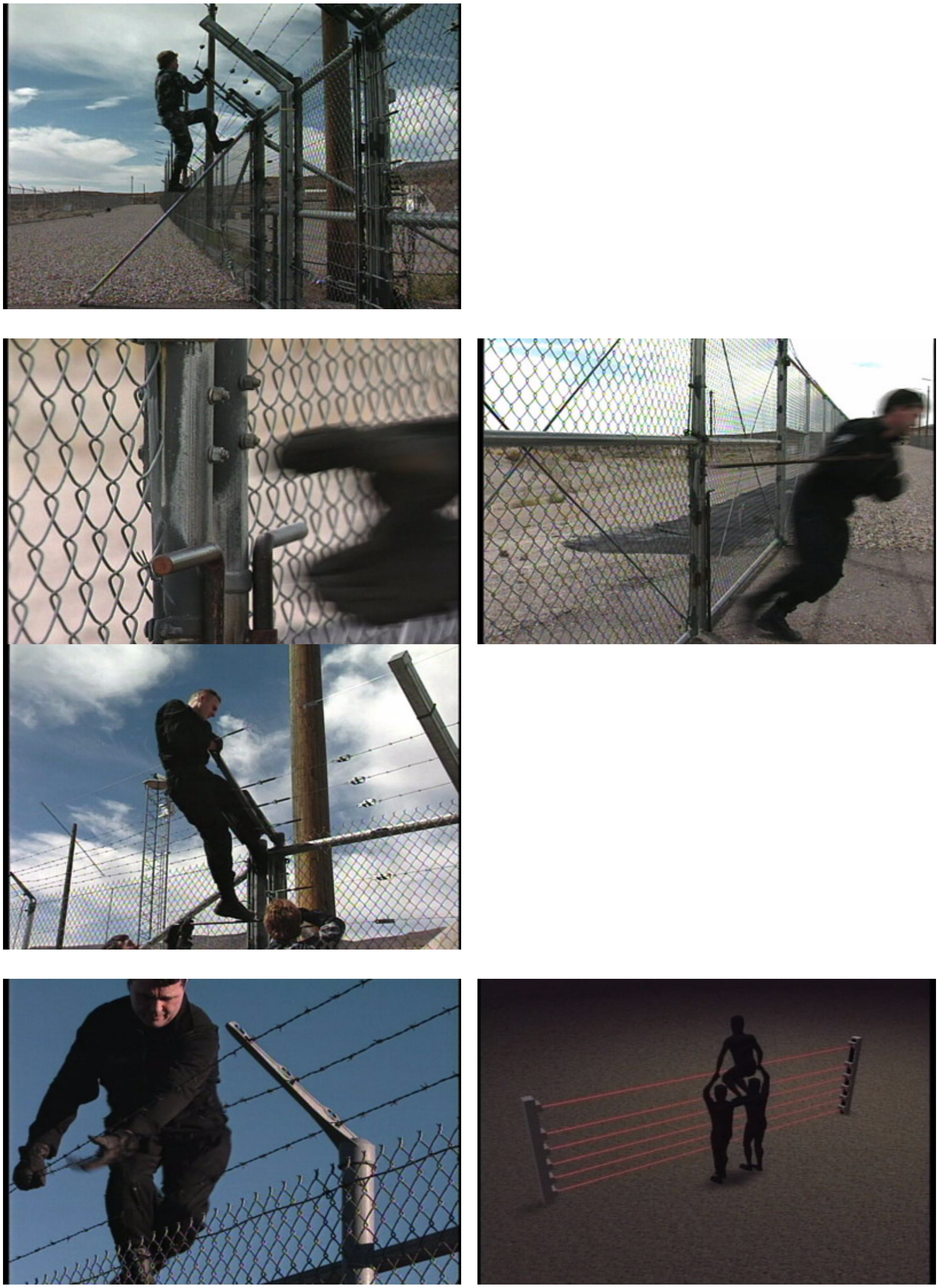


Figure LSS+4065 Intruders are able to penetrate a facility using a variety of techniques. Materials are removed from the fence and used as an aid to the climbing process. The top of the fence line can be used for support. A

three-man climb can be accomplished to jump over barriers, such as the photoelectric beams, as shown. Boards may also be used as ladders to scale the fence. Courtesy of DOE Office of Security and Safety Performance Assurance

40_3.2.3D.4 Crawling

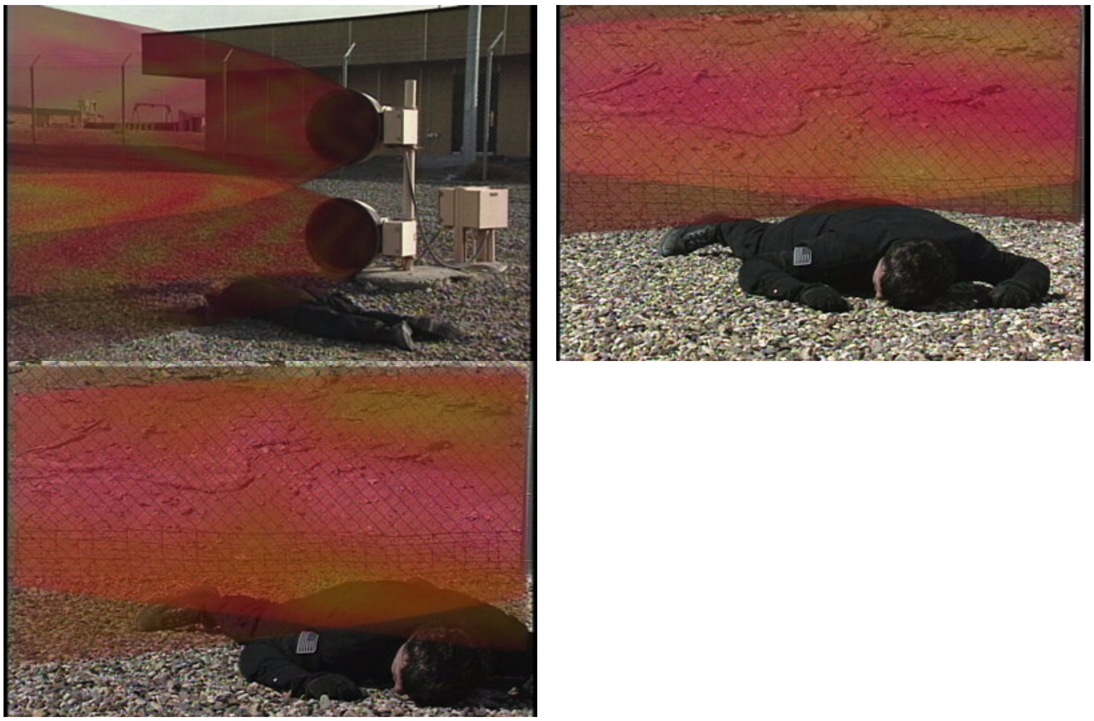


Figure LSS+4066 An intruder may crawl under or through sensor coverage. In the photograph, the intruder is able to circumvent a bistatic microwave system by passing under the RF field at an extremely slow pace. Courtesy of DOE Office of Security and Safety Performance Assurance

40_3.2.4 Wall Vibration

Vibration sensors are designed to be mounted on walls, ceilings and floors and intended to detect mechanical vibrations caused by chopping, sawing, drilling, ramming or any type of physical intrusion attempt that would penetrate the structure on which it is mounted. See the discussion in section 40_3.2.3 above.

Transducers that are designed to detect the low frequency energy that is typically generated during a physical intrusion attempt and transmitted via the surrounding walls, roof or floor. The sensors are mounted directly to the inner walls of the protected zone, and will detect the change in the normal "vibration"

profile.

There are two basic types of transducers that are utilized to sense these changes: piezoelectric and mechanical transducers. Both devices convert the seismic shock waves into electrical signals that are proportional to the acquired energy. These are processed and analyzed against known signatures.

Reliable operation requires that sensors should be securely and firmly spaced from eight to ten feet apart on a wall or ceiling where intrusion is expected. Actual placement is dependent upon the transmission characteristics of the target wall. The use of sensors should be avoided on walls of limited structural integrity, such as sheet rock, plywood or thin metal, unless bolstered by main supports. These materials are subject to external vibrations other than caused by an intruder. Likewise, walls that adjoin or are exposed to vibration created by trains, planes, trucks, or vibrating machinery should be avoided.

Supplementary detectors are recommended for added reliability of detection. Volumetric or infrared sensors that focus on vulnerable areas will increase security.

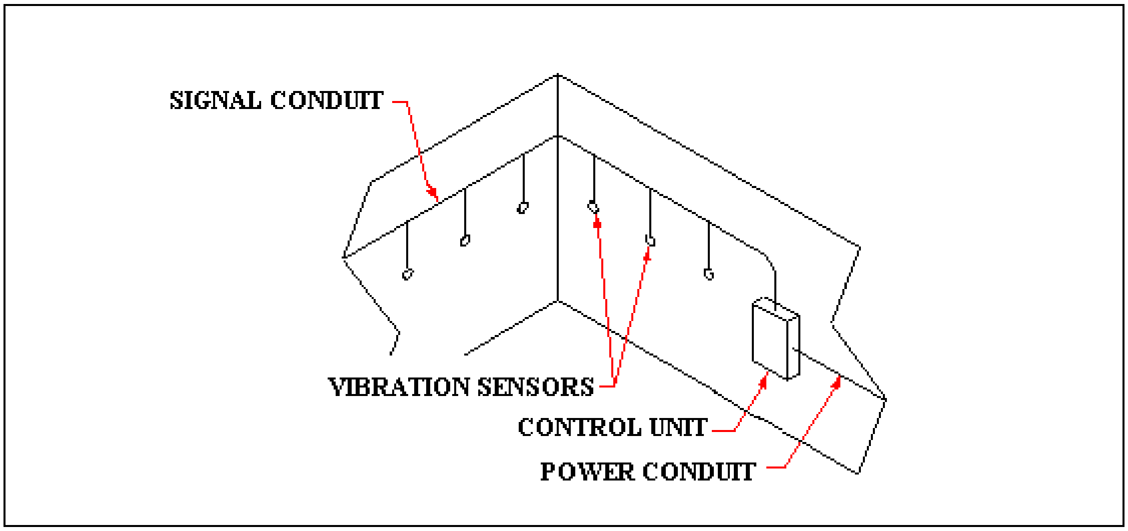
Problems can result from the improper placement of sensors, or their application to inappropriate surfaces. Erratic operation can result from:

- **Unstable or improper installation of units;**
- **Improper spacing of units;**
- **Mounting of the sensors to materials (rugs, fabric, heavy wall coverings) that are not conducive to detecting vibrations;**
- **Poor placement of sensors;**

These sensors can be bypassed by:

- **Avoiding entrance through the protected area;**
- **Selection of a point and method of entry in a segment of a wall, roof or floor that will permit the suppression or diffusion of vibrations created by the entry;**
- **Generation of a persistent but random number of false alarms over a long period of time.**

WALL VIBRATION SENSOR



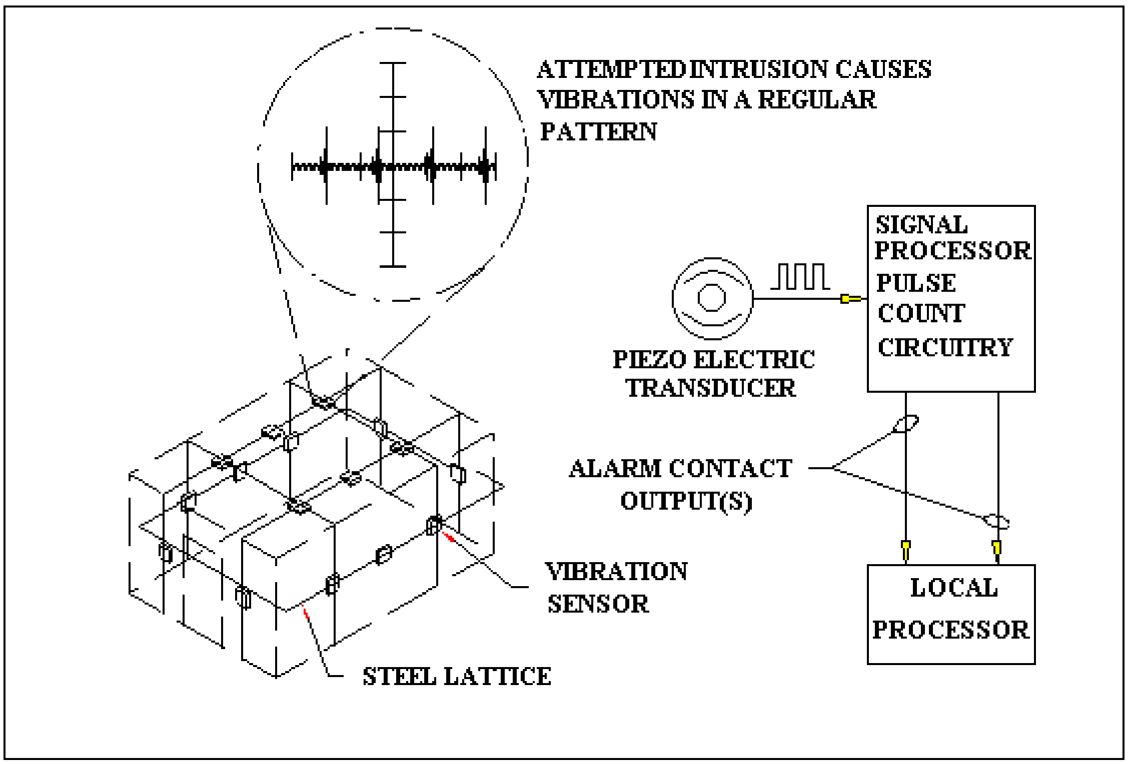


Figure LSS+4009 Wall vibration sensor

40_3.2.4.1 Defeat of Wall Sensors

Fiber optic wall sensors can be defeated by:

- **Avoidance;**
- **Targeting an insensitive or overlooked location as a point of entry;**
- **Bypass the sensor circuit while the system is disarmed.**

40_3.2.5 Fiber Optic Wall Sensor

This type of sensor is configured as an open mesh network (quilt) appliqué that can be applied directly to an existing wall or roof, or installed in a wall (or roof) during construction. The system is designed to sense vibrations at low frequency energy that are created by chopping, sawing, drilling, ramming or other physical attempt to penetrate the structure on which it is mounted. This detection is similar to other fiber optic devices described in this text. There is a source LED that generates light through the fiber, and received by a detector that is sensitive to changes in the transmitted energy. Signatures of various low frequency components are stored within the processor and matched to minute variations in transmitted energy.

Fiber optic wall detectors are extremely sensitive and are not suitable for every installation. They should not be installed on any wall or surface that is exposed to external vibrations, such as generated from aircraft, vehicles, trains, or machinery. They should not be used on walls of poor structural integrity, such as sheet rock, plywood or metal. Smart processors can be programmed for differing types of intrusion, but cannot distinguish between certain external stimulus.

As with other vibration detectors, unreliable operation will result if they are installed or calibrated improperly, or implemented on surfaces that are unsuitable. These systems can be compromised by an intruder avoiding entry through a protected area, or penetrating an insensitive location.

FIBER OPTIC STRUCTURAL VIBRATION SENSOR

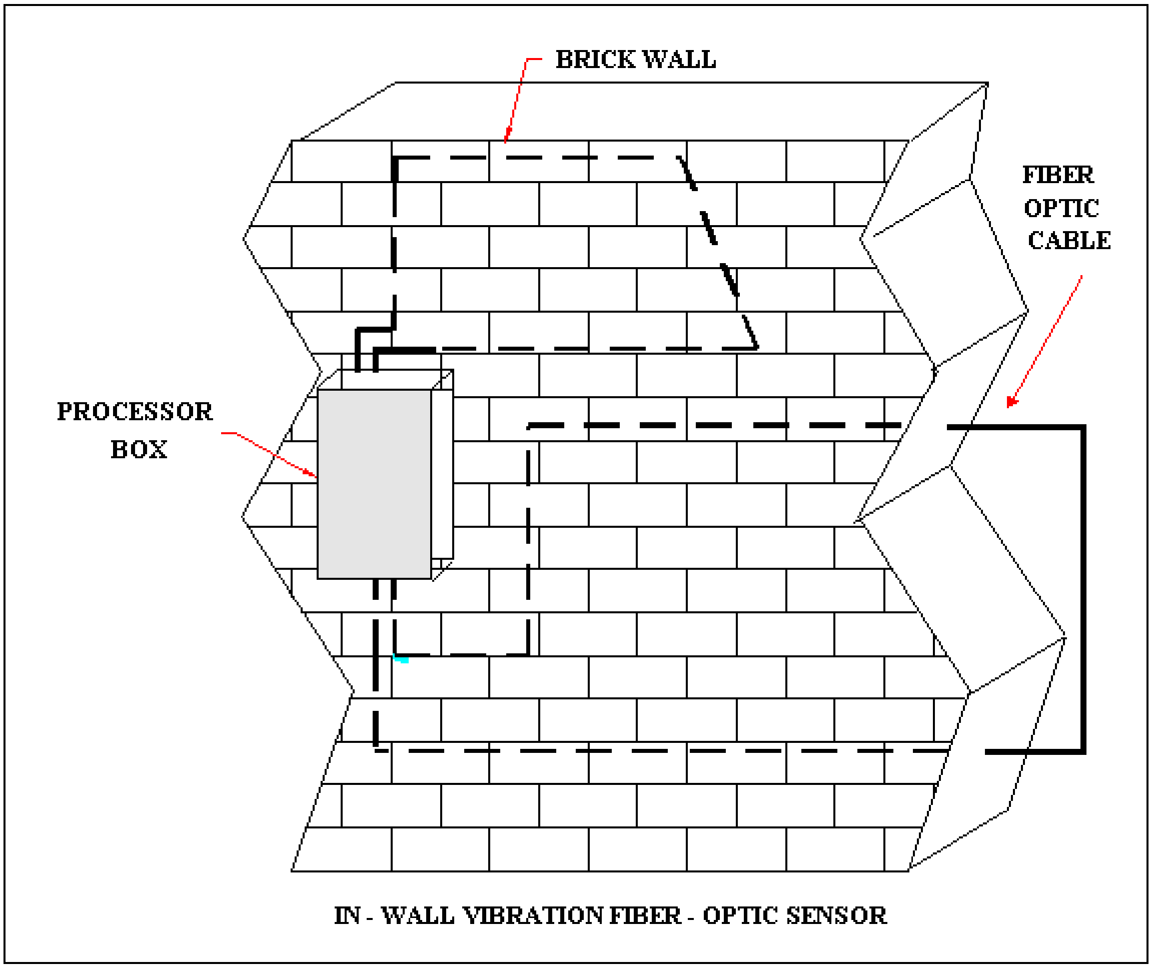


Figure LSS+4010 Fiber optic structural vibration sensor

40_3.2.6 In-Ground Fiber Optic Sensor

Fiber optics can also be used for an in-ground, pressure sensor. The theory of operation is similar to most other light emitting devices described in this text. A light source provides an emitter at one end of the glass network. The conductivity and reflectivity of the system is calculated, and the energy at the receiving sensor is constantly evaluated. Pressure on the cable can create changes in the characteristics of the received signal. Such pressure can be caused by vibrations from walking, running, crawling or jumping.

These systems should not be installed near poles, trees, in or under concrete or asphalt. If they must be located near a pole, then the protected zone should be at a distance equal to the height of the pole. The area of installation should have proper drainage in order to prevent water from collecting over the detection zone.

There are several conditions that will create false alarms when using in-ground fiber optic sensors:

- **Areas with erosion problems caused by heavy rain or lack of vegetation. This can result in the cable being exposed or buried deeper in the earth, causing any sensitivity settings to become ineffective;**
- **Tree roots can be affected by windy conditions above ground that can cause their movement underground and result in bending of the cable;**
- **Large animals passing over the zone of protection.**

These systems can be defeated by bridging over the sensor area. Because of this, supplementary sensors such as microwave are recommended.

IN-GROUND FIBER OPTIC SENSOR

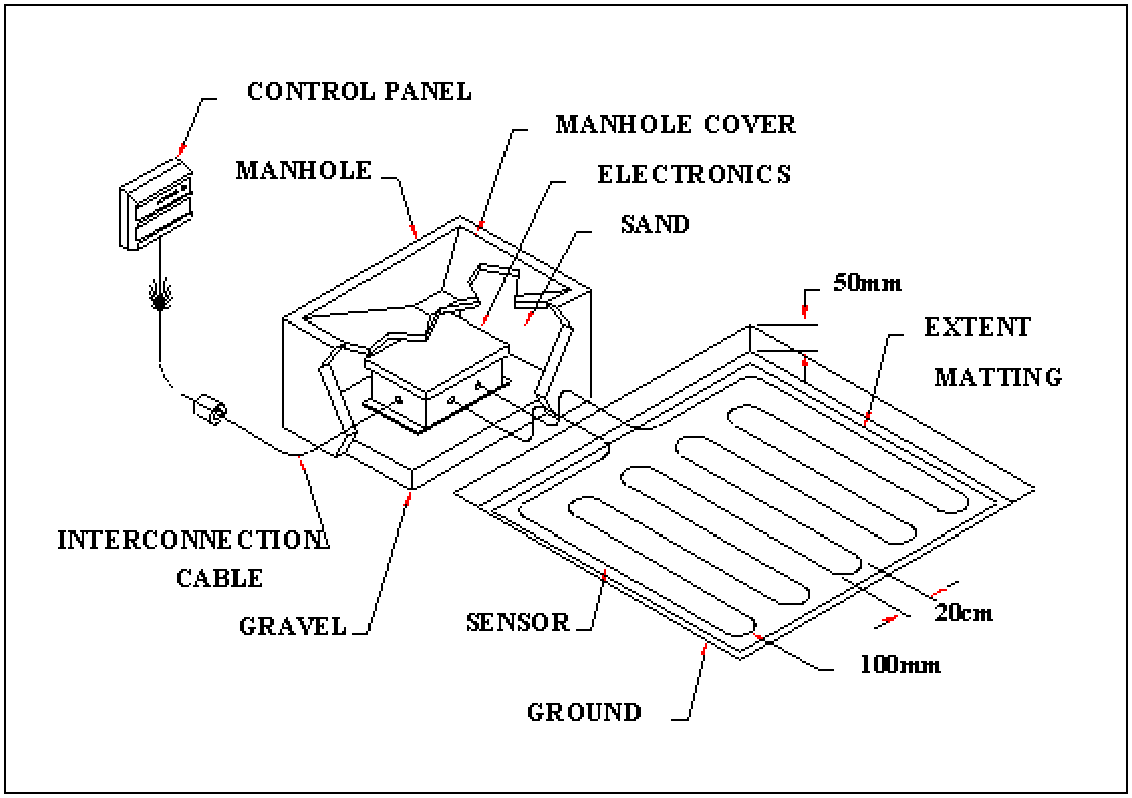


Figure LSS+4030 In-ground fiber optic sensor

40_3.2.7 Ported Coax Buried Line

LSS401: Buried Cable sensors

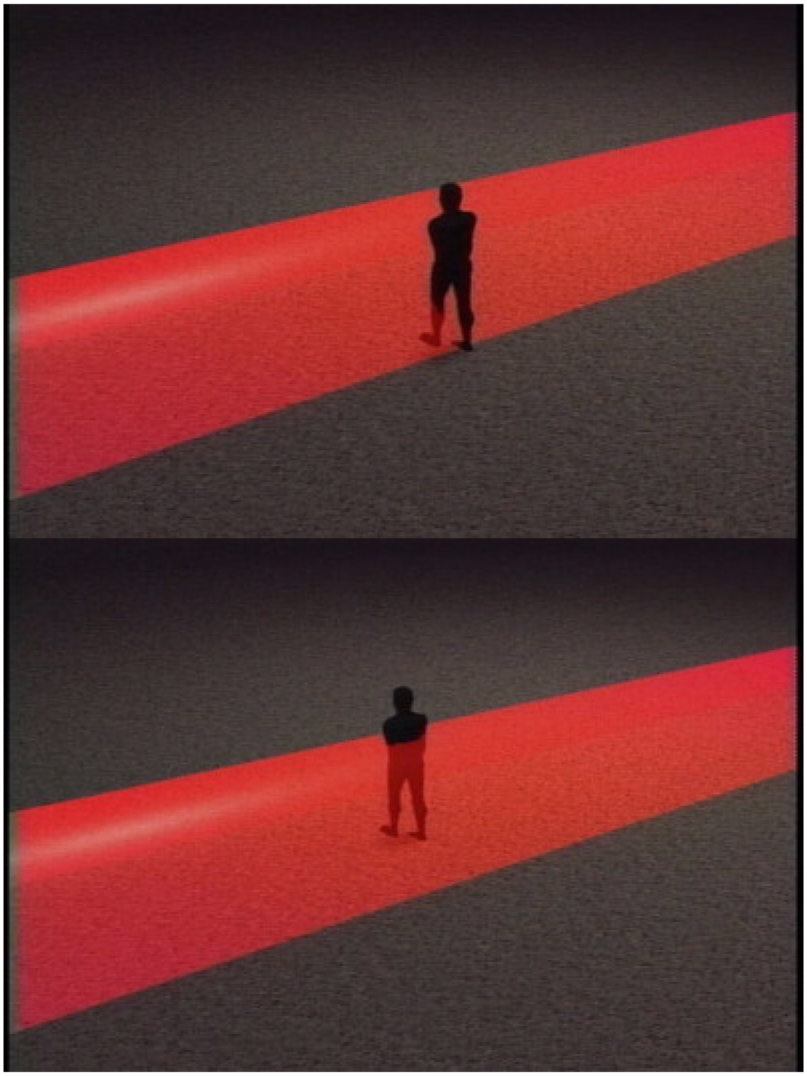


Figure LSS+4060 Ported coax emits an RF field above the cable that can detect an intruder as the beam of energy is crossed. Courtesy of DOE Office of Security and Safety Performance Assurance.

Ported coax buried line sensors are coaxial cables that have small, closely spaced holes in the outer shield that allow electromagnetic energy to escape and radiate a short distance. This emission creates an electric field that can be disturbed upon the presence of an intruder. The system requires that cables be installed in pairs spaced about five feet apart. Under the control of a central processor, a pulse of radio frequency energy is transmitted through one of the cables and received by the other. The pulse timing is constant and thus creates a signature that can be constantly evaluated by the processor. Any

interruption of the field will cause a change in this signature that can indicate an intrusion. The processor has the intelligence of updating its signature parameters to adjust for gradual changes in the environment and surrounding medium.

There are two basic types of sensors: **continuous wave**, and **pulsed**.

A constant emission of RF energy is transmitted simultaneously through the **continuous wave** sensor in both cables and received by the opposite number. This creates a detection zone above ground with a continuous surface. When an intruder enters this area, the electric field is disturbed.

Pulsed sensors emit a pulse of RF energy through one cable and receive it through its corresponding receive side. As the transmission speed is constant, this creates a standard amplitude signature that can be evaluated.

The cables are typically buried about nine inches below the surface of the ground, depending upon the soil density. This creates an electric field that is approximately three to four feet above the ground and extends nine to twelve feet in width. The variation in zone size depends upon cable separation and the characteristics of the burial medium. Using this sensor, zone length can extend up to five hundred feet.

Routing of cables underneath chain link fences, or running metallic pipes through the sensor field should be avoided. If this is impossible, they should be buried at least three feet below the ported coaxial cable. When installing the cables along or near fence lines, the cables must be installed between six and ten feet from the fence in order to avoid distortions and to reduce potential false alarms that can be caused by the motion of the fence fabric disrupting the detection field. Supplementary protection in the form of video motion detection can complement the cable sensor system.

Ported coaxial systems can suffer from false alarms and unreliable operation if installed incorrectly or in difficult environments, such as where there are nearby metallic fence fabric, vehicles, signs, and organic objects such as people, medium to large animals, and medium to large vegetation. Although individual small animals generally do not have the mass to affect these systems, a congregation of small animals can cause distortions.

Heavy snowfall can cause problems due to the limited height of the detection zone. In addition, burial mediums that have drain ducts located beneath the buried cables, and wind disturbance of standing water over the cables can pose a problem. In such cases, ducts must be constructed of metal. The burial zone should be graded to provide immediate runoff and good drainage. It should also be noted that ported coax sensors are affected by high EMI from sources such as large electrical equipment or electrical substations and should not be used in close proximity to these types of installations.

40_3.2.7.1 Defeating Ported (Leaky) Coax Cable Systems



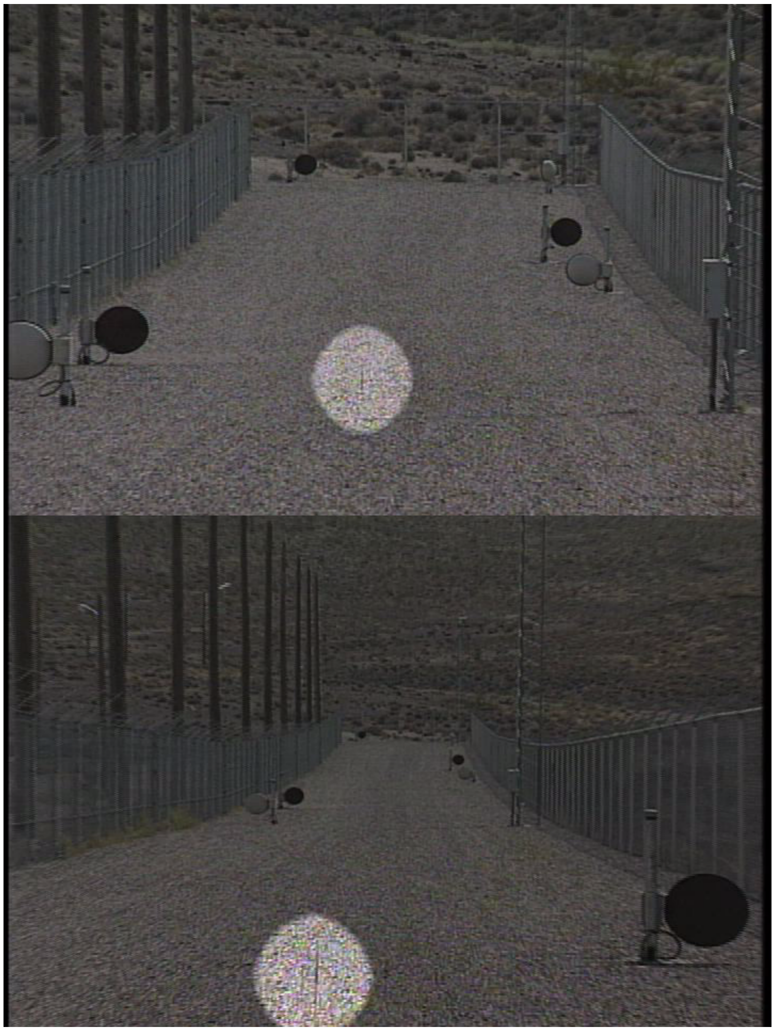


Figure LSS+4055 Marker points for buried coax systems should be removed because they provide an indication of coverage for an intruder. Courtesy of DOE Office of Security and Safety Performance Assurance.

Perimeter defense systems that utilize ported or leaky coaxial cable can be defeated through a variety of methods. These include:

- **Walking on wooden stilts;**
- **Bridging, two-man or pole vaulting over the detection zone;**
- **Alarm stacking;**
- **Leaching a salt water solution slowly through the cable in a specific zone over a period of time. This procedure will have the affect of desensitizing the sensor cable;**

- **Cut the cable from the fence to create an intrusion path;**
- **Bypassing the area of coverage;**
- **Using marker points as an indicator of coverage.**

BURIED PORTED CABLE SENSOR

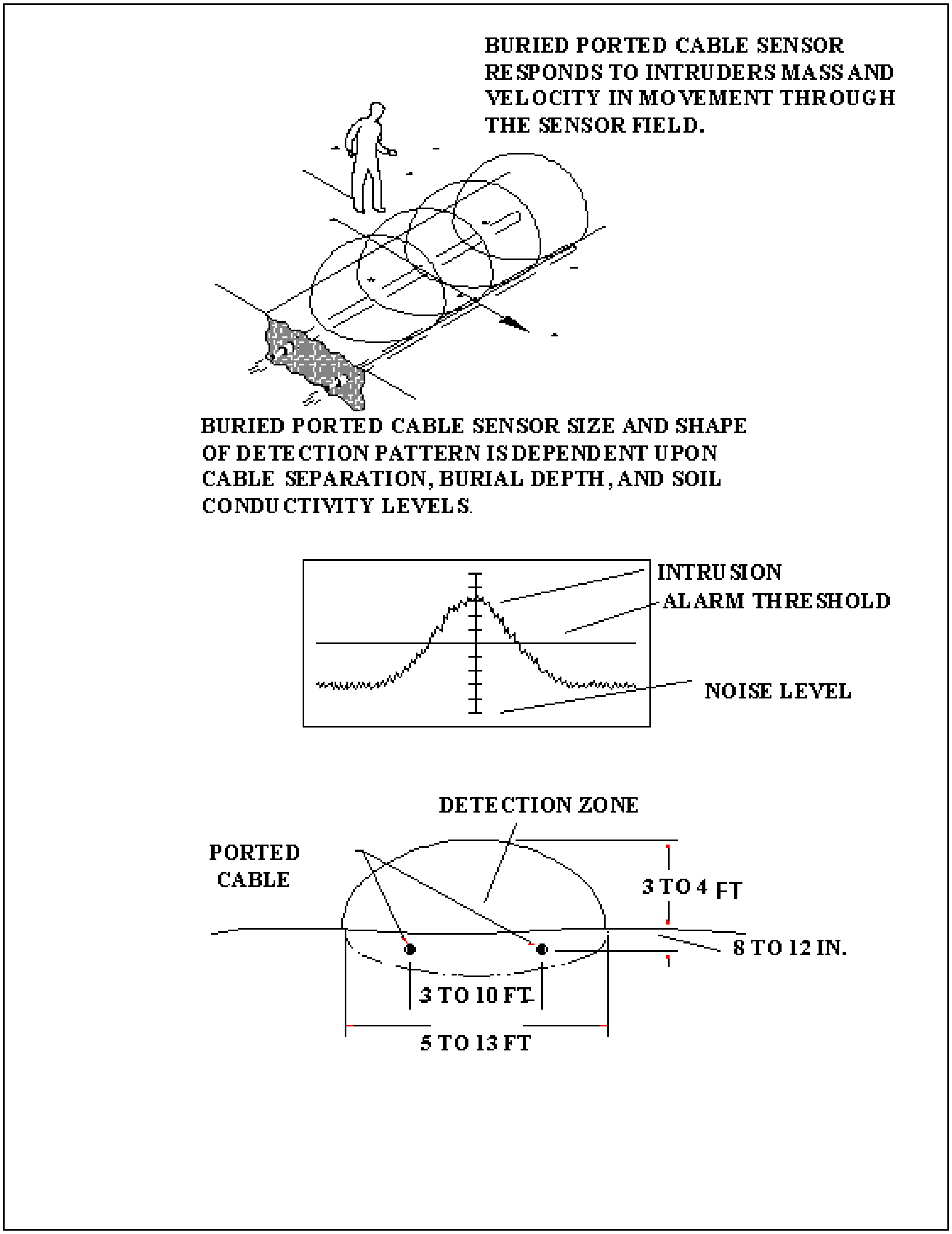


Figure LSS+4031 Buried ported cable sensor

40_3.2.8 Balanced Buried Pressure Sensor

A Balanced Buried Pressure line sensor is another type of in-ground system that detects vibrations and seismic energy that can be caused by personnel, animal or vehicular movement across the surface of the ground in which the sensors are installed. The tubes are extremely sensitive to pressure changes upon the medium in which they are located. Ground within a zone that is subjected to walking or running intruders, vehicles, or other forms of compression will cause proportional changes in pressure in the farthest tubes. This is processed and analyzed.

The amount of sensed pressure waves directly relates to the weight and movement impact that is created by objects contacting the earth. Each type of impact creates its own identifiable signature, much like sonar. Thus, a runner will create greater pressure than a person that is walking. Likewise, a heavy person that is walking upright will create more pressure than a smaller person moving on hands and knees.

Sensor zones (usually two sensor tubes) consist of pressurized, closed end, pliable tubes or hose segments filled with water or an antifreeze-like solution. The zone size will vary depending upon soil density and composition and the nature of any surface material. The tubes are very sensitive to changes in pressure and react to pressure exerted on the medium in which they are implanted or buried. A processor monitors and regulates the pressure inside the tubes and generates a signal if there is a deviation from a determined norm.

There is a self-compensating valve that is used to maintain pressure within the tubes, and to adjust to gradual or moderate (not rapid) changes that can be associated with the burial medium (not of personnel and vehicle movement and other man-made or sudden natural movements such as earthquakes and explosives). Such changes might include those caused by moisture content (rain) or temperature changes (frost or drought). The differential pressure system and the nature of the self-compensating valve provides a high degree of immunity to normal environmental noise and weather conditions.

A detection zone is created by burying the tubes approximately four feet apart, with the pressure-sensing unit linked and placed between the sensor tubes. Depending upon the nature of the soil,

this type of system can create a detection zone that measures up to a 350 feet radius. The depth at which the tubes are placed depend upon the composition of the medium in which the tubes are placed. Depth for different medium is as follows:

- **Earth and sand: ten inches is sufficient;**
- **Soil with an asphalt covering: four to eight inches;**
- **Concrete surface or area: bury just beneath the under-surface of the concrete, because this material is not a good conductor for waves created by personnel. It serves to dampen or insulate such waves, thereby reducing the probability of detection.**

Tree roots closer than ten feet to a sensor set can pose a false alarm problem, due to the potential for windy conditions above ground. Such movement can transfer pressure waves into the ground via the root system. So also, areas with heavy snowfall or shifting sand may create a problem for the system to properly sense seismic vibrations. In such cases, snow and sand look the same to detectors with respect to the shock waves created upon their movement. This would, of course, depend in part on the depth and composition of the snow or sand.

As with other systems discussed above, the improper installation or calibration of detectors can cause normal activity to be interpreted as an alarm condition. The location near heavy road or rail traffic or seismic activity from pulsating or shock machinery can generate nuisance alarms.

40_3.2.8.1 Defeat of Balanced Pressure Sensors

The ability to defeat these systems relies upon the avoidance of potential zone(s) of detection or of the following actions:

- **Cushioning movement vibrations;**
- **Dispersing or a lowering of impact energy;**
- **Attacking the sensor in extremely cold weather;**
- **Alarm stacking;**
- **Avoidance of sensor;**
- **Bridging or planking over or through the detection zone.**

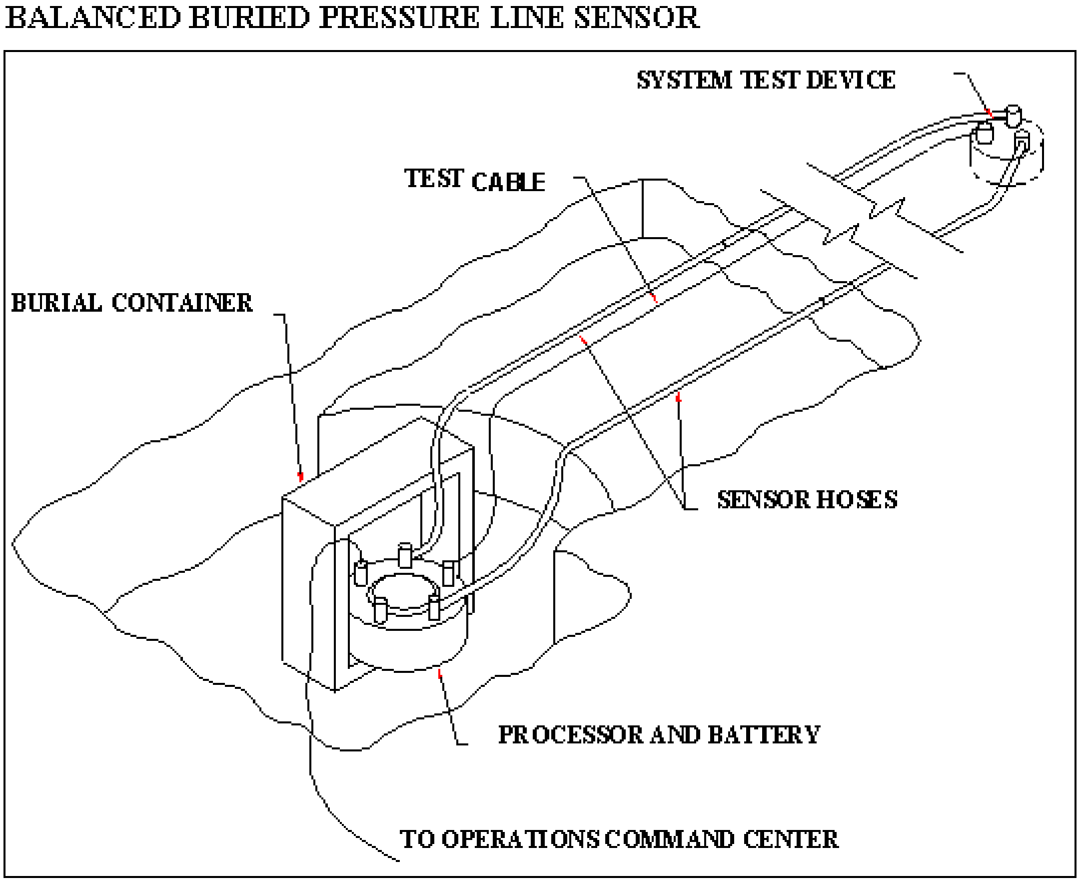


Figure LSS+4032 Balanced buried pressure line sensor

40_3.2.9 Buried Geophone

A buried geophone transducer is designed to detect the low frequency seismic energy created in the ground by someone or something crossing through the detection screen above the sensor by crawling, walking, or running.

The system consists of two elements, a processor and a series of geophone sensors. Signals are generated by the detectors that are then filtered and processed, based upon predefined signatures. In typical installations, twenty to fifty geophones are placed in a line of detection that can extend up to three hundred feet. They are buried between six and twelve feet apart to a depth of six to fourteen inches in soft to compact soil, and six inches in asphalt. Soil must be stable and relatively compact, with the geophones seated between layers of sand, due to its conductivity.

In many systems, direct audio monitoring is available to validate alarms by human operators. Much like Sonar in a submarine, a trained operator can usually differentiate between normal stimuli and that associated with intrusion attempts.

These systems are subject to unreliable detection and false alarms if the material in which the sensors are buried is inconsistent or loose. In such cases, the soil becomes a poor conductor of energy, resulting in little data being received by the geophone. On the other hand, the detectors are sensitive to low levels of seismic activity and thus, noise can be generated by animals, trees, fences, light poles and telephone poles. Each of these structures are anchored in the ground and are conduits for energy transfer. Because of this, a geophone should be located at least thirty feet from a tree, ten feet from any fence, and at a distance equal to the height of any nearby pole.

Geophones, as with all vibration detectors, can be defeated by bridging over the sensor.

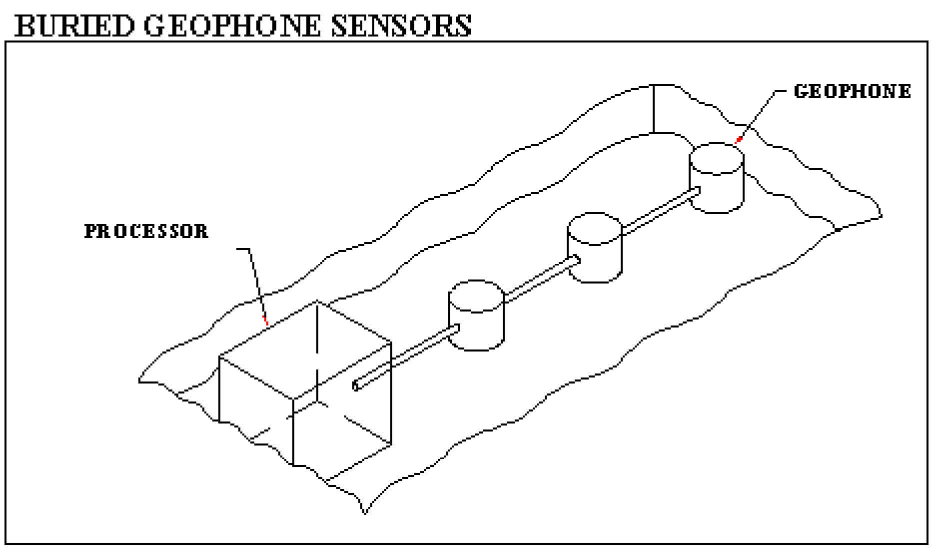


Figure LSS+4033 Buried geophone sensors

40_3.2.9.1   Defeat Techniques for Geophone

Sensors that detect vibration or seismic energy (geophones) can be defeated through a variety of techniques, including:

- **Bridging;**

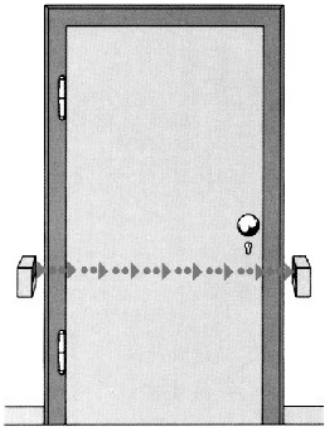
- **Tunneling under the sensors, or use of a two-man pole vault over the fence-mounted version;**
- **Stacking of alarms;**
- **Avoidance;**
- **Explosive penetration if pulse count is set improperly;**
- **There is a high probability of alarms during storms or wind. This fact can be used to bypass a system by creating trips that may be ignored;**
- **Spoofing and alarm stacking.**

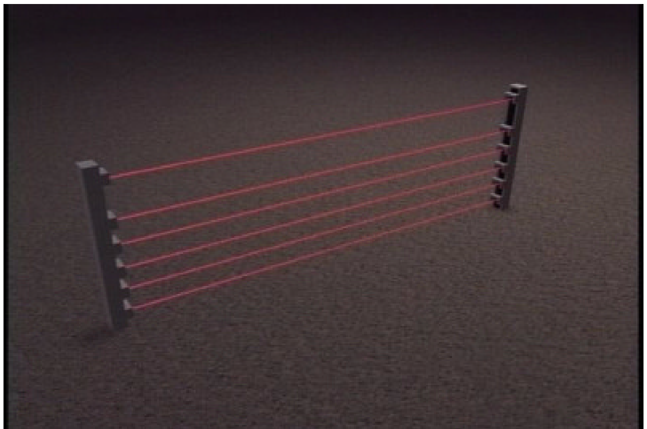
40_3.3 Light-Activated Sensors

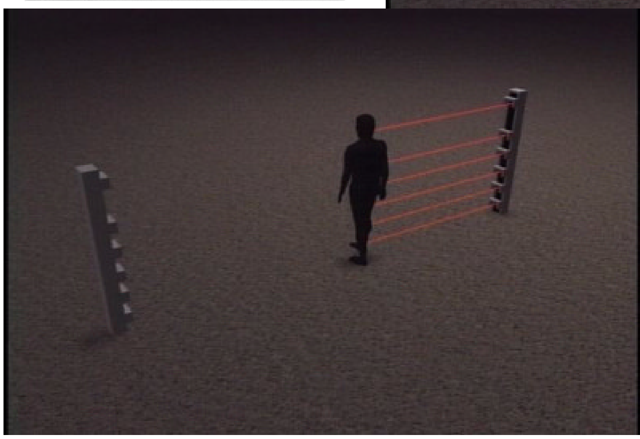
LSS401: Photoelectric sensors

Light sensors are employed to provide an invisible electronic barrier against entry. They can be positioned within a building or outside along a perimeter to protect a path against intrusion. Photoelectric sensors transmit a beam of infrared light to a remote receiver and thereby create an "electronic fence". Such sensors can "cover" openings such as doorways, walls, or hallways; they act like a trip wire. Once the beam is broken or interrupted by an intruder, a contact closure or other signal is generated. Photon-sensitive devices rely upon the transmission and interruption of one or more light beams for their operation. When photoelectric systems are installed properly, they will provide a reliable measure of protection for small or large areas.

A system consists of a transmitter and receiver. The transmitter emits one or more narrow light beams in a straight or reflected path to the receiving unit for a range of up to 1,000 feet. So long as the rays are not interrupted, the receiver will maintain a continuous circuit.







Photoelectric sensors are comprised of two critical components: a **transmitter** and a **receiver**. The transmitter utilizes a Light Emitting Diode (LED) as its light source. It generates a consistent infrared beam to a receiver. The receiver is actually a photoelectric cell that detects the presence of IR at a specific modulated frequency. If the detector fails to receive at least 90% of the transmitted signal for as brief as 75 ms.(time of an intruder crossing the beam), an alarm condition is created.

In most systems, the IR carrier (one or more beams) is modulated at a very high frequency, and this frequency is further changed at a rate of up to 1,000 times per second in an algorithm that correlates with that programmed into the receiver. This prevents bypass attempts through the use of a substitute light source. The only way to bypass this system would be to replicate the angle of the beam and modulation frequency.

In practice, the transmitter and receiver can be separated up to 1,000 feet and still provide reliable coverage. A photoelectric sensor is not affected by changes in thermal radiation,

fluorescent lights or Radio Frequency Interference (RFI). These systems exhibit a high probability of detection and low false alarm rate. The path of the beam can be altered using mirrors to create a less predictable detection barrier, although the use of mirrors can reduce the signal strength of the beam and diminish its effective distance. If mirrors are utilized, caution must be exercised because they are often accidentally knocked out of alignment, generating a need to calibrate and realign them periodically. They are also prone to dust build-up and refraction or diffusion of the reflected beam.

The major failure in these systems is the introduction of anything that blocks or interrupts the path of light between transmitter and receiver. Such action can affect the detection reliability of the sensor. Fog, smoke, mist, dust, and reflective particles cause the light to be refracted or scattered. If there is more than 10% reduction in the signal strength, an alarm is normally generated. Extreme variations in background lighting or sunlight may also reduce sensitivity.

A nuisance or false alarm can be caused by any objects that interfere with beam transmission, such as birds, animals, blowing leaves, or paper. The improper alignment of the transmitter, receiver or mirrors can also generate an alarm.

40_3.3.1 Defeat of Light Sensing Systems

Light level detection systems are triggered by the presence or absence of ambient light. They differ from photoelectric sensors in that they sense lighting conditions, rather than a specific directed beam across an identified path. Light sensing systems can be neutralized by:

- **Entry without alteration of the ambient light level;**
- **Use of night vision devices in an optically controlled environment;**
- **Blinding of the light sensor to simulate a specific condition;**
- **Blocking of sensor to prevent the detection of light. The photograph shows the use of black electrical tape to defeat a light level sensor at the diamond exchange in Antwerp, Belgium during a large burglary.**



40_3.3.2 Defeat of Photoelectric Active Infrared Sensors

There are several techniques for defeating internal and perimeter photoelectric detection devices. These include:

Interior Sensors

- Avoidance, moving or stepping over or under the sensor light beam or projected laser plane, by determining the location of transmitter/receiver or reflective tape. Proper placement of mirrors can counteract this vulnerability by creating a "zig-zag" multiple beam barrier pattern;
- Extension of fiber optic cable material from transmitter to receiver in order to create a new light path;
- Capture of a beam by external light source. This will generally apply to non-pulsed units using visible light only, although modulated IR or lasers may also be utilized;
- Interposing reflectors or mirrors in a single-ended systems (Bounce back);
- Spoofing and alarm stacking;
- Using a black and white camera or IR goggles to determine light source;
- Stacking of alarms using birds;

Exterior Sensors

- Tunneling or trenching under the sensor beam pattern;
- Bridging, two-man or pole vaulting over the sensor beam pattern;
- Beam capture of unmodulated sensors only;
- Avoidance of the sensor, by stepping or sliding through improperly spaced beams;

- Utilize the ridged sensor sunshades or the sensor itself as a ladder. This is model dependant;
- IR beams can be observed by using a monochrome CCTV camera or IR goggles to determine transmitter path;
- Alarm stacking using another IR light source aimed at the receiver.

40_3.4 Proximity and Capacitance Sensors

LSS402: Proximity sensor technology

Proximity detectors can signal the presence of intruders near to or touching a certain object or area by a change in capacitance, inductance or other characteristics of the structure. They are used in driveways, office areas, schools, banks, strong rooms, safes, and other locations where specific structures or items are to be monitored.

Magnetic point detectors are utilized to sense large metal objects such as vehicles driving across concrete.

LSS403: Magnetic point sensors

Capacitance sensors are designed to detect changes in an electrostatic field that is created by an array of wires. The presence of an intruder can change the capacitance of the field by approaching or contacting the wires. The sensors consist of three closely-spaced wires that are arrayed and installed on the top of a fence. A low voltage signal is induced in the array that creates an electrical field, utilizing the fence as the system electrical ground. A processor continually measures and compares the differential capacitance between the sensing wires and ground.

Three strands of closely spaced 16 gauge wire form the sensor array. The wires are secured to a fence top fabric or wall by using high-dielectric brackets, which can be adapted to any barrier. They are most commonly utilized on outriggers atop chain link fences. The sensor segment can extend 1,000 ft. In order to trip the sensors, physical touching of the fence is usually required. If the sensitivity of the system is increased, then close proximity can often trip the system. Supplementary sensors should also be installed, because these systems are subject to bypass by cutting of the vertical fence fabric. The systems are

impervious to weather, EMI, and RFI; such conditions have no effect on detection capabilities, although there is a high level of maintenance required to assure that the capacitance characteristics of the fence are always adjusted.

False alarms or unreliable detection can occur from vibrations caused by weather and animals (birds, squirrels and others). Vegetation coming into contact with the fence can also change the capacitance, thereby affecting the detection characteristics. Proper landscaping maintenance of the fence line must be insured (grass cut, trees removed, shrubs removed). Blowing debris or anything making physical contact that changes the characteristics of the fence can create an alarm condition. One countermeasure for this problem is inducing tension with springs at the termination points.

40_3.4.0 Defeating Proximity and Capacitance Sensors

Capacitance and proximity sensors can be defeated by a number of techniques, including:

- **Disconnection from protective detection loop while the system is disarmed. This will be effective in self-balancing systems only;**
- **Use of insulating blankets, rubber wet suits, or gloves to prevent shorting of the capacitance field to ground;**
- **Bypass the sensor circuit while the system is disarmed;**
- **Tunneling or bridging of the sensors.**

Differential Capacitance Systems, utilized in exterior applications, can be defeated by:

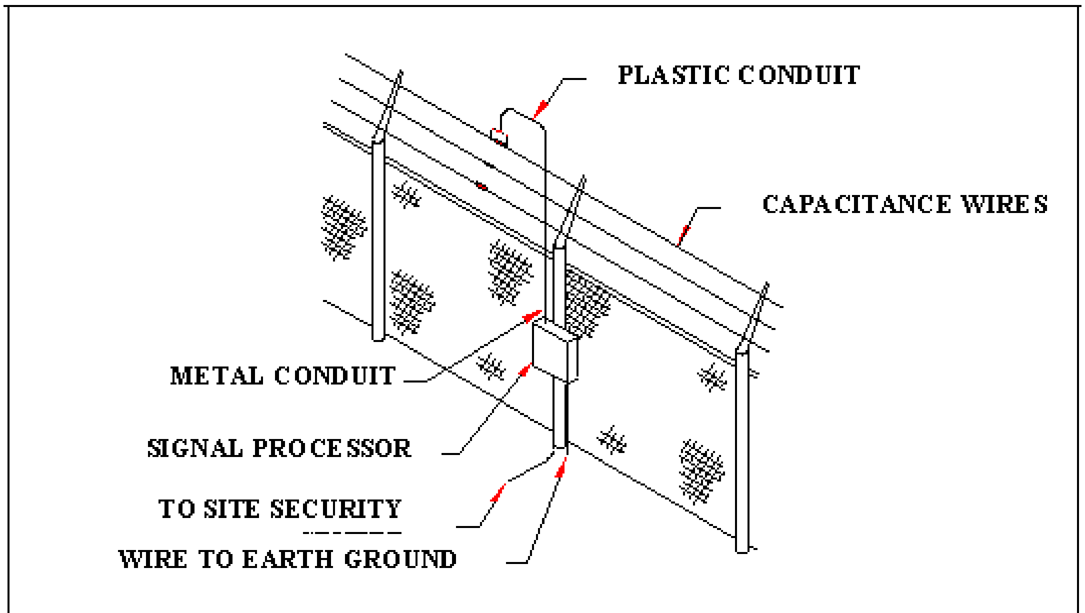
- **Tunneling under the sensor or barrier (such as a fence);**
- **Bridging, two-man or pole vaulting over barrier;**
- **Wearing heavy insulated clothing, gloves or other material;**
- **Alarm stacking;**
- **Avoidance by attacking or penetrating the location at gaps in the sensor coverage;**

Magnetic point and driveway alert sensors can be defeated by:

- **Bridging, two-man or pole vaulting over detection zone;**

- **Use of wooden stilts;**
- **Intruders do not have any metal;**
- **Avoidance;**
- **Alarm stacking.**

CAPACITANCE SENSOR APPLICATIONS



CAPACITANCE FENCE SENSOR CONFIGURATION

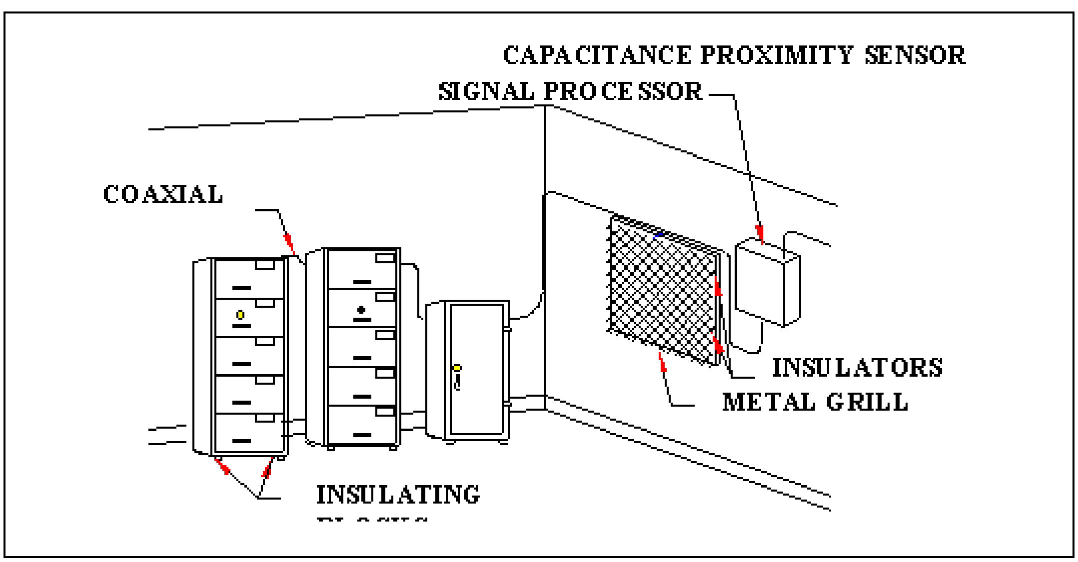


Figure LSS+4022 Capacitance sensor applications

40_3.4.1 Electric E-Field Sensor

LSS401: E Field protection





**Figure LSS+4048 An E field system by Siemens creates an electronic barrier through a series of
parallel wires across the fence line.**

Electric field sensors are designed to generate an electrostatic field between and around an array of wire conductors and an electrical ground. Sensors detect changes or distortion in the field which can be caused by anyone approaching or touching the fence. Sensor zone length can extend up to 1500 feet.

The E-field sensor consists the following components:

- **An alternating current field generator that excites a field wire (two or more sensing wires), around which an electrostatic field is created;**

- **An amplifier signal processor that detects changes in the signal amplitude of the sensing wires.**

The alternating current on the field wire creates an electrostatic field in the air between the field wire to ground. When an intruder enters the "field", large amounts of the electric charge flow through the intruder due to the disruption of the field by the human body.

To reduce false alarms, the signal goes through a filter which rejects high frequencies caused by wind vibration and low frequencies caused by objects striking the fence wires. However, the filter allows frequencies associated with intrusion characteristics to be evaluated by the processor. Three concurrent conditions must be met to signal an alarm:

- **The signal amplitude must exceed a preset value that discriminates small animals;**
- **The frequency must be in a range that is associated with humans;**
- **The signal must persist for a set period of time.**

E-field wire configurations are mounted on free-standing posts or chain link fences. All the wires are placed in parallel with each other and to the ground. This will achieve uniform sensitivity along the fence length. Springs are used at the connectors to ensure tension- reducing vibrations caused by wind.

An advantage that an E-field sensor has in comparison with other fence sensors is the self- adjusting circuitry that is built into the processor. Such systems will reject wind and ambient noise. In order to perform, this circuit requires the amplitude of an intrusion attempt to exceed a preset level for a preset period of time.

E-field sensors have a very low nuisance and false alarm rate. Sometimes, countermeasures such as bridging and tunneling can be detected. This depends upon the proximity of the disturbance activity to the sensor. This system should be considered if bridging or tunneling are anticipated intrusion tactics. Other fence sensors (vibration, taut wire) can be added to provide a higher level of detection probability.

Unreliable detection and operation can result:

- **From adverse weather conditions (such as rain and snow);**
- **Improper installation that results in incorrect tension or insulation coupling;**
- **During an electrical storm;**
- **Vegetation, grass, or shrubbery movement or growth along the fence line;**
- **Animal movement along the fence line;**
- **Large spacing between wires (this condition should be avoided because it can allow someone to move between the wires without causing an alarm);**
- **EMI can be a problem where multiple systems are deployed in a limited area, unless different frequencies are utilized by each system;**

Any action that causes fence vibration (weather, animals, birds)

40_3.4.1.1 Defeat of E-Field Systems



Figure LSS+4057 E-Field systems can be defeated by taking advantage of shadowed areas. Shown is a piece of
lumber that can be used to scale the fence at a vulnerable point. Note in the middle photograph a pizza cutter
can prevent this practice. An individual in shadow coverage (right) is not

detected. Courtesy of DOE Office of Security and Safety Performance Assurance.

E-Field Sensors can be defeated by:

- **Tunneling (six feet or deeper) under the protected area;**
- **Avoidance by attacking a lack of sensor coverage at buildings and other obstructions. Look for gaps in coverage;**
- **Bridging, two-man or pole vaulting over the detection zone;**
- **Alarm stacking.**

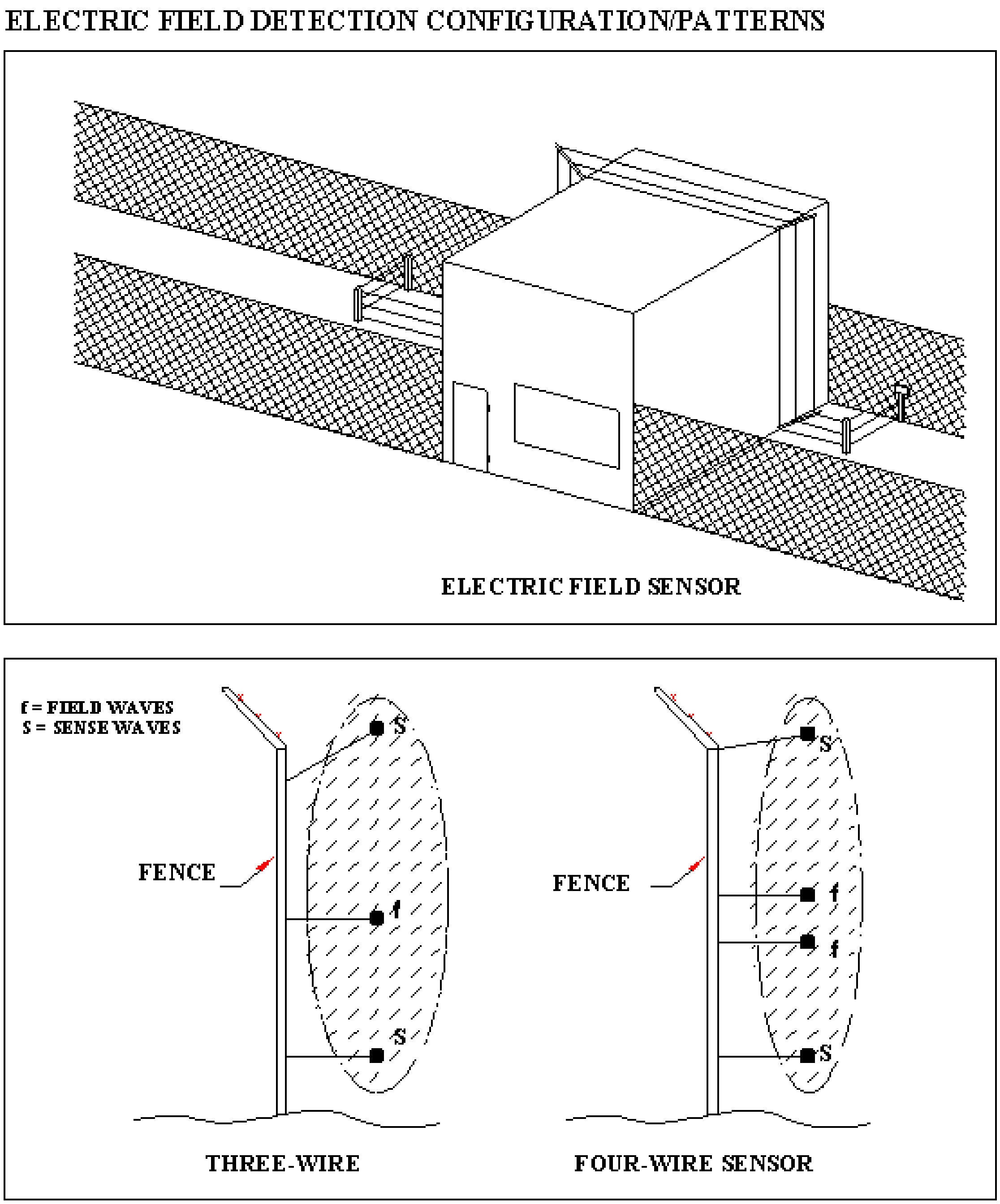


Figure LSS+4021 Electric field detection configuration/patterns

40_3.5 Volumetric Sensors

LSS403: DOE on sensor technology

Volumetric sensors are primarily used for monitoring an intrusion into enclosed areas where entry is through walls, floors, or ceiling. They utilize air pressure, ultrasonic sound, and radio frequency energy as a transmission medium to permeate an entire area and provide information as to changes resulting from penetration.

Volumetric systems are extremely economical where large areas are to be monitored. Because the sensors do not respond until an intruder is within a protected area, they should be installed as part of a comprehensive system of trips. Many different kinds of sensors are available that are reliable, sophisticated, and inexpensive. Often, two different technologies are combined within one detector in order to minimize the potential for false alarms. The most common example is the motion detector that contains microwave and passive infrared.

Volumetric monitoring does not rely upon the physical breaking of circuits that is required when using magnetic trips, foil, or photoelectric devices. The sensors can provide surveillance completely throughout an area from floor to ceiling and wall to wall, rather than just a specific door or window. This is a major advantage.

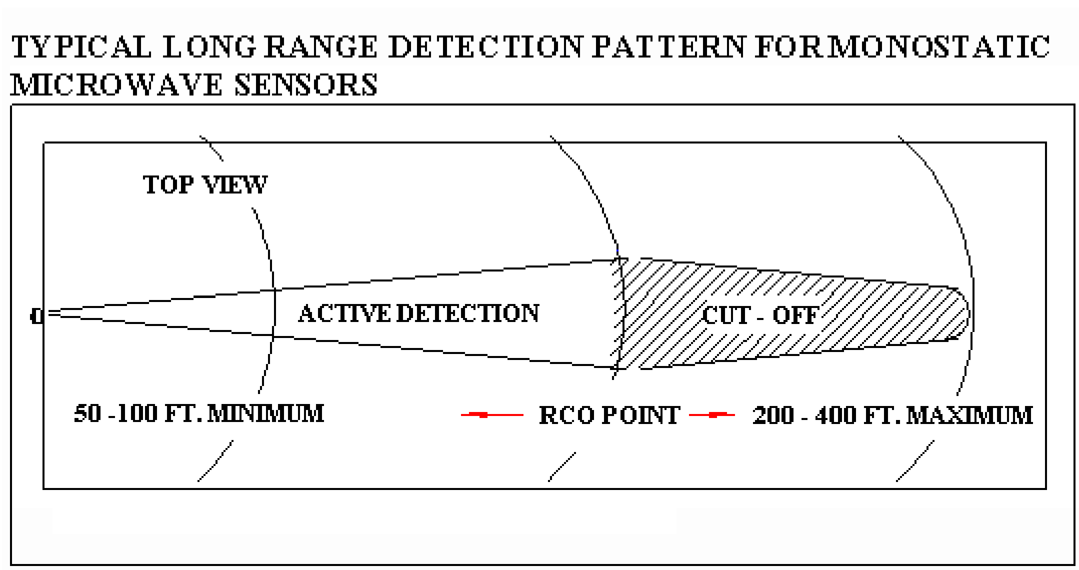


Figure LSS+4003 Typical long range detection pattern for monostatic microwave

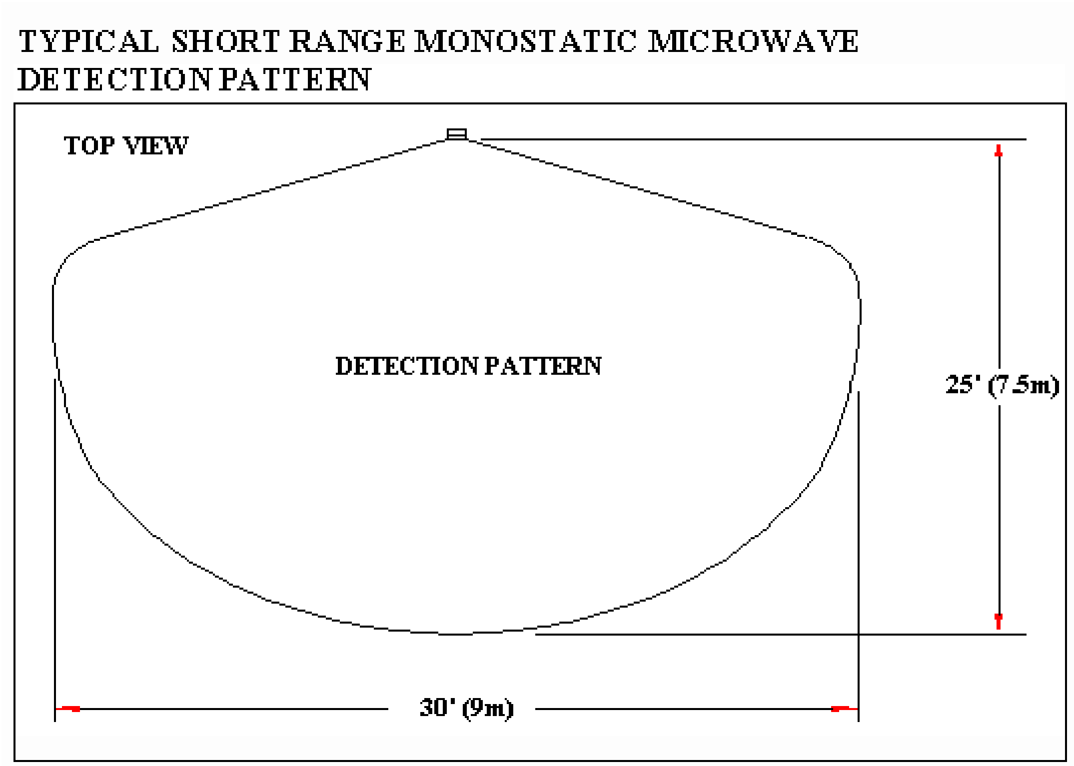
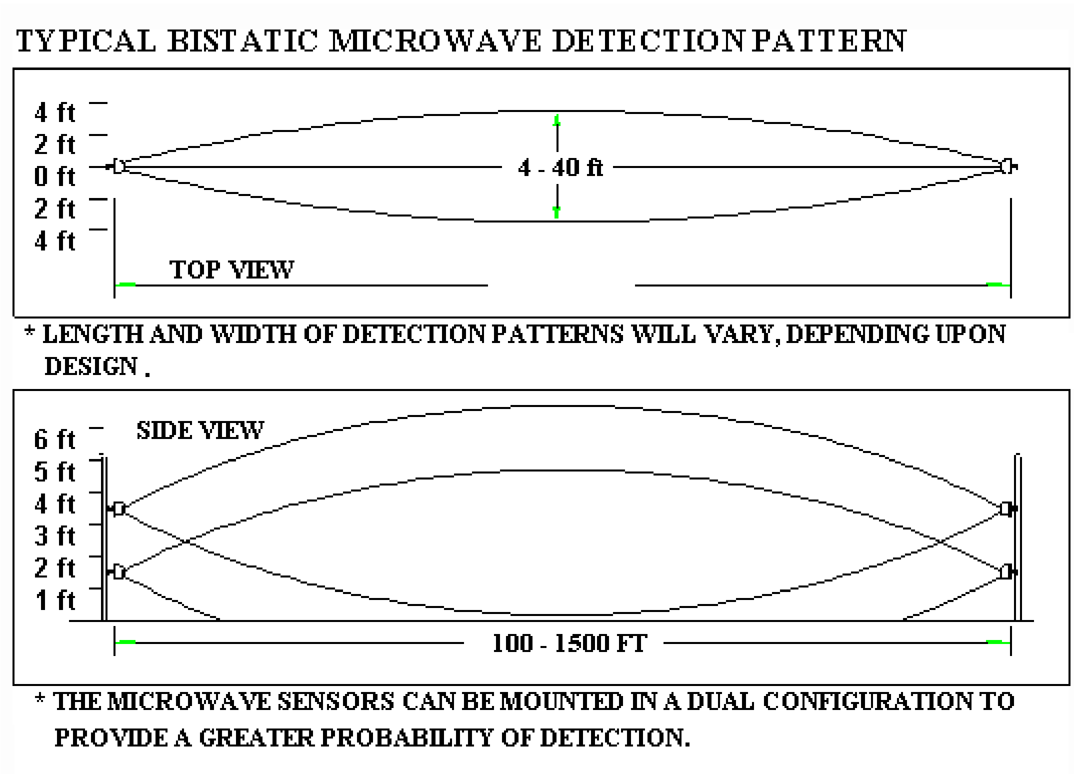
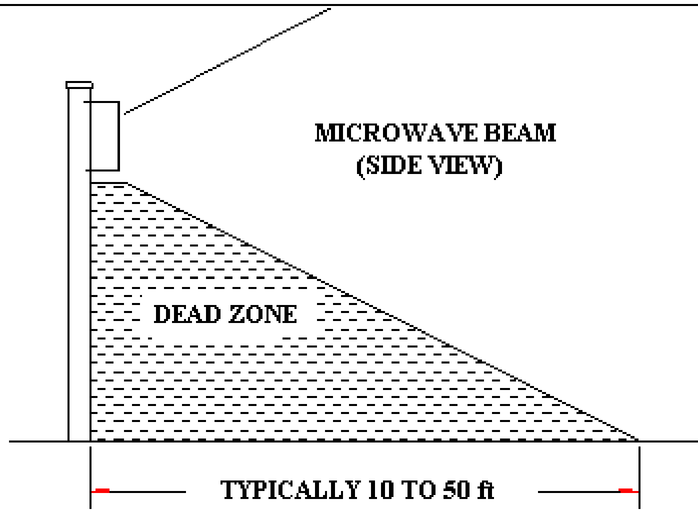


Figure LSS+4004 Typical short range monostatic microwave detection pattern

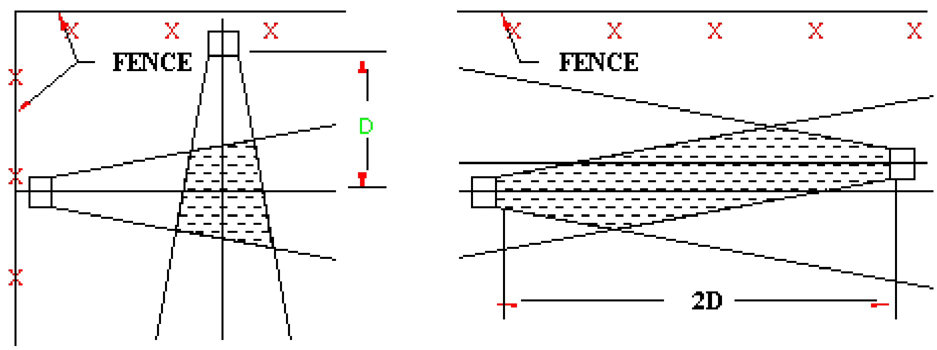


LSS+4005 Typical bistatic microwave detection pattern

MICROWAVE SENSOR ZONES

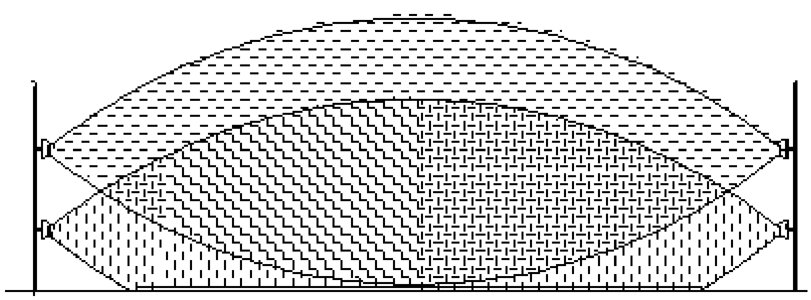


MICROWAVE DEAD ZONE



D = LENGTH OF DEAD ZONE

OVERLAP OF MICROWAVE ZONES



STACKED MICROWAVE CONFIGURATION

Figure LSS+4006 Microwave sensor zones

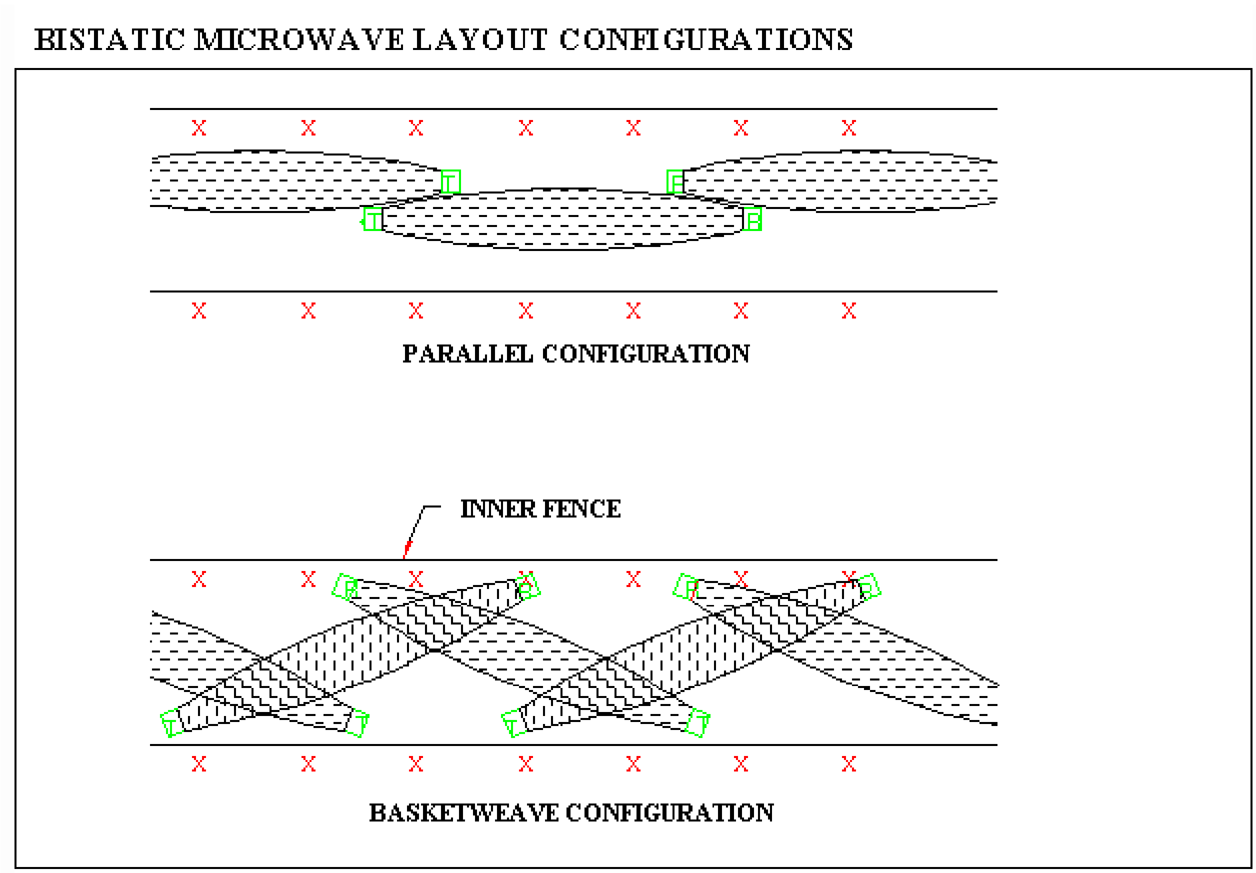


Figure LSS+4007 Bistatic Microwave Layout configurations

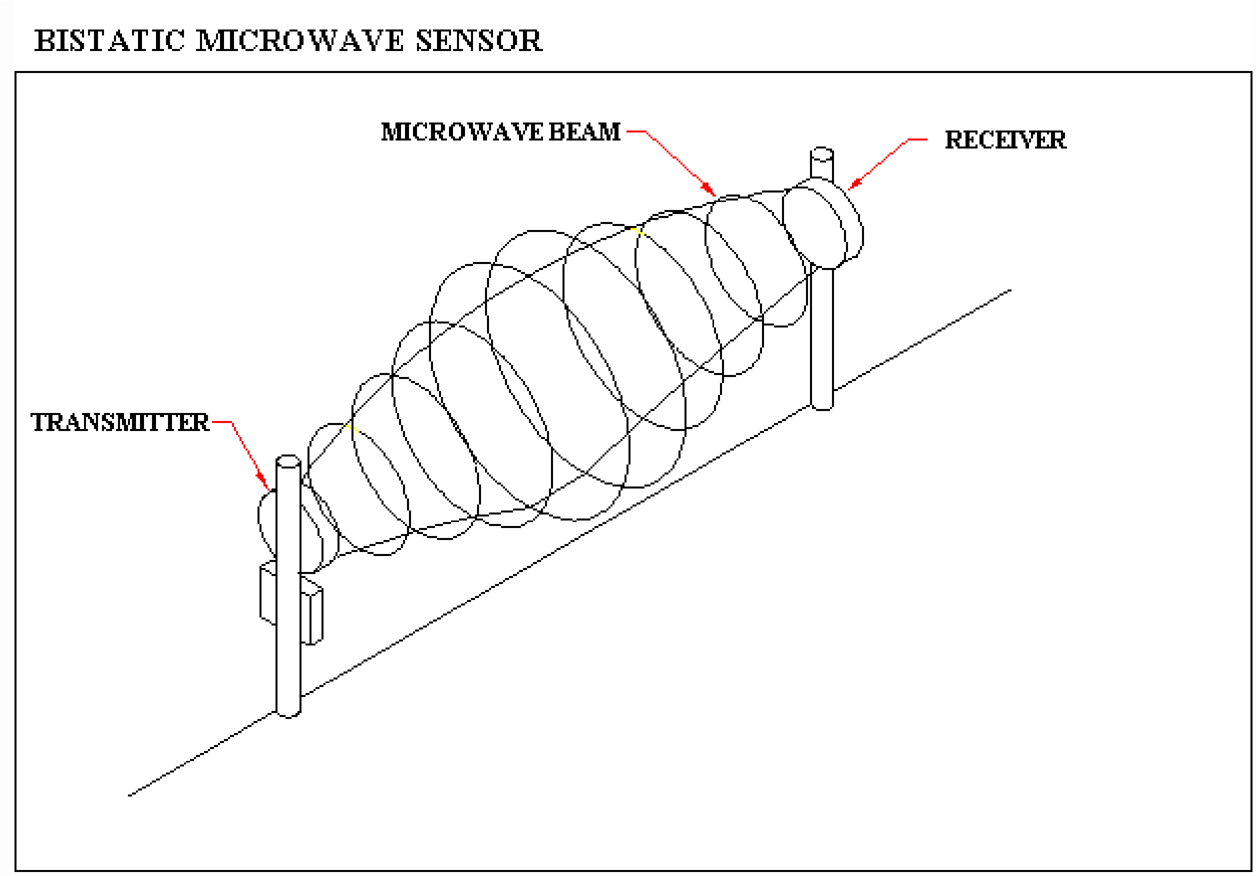


Figure LSS+4008 Bistatic microwave sensor

40_3.5.1 Microwave Systems

LSS401: Microwave sensor systems

LSS402: Issues with microwave sensors

Sensor technology based upon the transmission of microwaves utilizes radio frequency energy above 10 GHz to protect an enclosed space. The RF will penetrate everything within the target area as well as adjacent barriers. Minute changes in transmitted and received frequencies are compared by a microprocessor for a specific threshold. When the limit is exceeded, an alarm is initiated.

Microwave sensors are motion detection devices that transmit an RF field throughout a protected area. These systems can be utilized for both internal and external applications.

Microwave devices utilize Gunn diodes to emit low power energy in the "X" band up to 400 feet (line of sight). Microwave devices rely upon the Doppler frequency shift principle that measures a frequency shift between 20 Hz and 120 Hz. These frequencies are generated upon human movement within a protected area.

There are two basic types of microwave sensors: **monostatic**, which have their transmitter and receiver encased within a single housing unit, and **bistatic**, wherein the transmitter and receiver are separated, and create a detection zone between them. There are significant differences between the two systems, detailed below.

40_3.5.1.A Monostatic Units

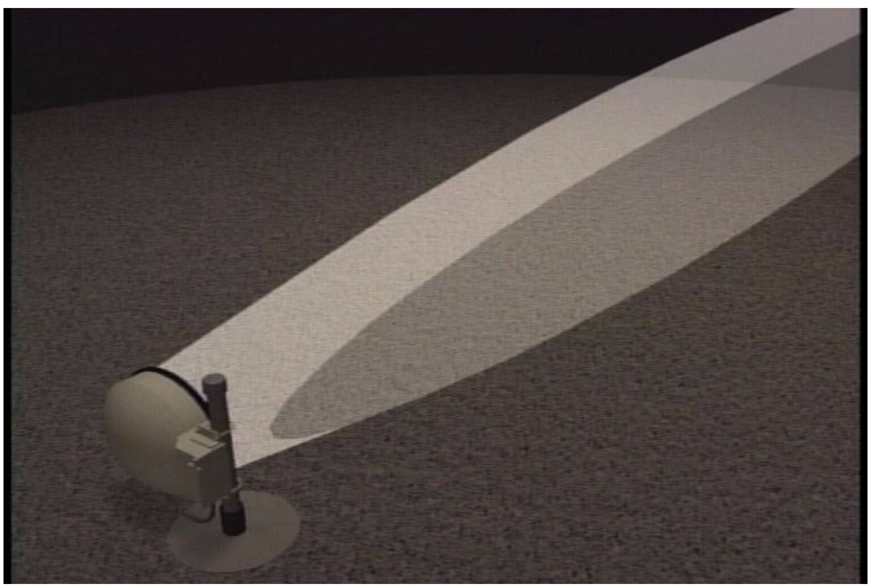




Figure LSS+4059 A monostatic system radiates a coverage pattern much like a flashlight beam. The dark gray area
shows diminshed coverage. Courtesy of DOE Office of Security and Safety Performance Assurance.

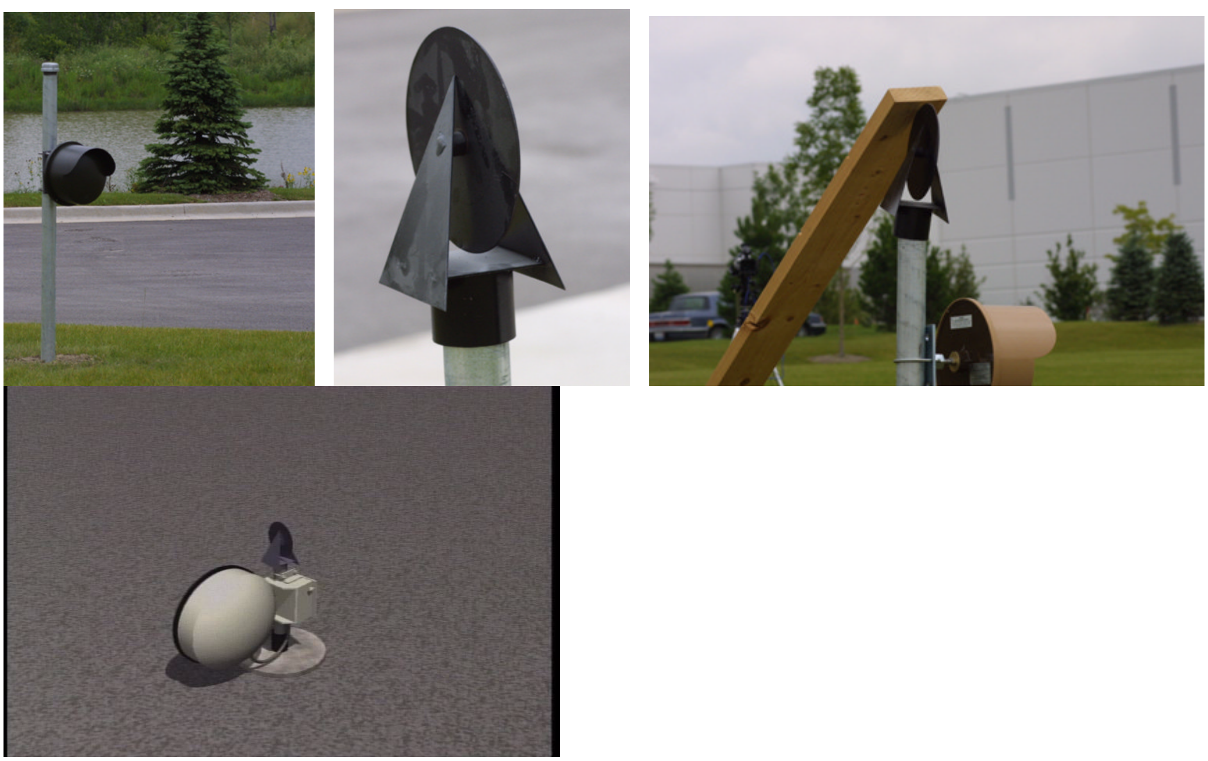


Figure LSS+4049 A microwave system must be protected against a bypass technique of climbing over the sensor.

A pizza cutter is one method to prevent this practice. The mounting pole should be cut just above the sensor.

In this configuration, the transmitter and receiver elements are packaged within a single dual function unit. The antenna is mounted within the microwave cavity, and its radiation pattern can be shaped to cover a specific area or detection zone. The actual shape of the beam can be changed to transmit a long, slender beam or a short oval one.

Monostatic systems operate at two distinct frequencies which are rapidly alternated. As each transmitted frequency is turned on or off, the receiver is shut down for a short interval after each transmission. Microwaves propagate at a constant speed; thus the receiver can be specifically programmed to receive those reflected signals that are sent and received from the receiver cut off (RCO) area within a specific time period. This system design allows the user to protect a well defined area and create a "zone of coverage."

40_3.5.1.B Bistatic Units



Figure LSS+4050 Bistatic microwave system

This configuration requires that the transmitter and receiver be separate units, physically located at opposite sides of the protected zone. The antenna can be configured to alter the signal field (width, height), thereby creating different detection zones. A bistatic system can cover a larger area and would typically be used if more than one sensor is required.

40_3.5.1.C Placement of Sensors

Microwave sensors can be used for monitoring exterior areas as well as interior confined spaces such as vaults, special storage areas, hallways and service passageways.

40_3.5.C.1 Exterior Sensors

Exterior sensors are utilized to protect an area or a definitive perimeter line, as well as to serve as an early warning alert of intruders approaching a door or wall. Where a well-defined area of coverage is required, monostatic sensors should be used, keeping in mind a coverage limitation of 400 feet. Bistatic sensors can extend their range up to 1,500 feet. Supplementary coverage is recommended for these systems.

Microwave sensors can suffer from false alarms as a result of several factors.

- **Close proximity to other high frequency signals can adversely affect the detection reliability of these sensors because of their operation in the x-band;**

- **Those areas that contain strong emitters of electric fields (radio transmitters) or magnetic fields (large electric motors or generators) can effect the ability of microwave sensors to function properly and should be avoided or compensated for by distinct signal separation;**

- **It is easy to determine the presence of these sensors with commonly available radar detectors;**

- **Bistatic systems are somewhat limited by poorly defined detection patterns. Nuisance alarms may be a problem if large metal objects are nearby or if windy conditions exist;**

- **Zones that contain fluorescent lights can cause unreliable operation, because the ionization cycle created by fluorescent bulbs can be interpreted as motion;**

- **Self generated signal reflection is a common problem. This is caused by improper placement or mounting by positioning the**

sensor externally and parallel to a wall. The solution is to embed the device within the wall;

- **Large metal objects can reflect signals and provide "dead pockets". Such objects should be kept out of the detection zone;**

- **Microwave transmission will penetrate and pass through walls, glass, sheet rock and wood. Thus, equipment whose operation involves external movement or rotating functions outside or adjacent to a protected zone can cause a false alarm;**

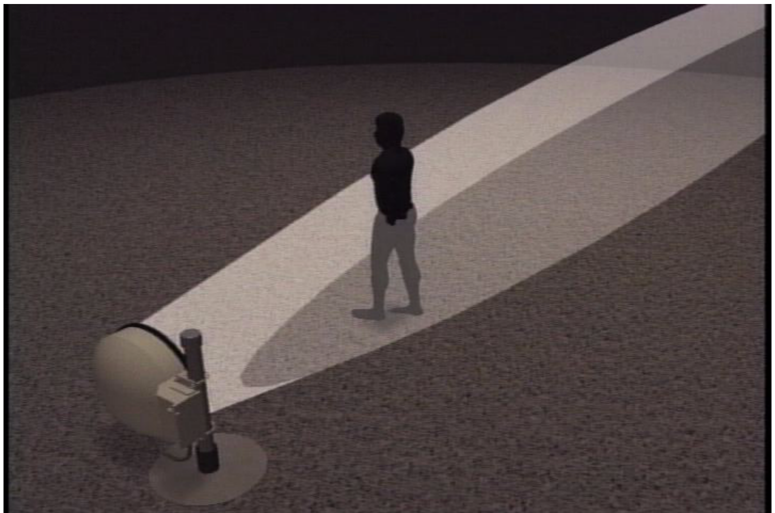
- **Detectors are not affected by moving air and changes in temperature or humidity, due to the high operating frequency;**

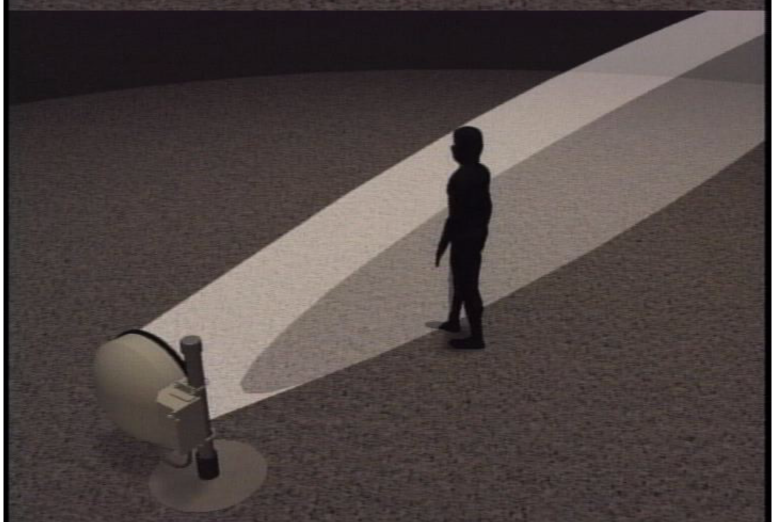
- **It is essential to test for, note, and compensate for any dead spots (areas of no detection) created by metal objects such as dumpsters, shipping crates, trash cans, and electrical boxes;**

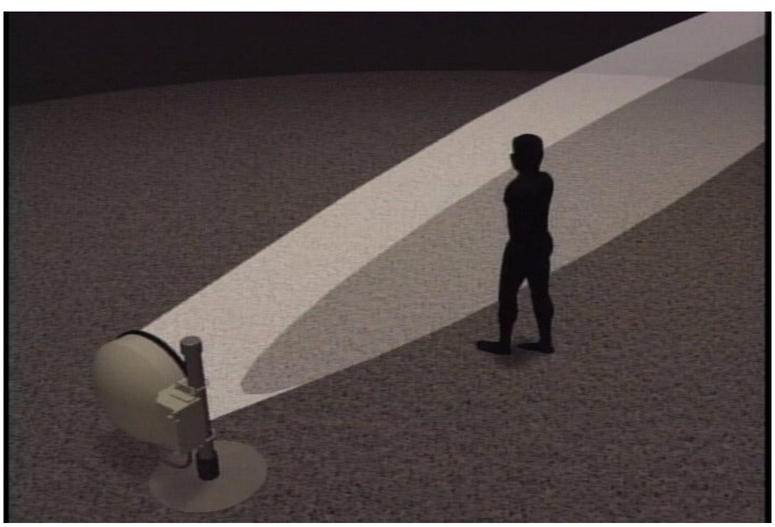
- **Dead spots and reflected zones can be created by metal objects such as dumpsters, shipping crates, trash cans, and electrical boxes. A careful analysis of such all zones must be made for the presence of non-protected areas. These locations must be noted and compensated for, because they are perfect areas for intrusions. Reflected zones can extend sensor coverage to unintended areas, thus increasing the potential for false alarms;**

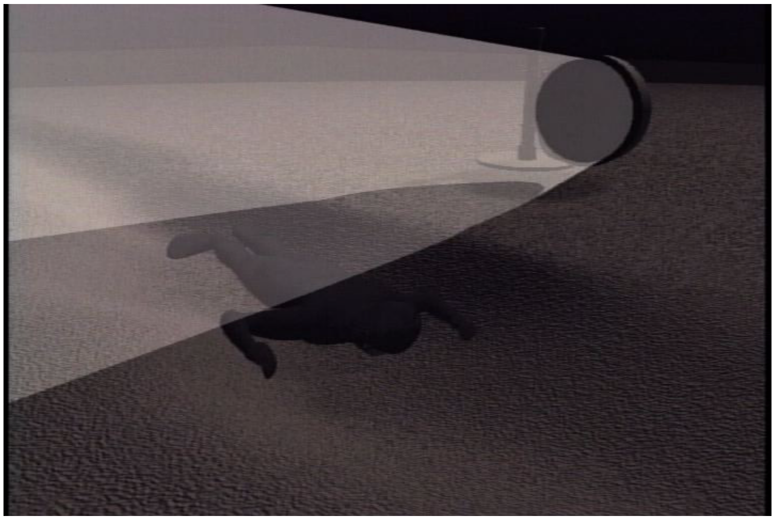
Microwave systems can be cased by a knowledgeable individual, and walk-through tests can determine the zones of coverage and conversant dead spots that might allow a bypass of the system. The detectors can also be fooled by extremely slow movement within the radiation pattern. The ability to circumvent these systems is enhanced if there are obstructions, as well as energy absorbing clothing. The placement of sensors must be carefully chosen so as not to allow tampering, disabling, or masking. In many burglary investigations conducted by the author, it was noted that sensors had been covered so as not to protect defined zones.

40_3.5.1.0 Defeat of Monostatic and Bistatic Microwave Sensors









Monostatic and bistatic microwave sensors can be defeated through a variety of techniques. These include:

Monostatic Microwave

- Avoidance of detection zone;
- Careful, slow, and deliberate lateral movement;
- Masking of the target through the use of RADAR absorbing material The technique is utilized to mask and create an intrusion path;
- Alarm stacking;
- Avoidance by exploiting poor sensor coverage;

Bi-Static Microwave

- Tunneling under detection beam pattern;
- Use of a pole or two-man vaulting over detection beam pattern;
- Bridging;
- Stilt walking;
- Slow parallel crawl;
- Slow walk around improper offsets;
- Avoidance;
- Use of noise or RADAR absorption material to create path through detection beam pattern at a very slow movement pace;
- Avoidance by exploiting poor installation coverage, washouts, depressions and snowfall;
- Alarm Stacking.

40_3.5.1.0.1 Defeat of Microwave Sensors: General Issues

Microwave sensors can be defeated through many basic techniques, including:

- **Blocking: physically blocking the microwave energy pattern with a containing material;**
- **Very slow and deliberate speed of movement by the intruder, thus avoiding a significant Doppler shift. Remember that microwave is more sensitive to motion that is toward and away from the sensor;**
- **Avoidance;**
- **Use energy absorbing materials;**
- **Use crosswalk motion;**
- **Take advantage of energy blocking, using man made or natural barriers to create a path past the sensor detection pattern;**
- **Bypass the sensor circuit while the system is disarmed**

40_3.5.1.1 Microwave/Infrared Motion Detector

LSS402: Alarm defeat methods for dual technology devices

LSS403: Dual technology devices utilized in outside environments

A Doppler microwave detector is combined (ANDed) with infrared as a dual-mode or dual-tech sensor. The coincidence of alarms from microwave and infrared provides an extremely reliable (lower FAR) indication of intrusion than is obtainable with either sensor alone.

The Dual-Technology sensor utilizes a passive sensor (infrared PIR) and an active sensor (Microwave) that are packaged within one unit. The two detectors are combined in an AND circuit: they both must trigger before there is a valid alarm condition. The areas of coverage for each of the sensors is optimized for overlap.

Dual-tech systems can be deployed along a perimeter line, a fence or a delineated buffer zone, or as a defense against intruders approaching a door or wall. These systems offer both an advantage and limitation in their operation. Although the false alarm rate

is decreased, so also is the probability of detection. This is because two sensors must sense the same condition at the same time. The mathematical probability of detection for the dual-tech unit is the product of the probability of detection for both individual units. For example, if there is a theoretical individual detection rate of 99 percent and 98 percent, the detection percentage for the Dual-Technology (AND logic configuration) drops to 97.02 percent.

There is an inherent problem with dual-technology sensors: passive and active sensors have differing probabilities of detection based upon the movement of an intruder. Remember, the AND gate logic requires coincident signals from both detectors simultaneously to generate a valid alarm. Passive sensors are most effective when an intruder is moving transversely; active detectors work best when the intruder's movement is radial. Thus, the position of the sensor will require a compromise that can diminish detection capability.

So also, any environmental conditions that affect the performance of either sensor will reduce the effectiveness of the system. Notwithstanding these issues, the dual-tech sensors are cost effective and offer greater protection than individual sensors if deployed in a controlled environment.

False and nuisance alarms for the dual technology sensor are infrequent. However, a combination of environmental conditions (e.g. fluorescent lights, heater exhaust) can cause falsing.

Dual-tech sensors can be defeated in certain conditions:

- **Dead spots in the detection pattern (and an intruders knowledge thereof) will permit bypass of all active regions;**

- **Extreme slow movement can be very difficult for microwave sensors to detect;**

- **Blocking or masking of the infrared sensor's field of view can decrease its sensitivity and reduce the probability of sufficient "heat" being detected by, or focused upon the PIR portion of the sensor. Silicone spray or Vaseline can be used to defeat the sensor unless anti-masking software is operational;**

- **Walking into the PIR sensor, rather than across its field of view can reduce the detection capability of the sensor by not**

"breaking" the boundaries of the PIR detection beams.



This photograph shows a dual-technology microwave/passive infrared sensor that was defeated in a major diamond theft in Antwerp, Belgium. Silicone was used to mask the device and prevent its proper operation.

40_3.5.1.2 RADAR

Radar (RAdio Detection And Ranging) is an active sensor that was introduced in the early 1940s. Since its first deployment as a mode of detection, the technology has been vastly enhanced and improved. These sensors operate in the ultra high frequency region of 100 MHz. to 1 GHz. Transmitted signals are bounced off of objects within zones of protection. A processor will evaluate the signal to determine relative size, azimuth and distance. RADAR and microwave systems are quite similar in concept and design, although their operating parameters are quite different. These systems are quite useful, for example, for the detection of planes or helicopter-borne intrusions that would bypass ground-oriented sensors and microwave systems.

As with the previously described microwave systems, there are two basic types of radar sensors: monostatic and bistatic. However, their operation is different than traditional microwave.

With monostatic sensors, detection of intrusion is achieved by the radar transceiver rotating in a preset "sweep" pattern. During rotation, the transceiver emits high frequency energy pulses, forming and scanning a detection zone. When a moving, foreign, or new object is detected, a Doppler shift in the reflected energy is created. When the magnitude of the reflected energy surpasses the preset criteria stored within the processor, an alarm is generated.

The transmitter in a bistatic configuration is typically creating a designated "sweep" pattern, with receivers at several locations that are designed to maximize the potential for detection. The transmitter generates a field of high frequency energy, which "bounces or reflects" off of "foreign" objects and is sensed by one or more receivers.

Radar sensors are best utilized to monitor exterior areas, although in some situations radar sensors can be used to monitor large interior open areas. Optimum performance requires that the ground be reasonably level and the perimeter boundaries straight. If portions of the perimeter are hilly or have crooked boundaries, the radar unit may be elevated to provide a better line of sight view. Radar sensors can also be used to monitor the straight and level sections of the perimeter, while other types of detectors (e.g. in-ground sensors or video motion detection) can evaluate the remaining sections.

Safe havens for intruders can be provided by "Dead zones" that are created by large objects, buildings or hill masses or depressions. Extreme weather conditions such as rain or snow storms can decrease detection potential of radar. False or nuisance alarms can be caused by the detection of foreign objects not within defined zones resulting from the undesired reflection of RF energy.

Uneven terrain can create "hidden pockets." So also, a slow and low approach by an intruder may defeat sensors.

40_3.5.2 Ultrasonic Systems

LSS402: Ultrasonic alarm sensors

Ultrasonic sensors operate above a frequency of 19 KHz and function similarly to microwave in many respects. They are based upon the Doppler theory and sense minute changes in forward and reflected waves caused by absorption characteristics of the intruder. Whereas microwave systems utilize super high frequency (SHF) radio waves, the ultrasonic device will transmit sound waves above the normal hearing range.

40_3.5.2.1 Passive Ultrasonic

The passive Ultrasonic sensor "listens" for ultrasonic sound energy that has a frequency range between 20-30 KHz in a

protected area. The frequencies in this range are generally associated with intrusion attempts representative of metal striking metal, hissing of an acetylene torch, and shattering of concrete or brick. The sounds thus generated are transmitted through the surrounding air and travel in a wave-type motion. The detector evaluates the patterns against stored characteristics.

Ultrasonic sensors are typically mounted on a wall or ceiling and are frequently used in tandem with another sensor, such as a passive device (Passive Infrared-PIR) to provide a greater probability of detection (PD). Environmental issues can increase FAR, depending upon the variability and uncontrollability of the characteristics of the zone. These devices are unaffected by heat changes within a protected area. Unlike microwave and radar, ultrasonic energy can be easily contained within a defined area because it does not pass through obstructions such as walls, roofs, or partitions. Unfortunately, waves do not pass through furniture or other obstructions such as boxes and crates and can thereby create dead zones which must be protected by other sensors.

False alarms and unreliable detection can result from a number of conditions:

- **Extreme changes in temperature or humidity from those conditions that existed at the time of installation and calibration;**
- **Any noise within the ultrasonic range;**
- **Air movement from heating and air conditioning systems;**
- **Drafts from doors and windows;**
- **Hissing from pipes;**
- **Dead zones which are created from objects and material that block transmission from sensors;**
- **Anything that causes movement, such as animals;**
- **The ringing of a telephone.**

Passive ultrasonic sensors have a limited frequency spectrum; sounds caused by an intrusion that fall outside the unit's spectrum (such as drilling), may not generate an alarm.

PASSIVE ULTRASONIC MOTION SENSOR

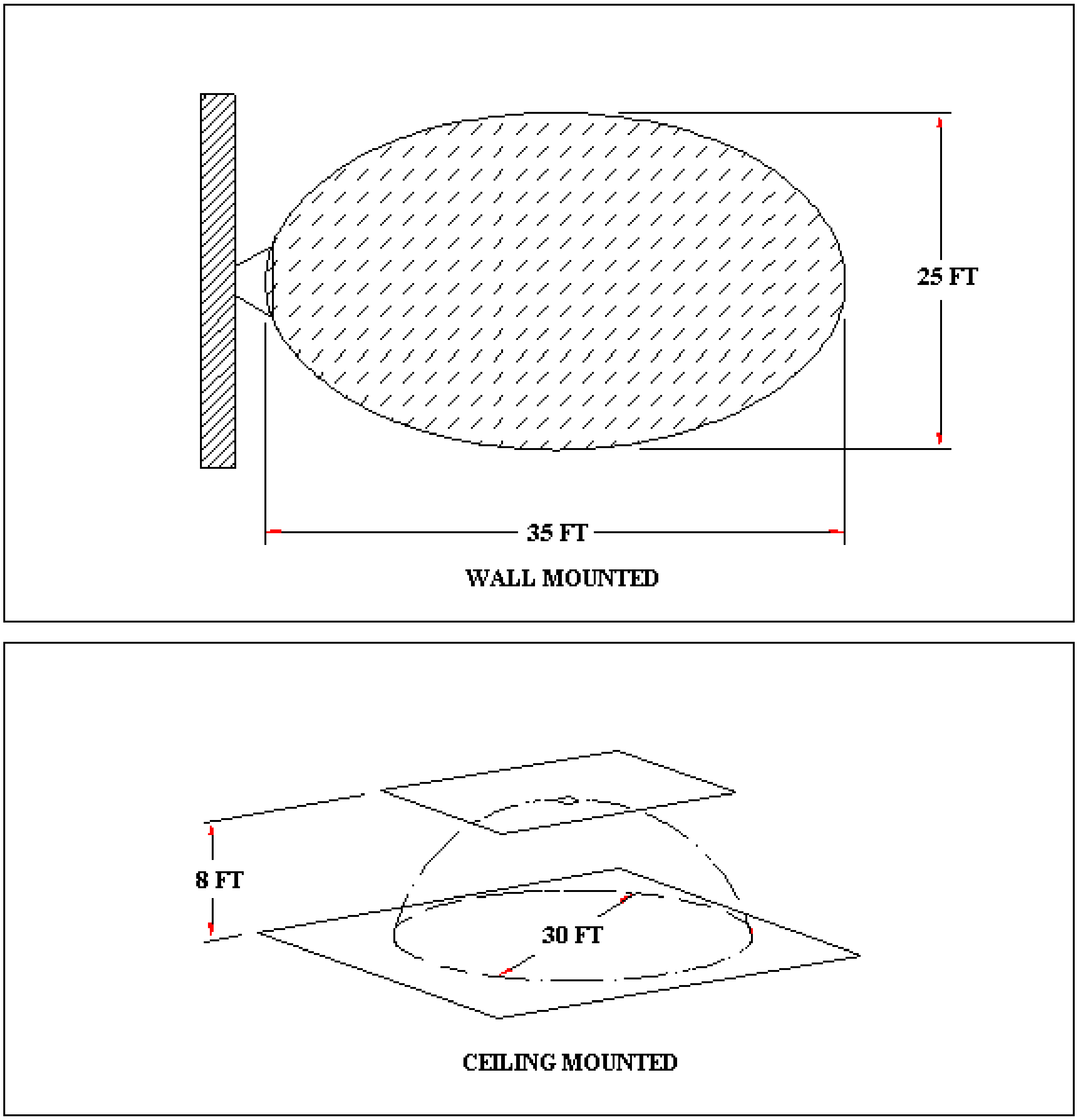


Figure LSS+4011 Passive ultrasonic motion sensor

40_3.5.2.2 Active Ultrasonic

The active ultrasonic sensor emits sound energy into a defined area and reacts to a change in the reflected energy pattern. These sensors operate on a theory based upon a frequency shift in reflected energy. Ultrasonic sound is transmitted from the device

in the form of energy through the air in a wave-type motion. Waves are reflected back to the receiver and provides a sound signature of the protected area. Any disturbance will cause the reflection to occur faster, thus changing the frequency slightly. Both passive and active ultrasonic sensors are installed in virtually the same manner.

Unreliable detection can result from many causes. See the listing of conditions in the above section.

Active ultrasonic systems can often be defeated by slow horizontal movement across the area of coverage. Proper calibration is critical to minimize this potential. A knowledgeable and properly equipped intruder can use special "test lights" to detect coverage patterns and circumvent these areas.

ACTIVE ULTRASONIC MOTION SENSOR

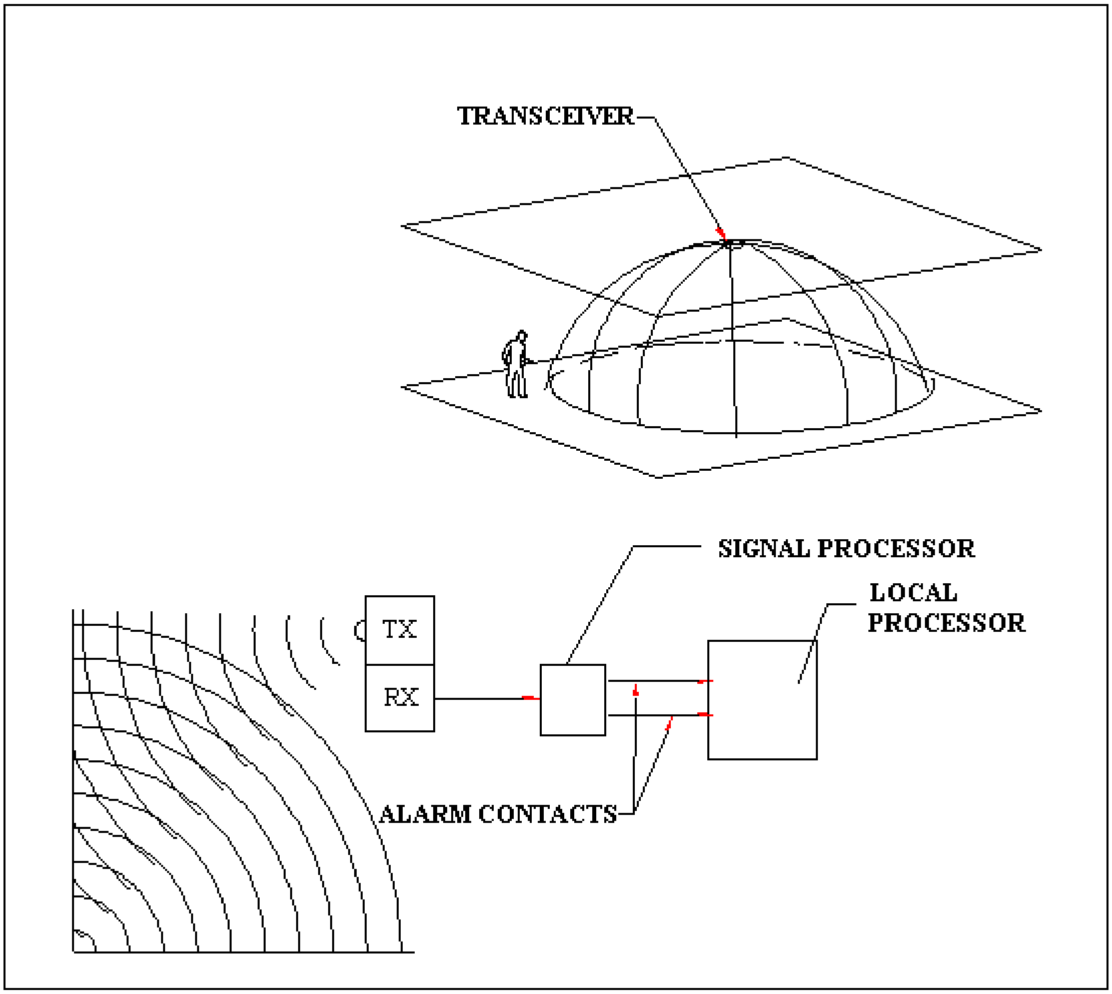


Figure LSS+4012 Active ultrasonic motion sensor

40_3.5.2.3 Audio Sensors

Certain sensors are designed to listen to the audible range for noises that are created by intrusion into protected areas. These detectors are generally utilized within structures rather than being subjected to the outside environment. The system is usually comprised of microphones (transducers) that are mounted on walls or ceilings, and a processor that analyzes noise signatures that are consistent with the protected zones and possible intrusion attempts.

It is essential in the design of these systems that sensors be

located in areas where the predicted intrusion noise will exceed the normal environmental noise floor. Failure to properly calibrate the detectors will result in noise masking, making it impossible to differentiate ambient from intrusion generated sounds. These sensors are generally utilized in conjunction with other systems, such as motion detection or photoelectric, to insure a high probability of detection. Sometimes, audio detection is combined with thermal imaging motion detection. This can provide for a record of both audio and visual tracking of a break-in. Audio sensors are particularly well suited to this application because they are not sensitive to the thermal environment and florescent lighting. If excessive background noise is present, the audio sensor should not be considered.

Erratic or unreliable detection can result from:

- **Improper setup and calibration that affects sensitivity settings either positively or negatively, causing the detector to react to extraneous background noise, such as clocks, office equipment, boilers and heating or air conditioning units;**
- **Excessive background noise, such as airplanes, trains or loud weather conditions (thunderstorms) may cause significant noise levels);**

Slow, deliberate actions by an intruder can defeat these sensors. Likewise, muffling the normal sounds of movement while intentionally allowing sufficient lag time to occur between any noise generated can bypass the detectors.

40_3.5.2.4 Acoustic Detection (Air Turbulence Sensors)

Acoustic air turbulence sensors detect low frequencies (within a range of 20 - 40 Hz, depending on the model) created by helicopters that are in their final landing phase or at close range (one to two miles), and are utilized for intrusion attempts. Some of the quietest helicopters, such as the Hughes 500C, Bell 47, Bell 206, and the Jet Ranger, have been detected at distances up to 500 feet. For increased probability and reliability of detection, detector sensitivity is typically set for a range of 300 feet.

Typically, such detectors are employed because traditional systems, such as perimeter and in-ground technology would be bypassed. These devices "listen" for basic sound pressure

generated by helicopter rotor blades and engine. There are four specific signatures that are sought:

- **Downward wash, caused by the energy that is required by the rotor blades to maintain airborne status;**
- **Blade slap, which originates from the forward traveling blade as it penetrates the trailing tip vertex remaining from the previous blade passage;**
- **Tail rotor, which is directly geared to the main rotor that generates harmonically-related frequencies;**
- **Engine noise, which is not usually muffled because of the power needed for rapid changes in flight performance.**

In order to assure reliable detection of inbound aircraft, regardless of their approach once they enter the protected zone, such areas should be covered by overlapping sensors. With proper design, there is no restriction on the distance of sensors from the main control unit; thus, zones of protection can extend for miles.

Unreliable detection and false alarms can result from the following causes:

- **Location of sensors near to any vehicular or road traffic, especially truck movement;**
- **Location of sensors near railroad right of ways;**
- **Location of sensors near anything that generates pressure or wind turbulence. Sensors are particularly sensitive to broadband noise;**
- **Turbulence generated at a distance and conveyed by air pressure propagation;**
- **Pressure caused by wind viscosity and the roughness of the terrain;**
- **Sensitivity settings set too low to compensate for vehicular traffic;**
- **Improper spacing of the sensors, allowing some areas not to be covered by the detection pattern.**

These systems will not detect airborne assaults that utilize other flying technology, such as glider, parachute, or ultra light.

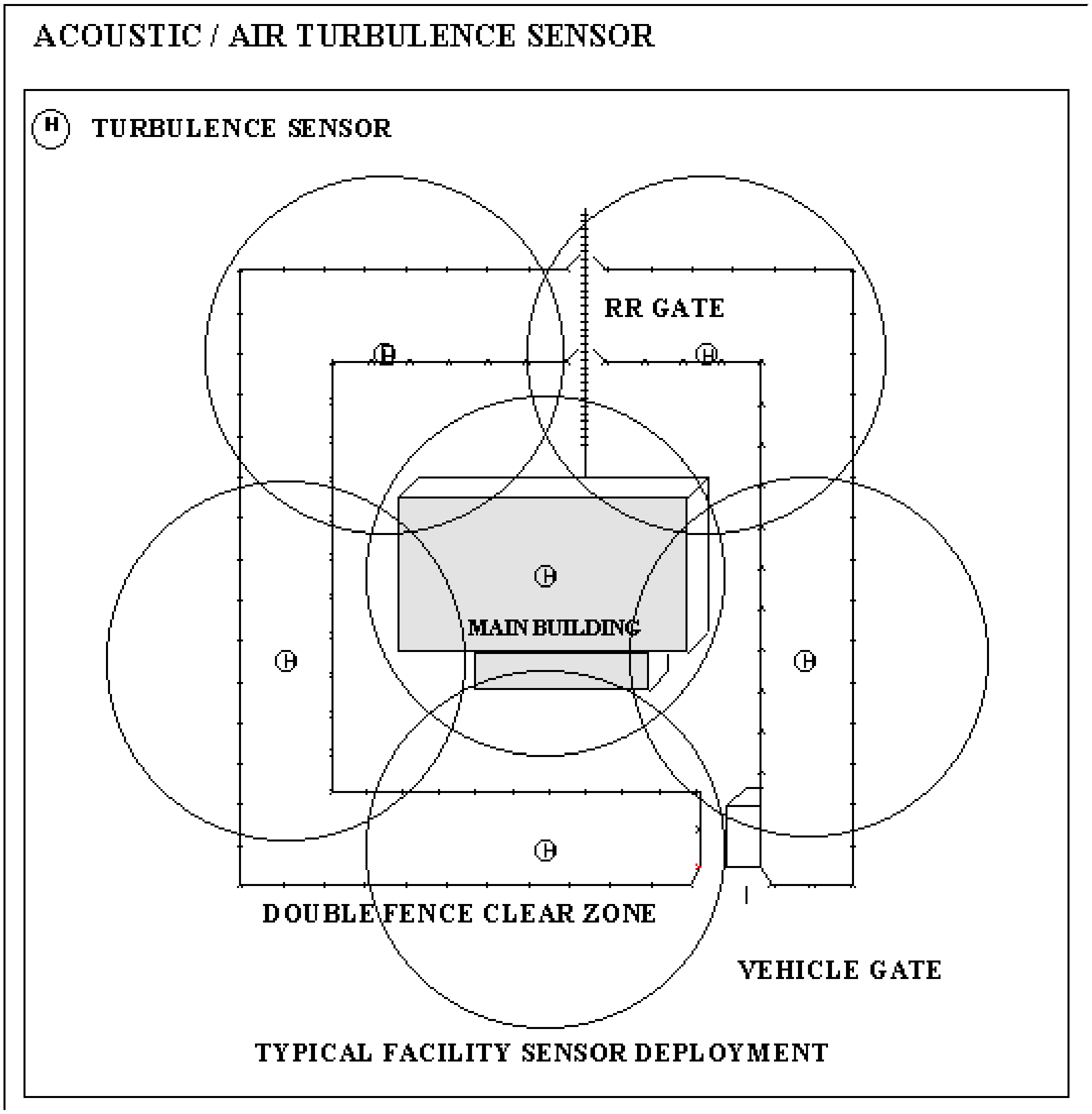


Figure LSS+4034 Acoustic/air turbulence sensor

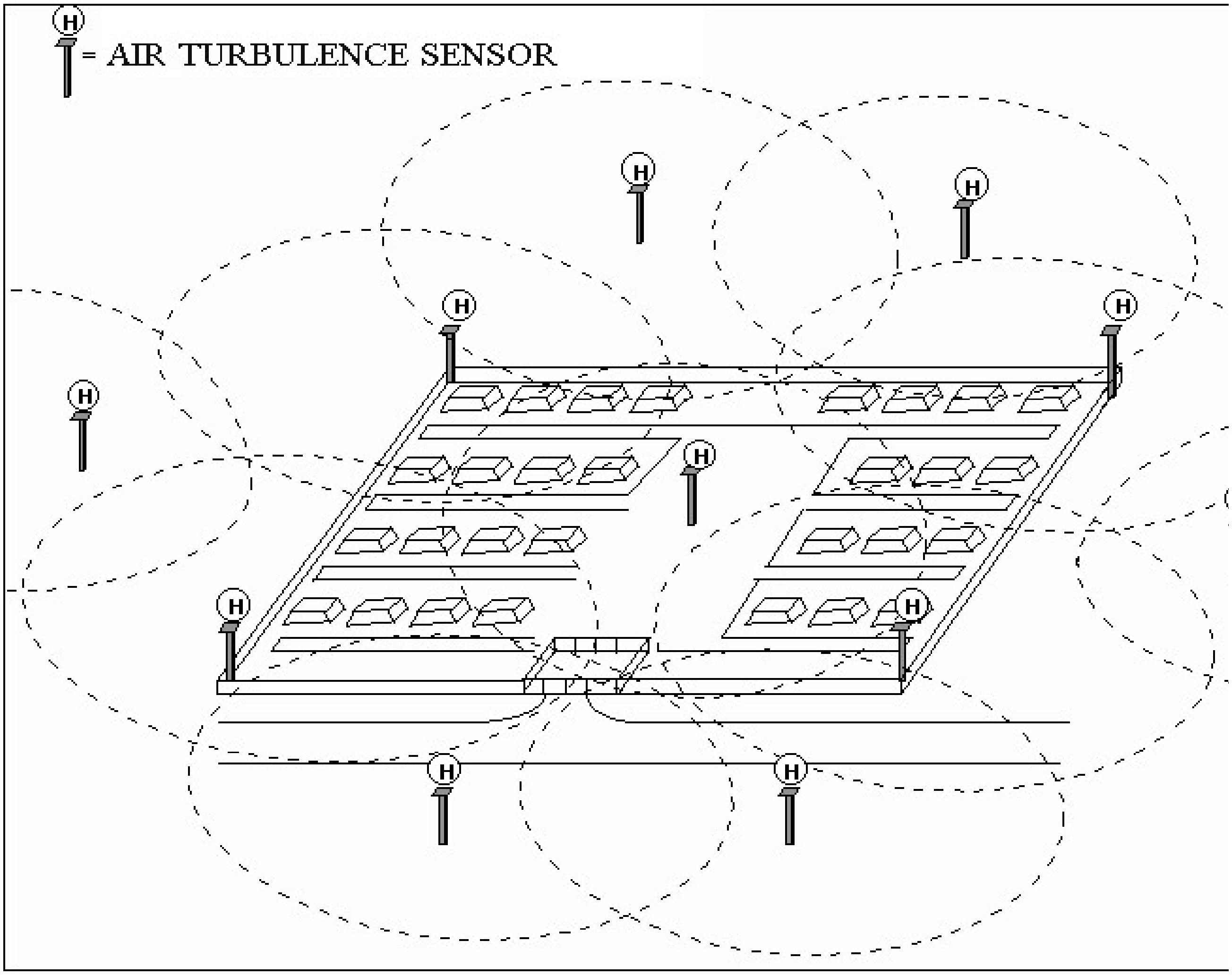


Figure LSS+4035 Logistic/munitions storage complex

40_3.5.2.5 Defeat Techniques for Infrasonic and Ultrasonic Sensors

Sensors that utilize sound, either below or above the normal range of hearing, are subject to defeat by employing a variety of techniques. These are summarized for all forms of sound energy sensors. It should be noted that these systems, which operate between 20-45 KHz. may bother pets, due to their increased sensitivity to sounds above the normal range of human hearing. This may provide an indication that ultrasonic energy is present.

Infrasonic

- Entry through opening that does not create infrasonic waves, such as a sliding door or window;
- Concealment within protected area;
- Masking detector;

Active Ultrasonic This type of sensor is more sensitive to motion toward and away from sensor.

- Very slow intrusion speed and movement, thereby avoiding a significant Doppler shift;
- Use of ultrasonic energy-absorbing blanket or material, including aerosol Styrofoam filler;
- Blocking the transceiver or using an object to block the transmitter;
- Spoofing the sensor into believing it is secure. Use Freon gas, water or similar substances;
- Create a loud noise to create a false alarm;
- Use of a high power transmitter at the same frequency;
- Use crosswalk motion;
- Take advantage of man made or natural barriers that create a path past the sensor detection pattern;
- Bypass the sensor circuit while the system is disarmed;

Passive Ultrasonic

- These sensors have a limited frequency spectrum of sensitivity. Exploit the fact that certain intrusion sounds outside of the sensitivity of the sensor (such as drilling) will not activate it;
- Alarm stacking;
- Bypass the sensor circuit while the system is disarmed;

Active Sonic

- Use of very slow movement by intruder;
- Use of energy-absorption blanket or other material;
- Block the transceiver by using tape or other material;
- Take advantage of natural barriers in the protected area to avoid detection;

Spoofing;

- Alarm stacking;

- Bypass the sensor circuit while the system is disarmed.

40_3.5.3 Operational Difficulties with Volumetric Systems

Volumetric sensors are prone to technical operating problems and failures if they are not installed correctly. The following guidelines apply to their use:

- **RF fields in microwave systems may penetrate through walls into adjacent facilities, registering movement in areas not intended to be monitored. This can cause a false alarm;**
- **Propagation patterns for microwave systems may not completely cover a desired space. This can be due to irregular shapes of rooms to be protected or a shielding effect of items within the coverage area;**
- **Frequent false alarms may result if precise testing is not periodically done for a specific area, in order to take into account physical differences;**
- **Ultrasonic systems will not penetrate adjacent walls, ceilings or floors;**
- **Ultrasonic sensors will detect heat and can be triggered by hot air turbulence;**
- **Ultrasonic detectors may register a false alarm from heating and air- conditioning equipment, sonic booms, thunder, jet aircraft, and other shocks;**
- **Ultrasonic systems, unlike microwave, cannot be set to protect a close pattern or area;**
- **Microwave is more stable than ultrasonic.**

40_3.6 Heat Detection: Passive Infrared Sensors

LSS401: Outside passive infrared sensors

LSS401: Thermal imaging and sensing

LSS402: Passive infrared sensor technology





Figure LSS+4051 A thermal imaging sensor will detect body heat of an intruder.

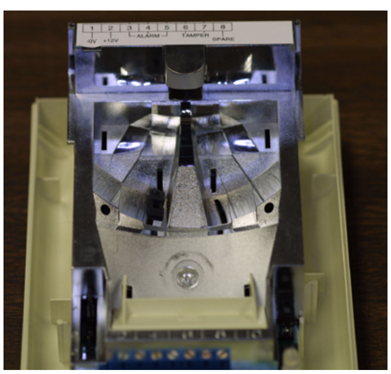
The wavelength of infrared radiation lies between .7 - 100 µm in the electromagnetic spectrum, and is slightly higher than radio waves. It is not visible to the human eye but is perceived by the heat receptors of the skin. Energy in the form of rays is transmitted or reflected by all objects, even a block of ice. The amount of radiation and its frequency are dependent upon and directly proportional to structure and temperature of the surface. Thus the sun, having a surface temperature of 6000 C, radiates IR in the visible spectrum at a wavelength of .3-.8 µm. In comparison, the human body gives off energy at a frequency of 7-14 µm. In order to avoid capturing environmental thermal deviations, rate of change measurement circuitry or

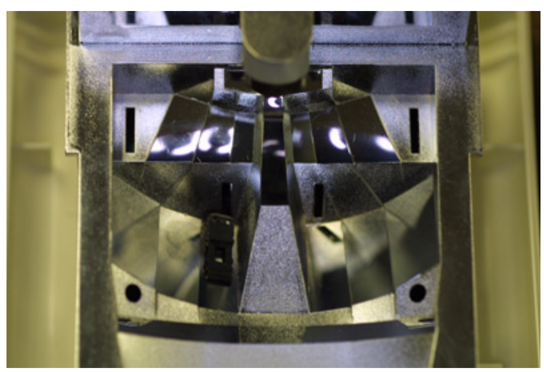
bi-directional pulse counting circuitry is employed.

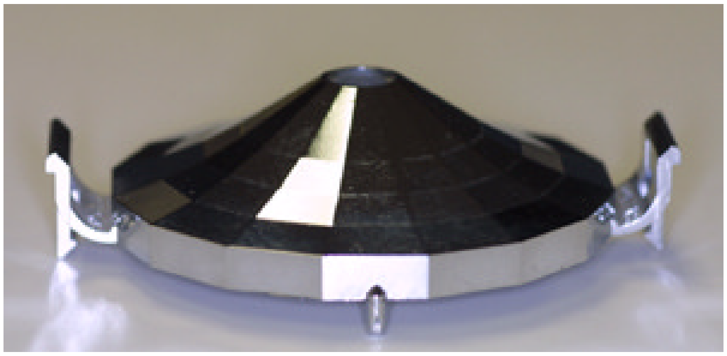
The PIR wavelength is subdivided into two major range detection categories: one covers **near infrared energy** (e.g. thermal energy emitted by TV remote control devices), and the other covers the **far infrared energy** (e.g. thermal energy emitted by people). It is this latter category which is employed in security applications.

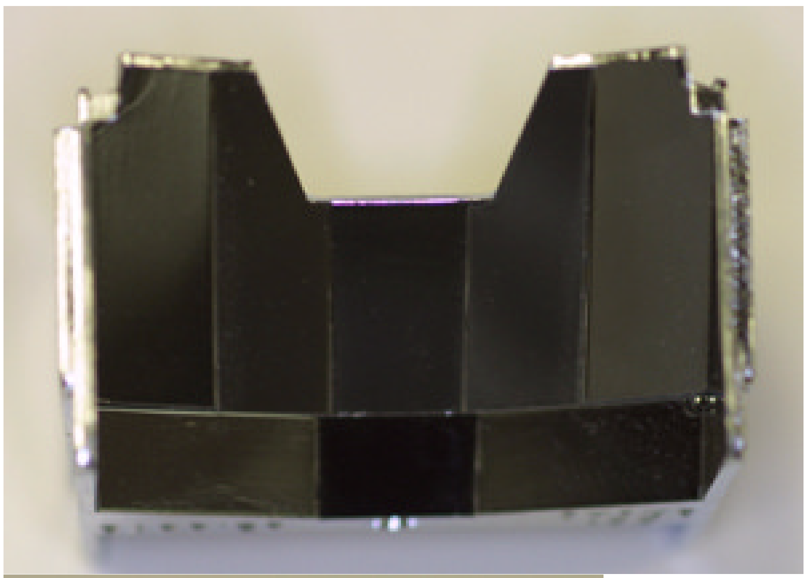
The infrared sensor will detect a narrow frequency band of radiated energy in the target area. It is referred to as a passive device because it receives its information from the area being monitored, but does not transmit any energy. Power consumption is low, in contrast to active devices such as microwave that require emission of RF.

Passive IR devices are constructed with a multi-segment concave mirror and infrared measuring sensor at its focal point. The shape, size, and number of such segments will vary, depending upon the design of the detector and the coverage pattern. Some areas of the mirror will be sensitive to IR; others will not. The sensor head is typically divided into several sectors or zones, each correlated and defined for specific boundaries. Detection occurs when thermal energy is emitted from a heat source and this energy crosses two adjacent sector boundaries or crosses the same boundary twice within a specified time.









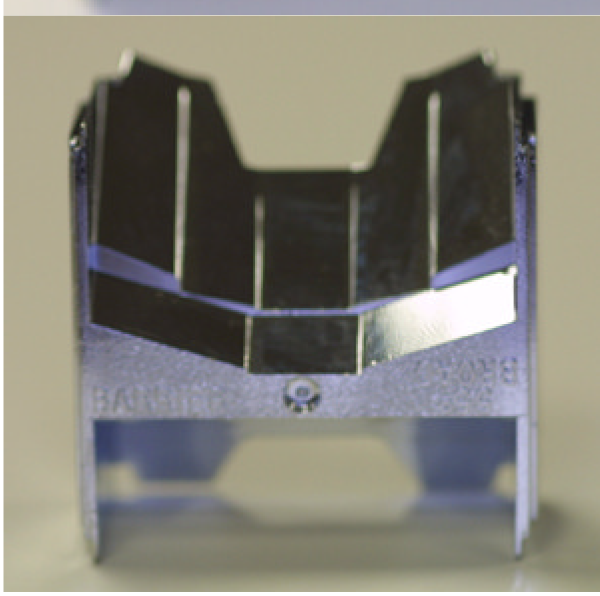
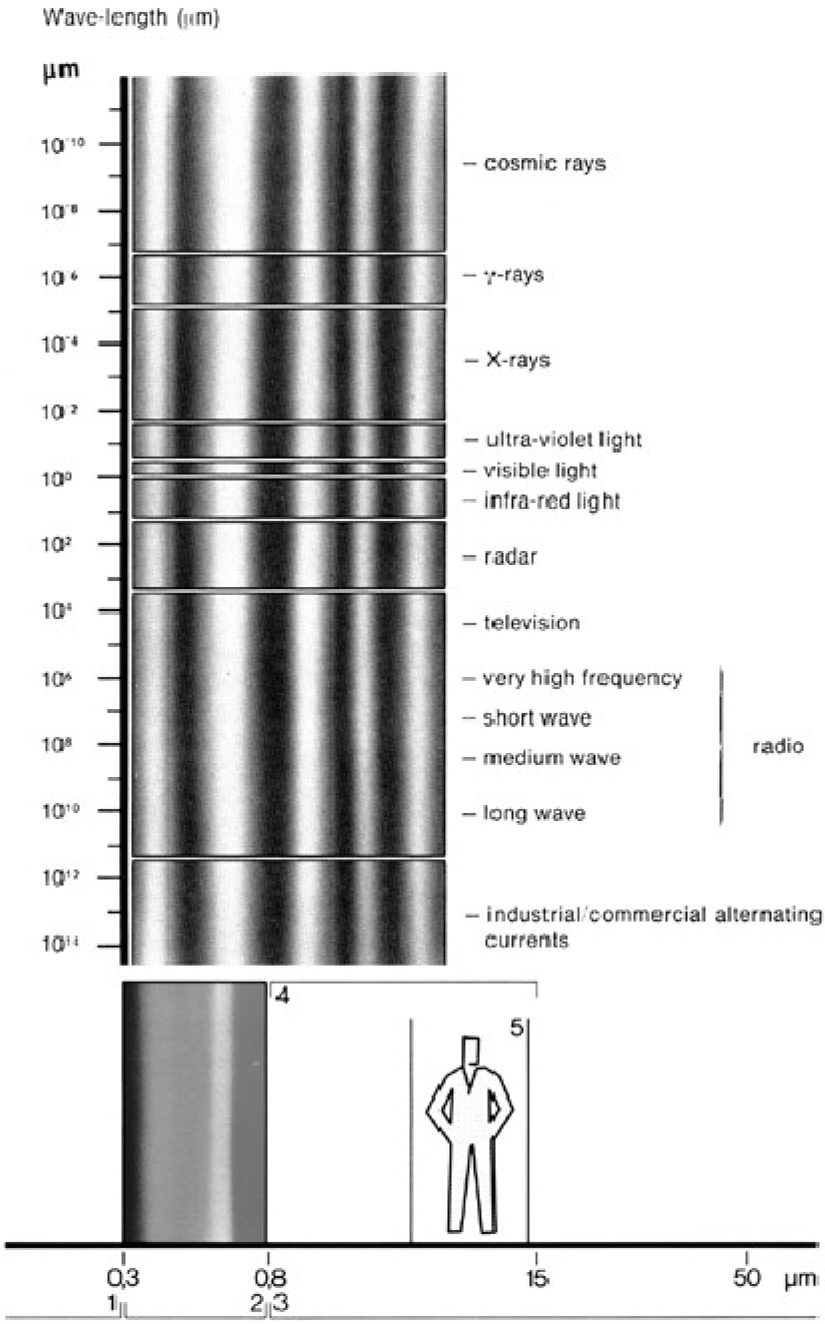


Figure LSS+4052 A variety of lens configurations are utilized for infrared sensors to

focus energy on the sensor and create zones of protection.

The processor will compare the intensity of signals between a moving object and its background, taking into account distance. A threshold value will be set to minimize false alarms. There must be a sudden, rapid, and substantial increase in energy before a valid alarm is triggered. Temperature variations caused by heating, air-conditioning or blowing wind will not be recorded because they do not occur rapidly enough. Passive IR devices operate within a temperature range of –10 C to +50 C.



These sensors detect (but do not measure) electromagnetic radiated energy generated by sources that produce temperatures below that of visible light. They are sensitive to the change of thermal radiation. PIRs "see" or "detect" infrared "hot" images by sensing the contrast between the "hot" image and the "cooler" background.

In rate of change measurement, the processor evaluates the speed at which the energy in this field of view changes. Movement by an intruder in the field produces a very fast rate of change, while gradual temperature fluctuations produce a slow rate of change. In the bi-directional pulse counting technique, signals from separate thermal sensors produce opposite polarity. An unprotected or unshielded human that enters a field of view and moving at a typical speed (walk or above) will normally emit or produce several signals which allow detection to occur.

Optics and reflective principles play a very important role in the design and function of PIRs. Because of the need to precisely focus thermal radiation, the reflection and focusing of the energy waves is done in two ways: r**eflective focusing** and the **fresnel lens** method.

Reflective focusing: The energy waves are reflected off a concave mirror and directed into the sensing element. **Fresnel lens:** This technique allows the energy to travel directly to the sensor. Both methods use some type of protective covering on the sensor, so that the loss of some energy is unavoidable. The performance of both sensors is excellent.

Passive infrared sensors are usually installed on walls or ceilings, aimed at and defining the desired protection zone. Each detection/surveillance zone can be thought of as a "searchlight" with the beam width gradually widening as the zone extends farther from the sensor. Different segments will be illuminated while others are "dark". This design characteristic allows the user to focus the "beam" on areas where protection is needed while ignoring other areas, such as known sources of false alarms. Tower or ceiling-mounted PIRs theoretically provide a 360 degree detection pattern.

A PIR looks for thermal radiation projected and in contrast with a cooler background; its sensitivity is based upon the detection and comparison of temperatures. As the environment approaches the same temperature as the intruder, the detector become less sensitive. This is especially true for environments ranging between 80-100 degrees. Theoretically, if a person was radiating the same temperature as the environment, he would be invisible to the sensor.

There are several reasons for false alarms:

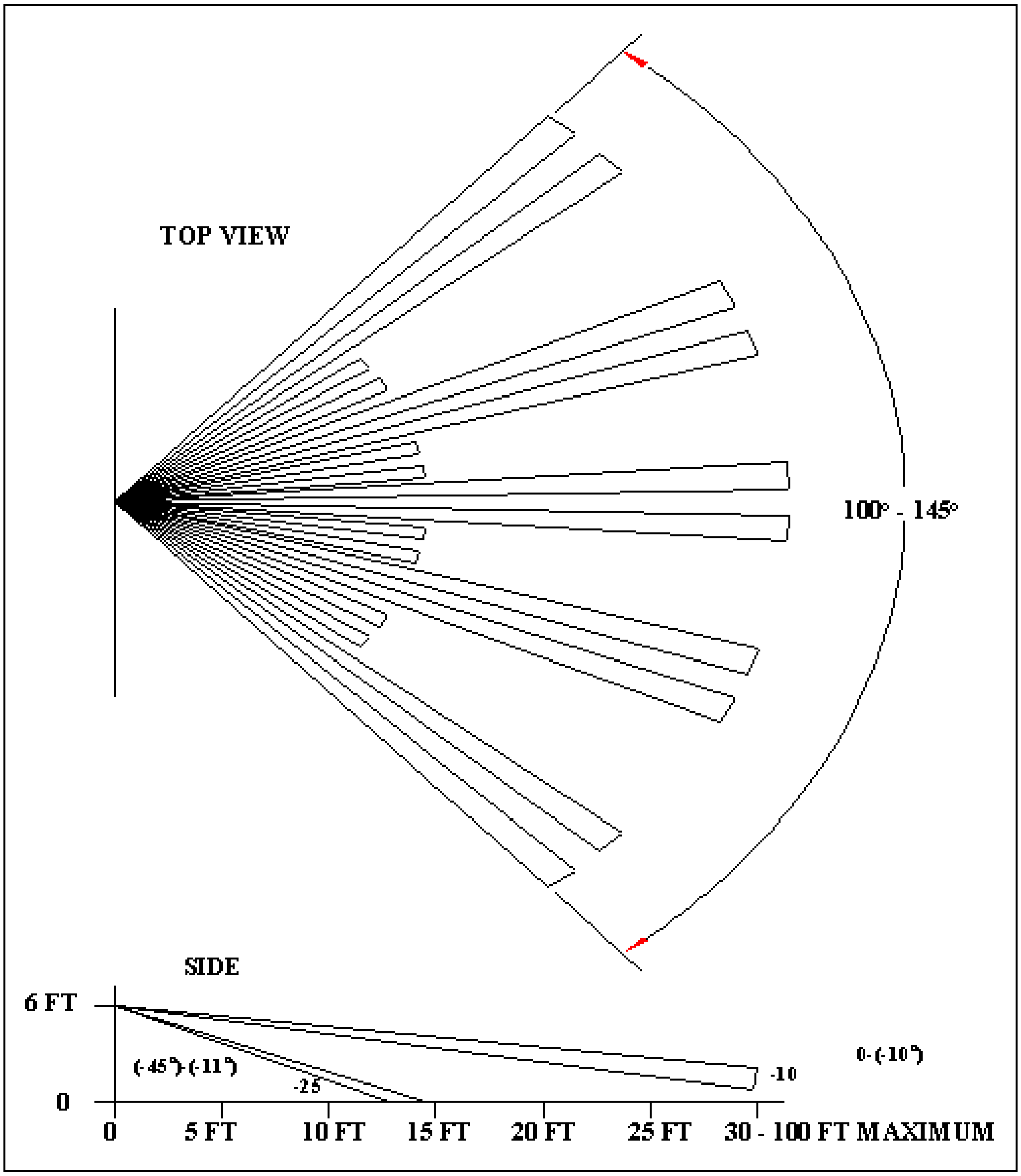
- **Heat radiating from small animals or rodents;**
- **Time-activated space heaters, ovens and hot water pipes within the field of view;**
- **PIR sensors that are not designed with the capacity to ignore visible light can be affected by car headlights or other sources of focused light;**
- **Objects in a room can become heated over time and subsequently begin emitting or reflecting infrared energy. This can occur from sunlight. If the light is, in effect, turned on and off, such as by the movement of clouds, an alarm can be generated.**



Figure LSS+4053 An infrared sensor is blocked from proper operation. The sensor is on the far wall in the corner.

Shadowing, cloaking or masking the intruding heat source from the field of view can decrease the probability of detection. This is because it reduces the possibility of sufficient radiated or emitted heat from being focused on the thermal sensor. A knowledge of the dead spots of the detection pattern can permit an intruder to bypass active regions. Walking **into** the sensor rather than **across** the sensor's field of view can also reduce the detection capability. In the photograph above, the sensor is located in a warehouse and is blocked by storage of items, greatly reducing its reliability.

PASSIVE INFRARED SENSOR



THE NUMBER, RANGE, AND PROJECTION ANGLES OF THE DETECTION BEAMS VARY DEPENDING UPON DESIGN.

Figure LSS+4013 Passive infrared sensor

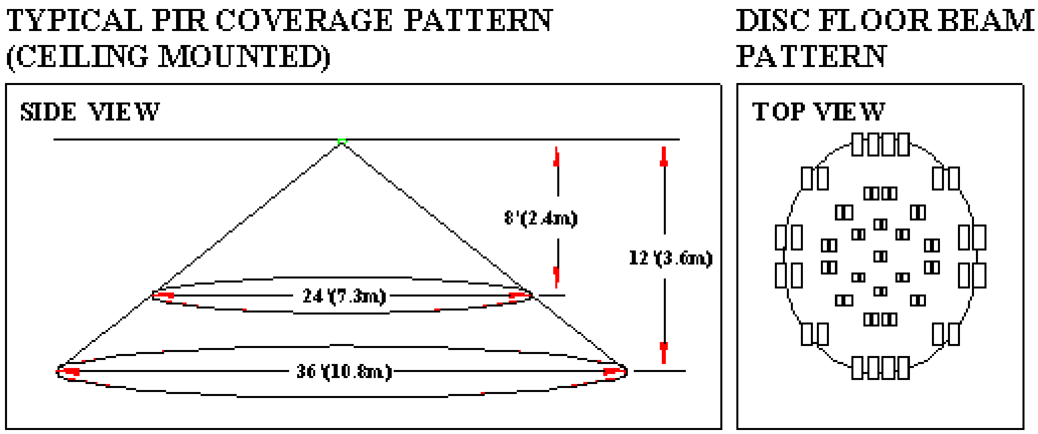


Figure LSS+4014 Typical PIR coverage pattern (ceiling mounted) and disc floor beam pattern

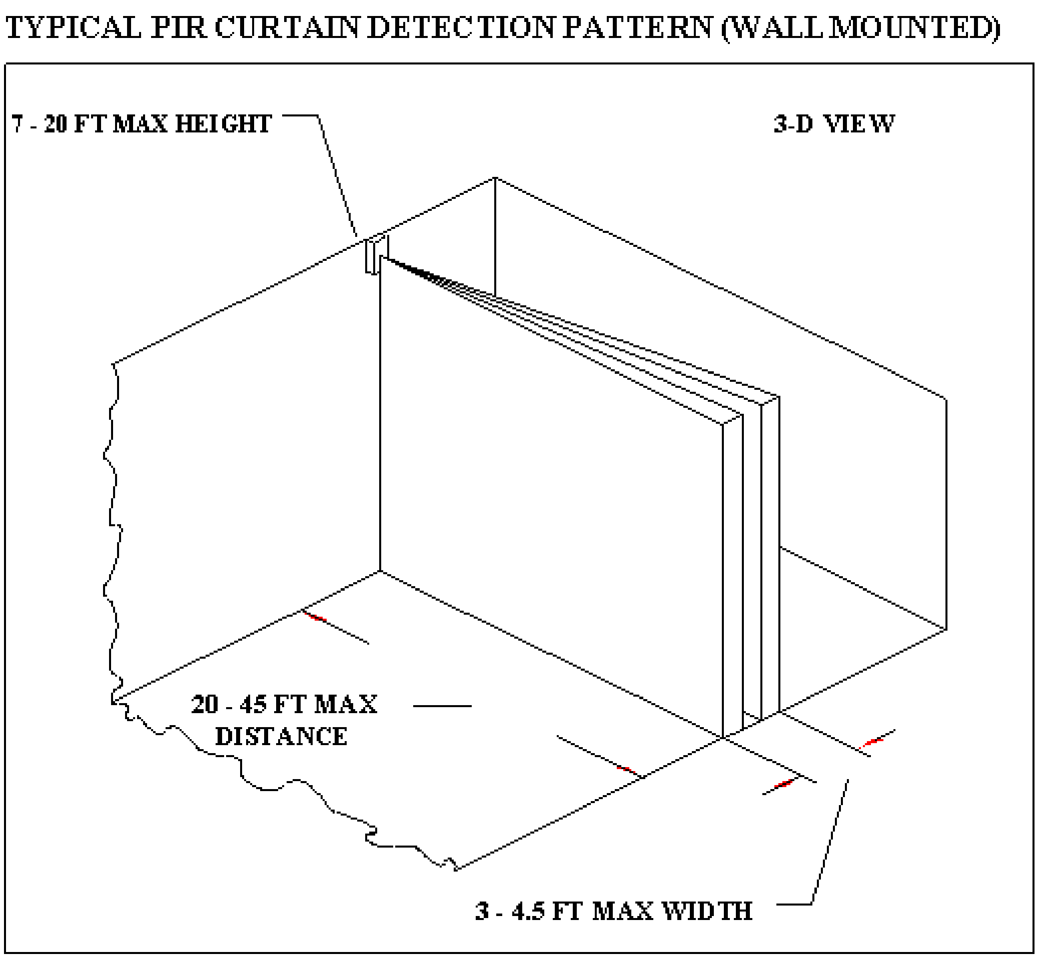


Figure LSS+4015 Typical PIR curtain detection pattern (wall mounted)

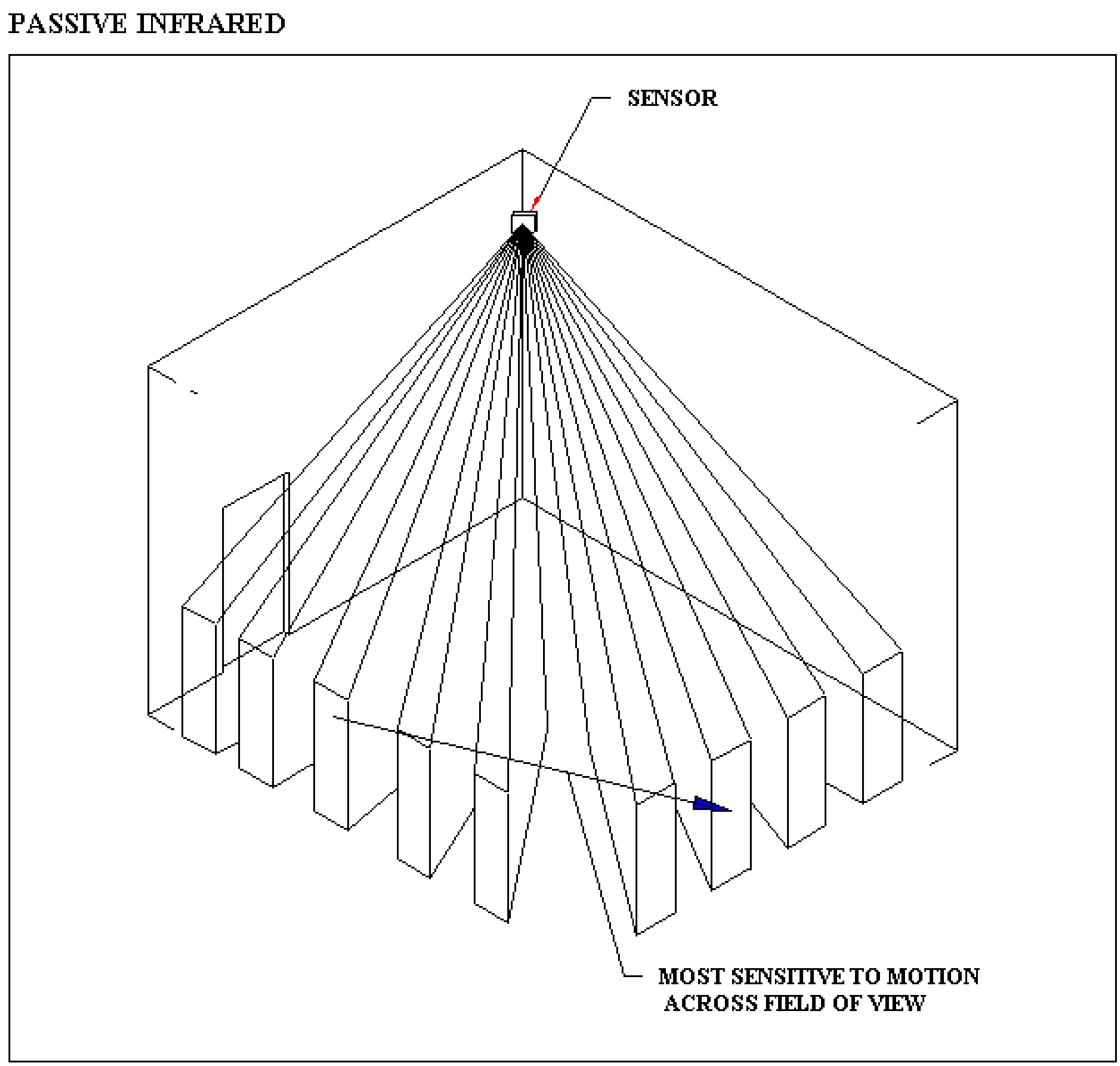


Figure LSS+4016 Passive infrared

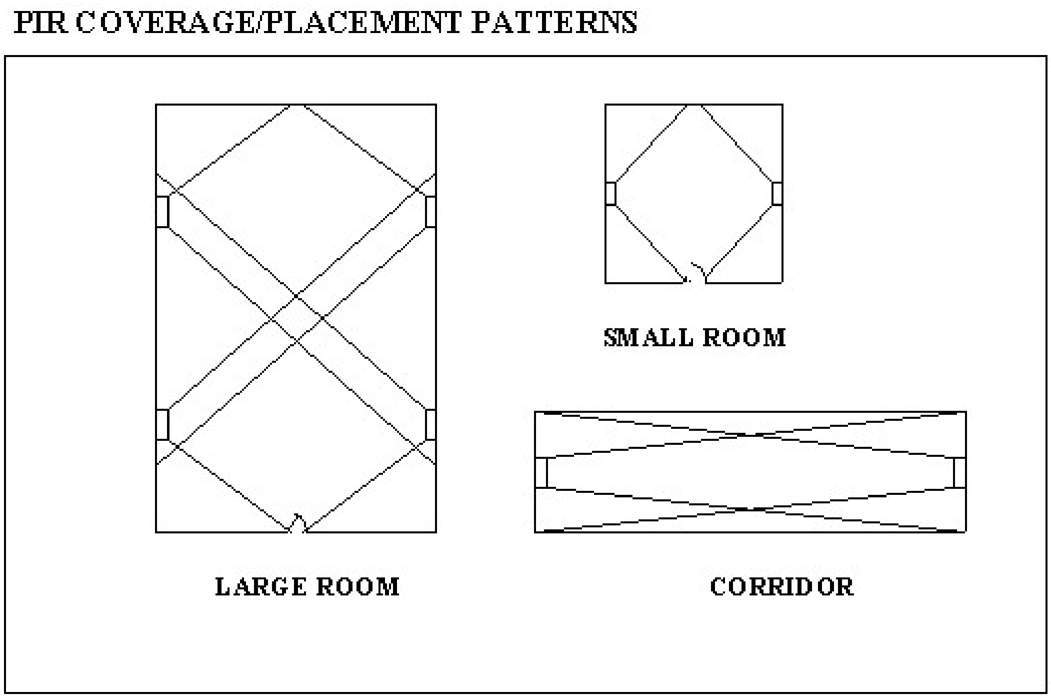


Figure LSS+4017 PIR coverage/placement patterns

40_3.6.A Interior Active Infrared

Interior active infrared sensors transmit a curtain-pattern of modulated infrared energy for a designated area of protection. The sensor reacts to a change in the modulation of the frequency or an interruption in the received energy, both caused by an intruder.

These sensors are comprised of a transmitter and receiver that are packaged within a single unit. A laser is utilized for the source. Its plane is projected onto a special retro-reflective tape that is employed to defines the end or edge of the protection zone.

Energy is reflected from the tape, back to the receiver. This energy passes through a collecting lens that focuses the rays onto a cell which then converts the IR to an electrical signal. The processor evaluates the signal level: if it drops below a specified threshold for a defined period (caused by an intruder), an alarm will be generated.

Depending upon the reflectivity of the tape, coverage patterns can be between 15-25 feet wide by 17-30 feet long. The laser plane angle can be adjusted from 37º to 180º. The temperature of the environment nor the speed or direction of the intruder have any affect on detection characteristics. Thus, the systems are quite reliable.

There are a number of conditions that can cause unreliable operations or false alarms:

- **Dust or other particles collecting on the surface of the reflective tape;**
- **Any degradation of the detection capabilities of the sensor;**
- **Reflective tape must have no gaps and be continuous;**
- **The angle from the sensor to the ends or corners of the tape must not exceed 45 degrees;**
- **The activation of an incandescent light which shines directly into the sensor;**
- **Incandescent lights greater than 100 Watts (or sunlight) falling directly in line with the tape will be reflected back to the receiver with a sufficient magnitude to trigger an alarm;**

Interior active infrared systems can be defeated by the avoidance of the projected laser plane by a knowledgeable intruder. He can determine the location of the field of the potential detection pattern from the placement of reflective tape; he can then plan his movements to avoid detection.

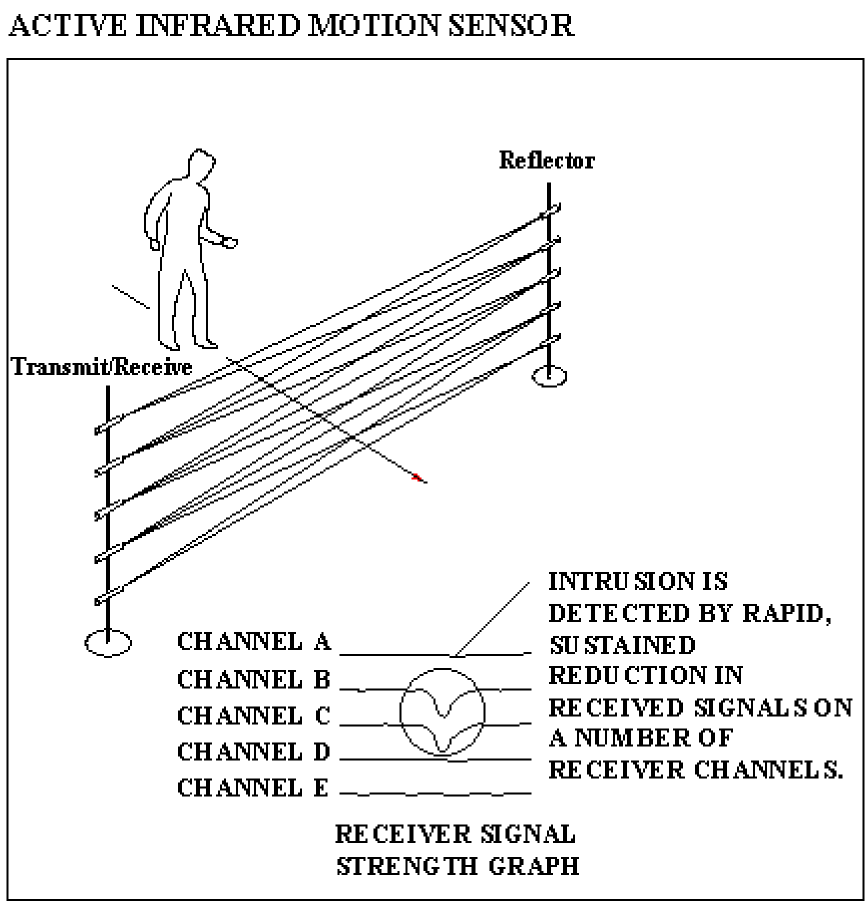


Figure LSS+4018 Active infrared motion sensor (Interior)

40_3.6.B Exterior Active Infrared

In the active infrared design, the transmitter and receiver are separated by the protected zone. A modulated multiple frequency straight-line beam is generated, producing an electronic fence, much like the photoelectric beam system. An interruption in the received energy or the modulating frequency can trigger an alarm.

These sensors are line-of-sight devices, and therefore require that the area between the two units must be uniformly level and clear of all obstacles and obstructions. Holes can be created in coverage by low spots in the terrains that will disrupt the "coverage" pattern. Typically, active infrared systems are employed in conjunction with a single or double fence barrier which defines the perimeter to be covered. A sensor zone length

can extend up to 1,000 feet.

As with all other optical detectors that utilize separate transmitter and receivers, precise alignment of the emitter-receiver path is critical for reliable detection. The beam width is relatively narrow and requires regular calibration and realignment on a frequent basis. Misalignment can be caused by a number of issues:

- **Movements in the ground (e.g., earth tremors);**
- **Objects hitting the unit (e.g., falling rocks, vehicles, falling trees);**
- **Freezing and thawing of the ground;**
- **Dirt and dust build-up on the receiver or transmitter;**
- **Inadvertent movement of objects into the transmission path;**
- **Extremely heavy snow or rain.**

Reliable operation and detection can be insured in the following circumstances:

- **Freezing ground or extreme winds: deep foundations for the mounting of transmit and receive sensors to minimize movement;**
- **Sensor hitting or jarring: install protective barriers around the sensors;**
- **Snow and grass around the sensors: remove by hand or blower to prevent damage or misalignment;**
- **Poor weather conditions, such as fog, heavy rain, or severe dust or sand: consider another technology, or decrease detection zone to compensate for energy attenuation;**
- **Interaction of animals in the protected area: provide barriers to entry;**
- **Vegetation: do not let it grow to a size that its movement will interfere with the IR path.**

Bridging or tunneling is a common method of defeat. There should be no dips or gullies between transmitter and receiver, or they should be brought to a uniform level. The pedestals or columns that the sensors are mounted on can be utilized to support vaulting over them. Overlapping beams can prevent this practice.

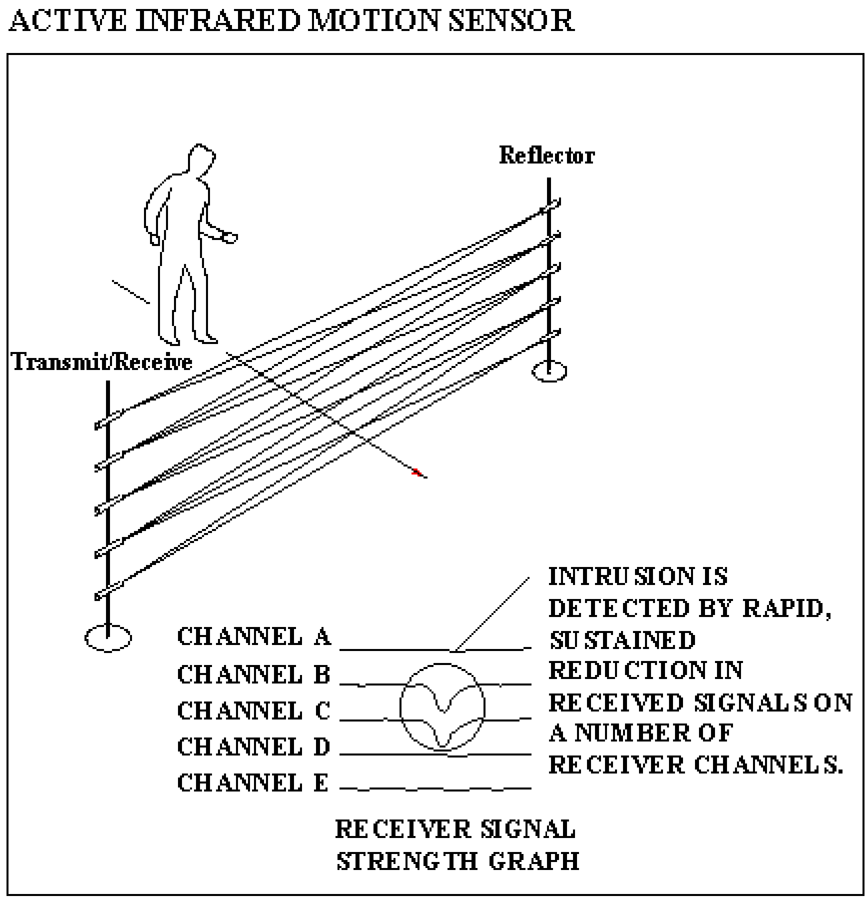
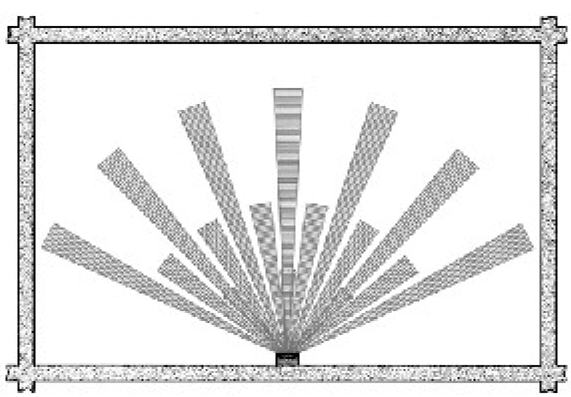
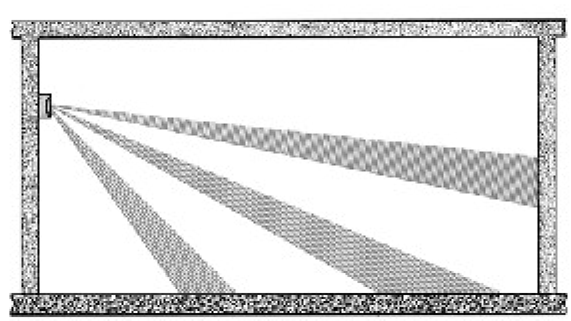


Figure LSS+4019 Active infrared motion sensor (Exterior)

40_3.6.1 Guidelines for Installation of IR Devices



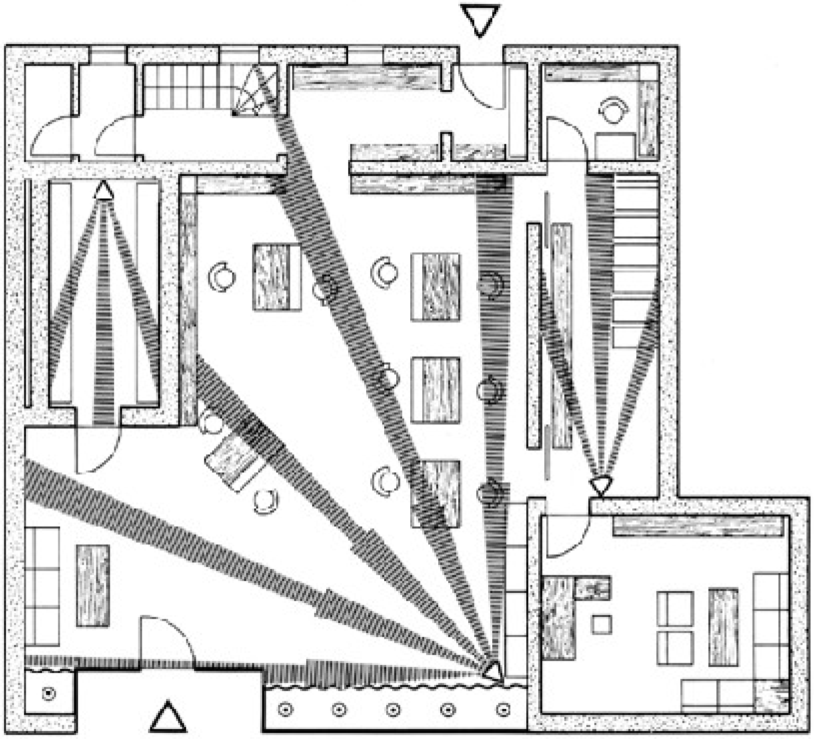


Although passive infrared detectors are an extremely reliable

component of an alarm system, they must be installed correctly to avoid loss of sensitivity and false alarms. The following guidelines apply:

- **Sensors must not be installed so that they face the sun;**
- **Most sensors are designed for indoor use, although some "single beam" devices are available for external application;**
- **Use of different reflectors allows the coverage pattern to be modified. Thus, most sensors can be utilized for any surveillance requirement;**
- **A reduced monitoring angle allows for an increased range, and vice versa;**
- **Sensors can typically monitor an area of up to 60 meters, with a horizontal angle between 7°-120°;**
- **Depending upon the use (trap or room monitoring), the detector should be installed at a height of between 1.5-3 meters;**
- **Individual reflectors within a sensor can be manipulated to control coverage patterns;**
- **False alarms can be caused by detectors responding to rapid changes in radiated energy. Conditions that must be avoided will include:**
    - **Light bulbs being turned on and off;**
    - **A swinging lamp shade;**
    - **Filaments in fan connectors;**
    - **Sunlight interrupted by passing clouds;**
    - **Automobile headlights;**
    - **Humidity;**
    - **Sharp temperature changes;**
    - **Naked flames;**
    - **Direct sunlight.**
- **Pets can trigger an alarm. They should be kept out of areas that are monitored;**
- **Insects can cause a false alarm, thus an insect-repellent strip should be placed near the sensor;**
- **A detector can be desensitized by heating systems and warm-air vents. A sensor must be installed an adequate distance from heat sources;**

- **Ambient temperatures of 32 C to 38 C are unsuitable for fully effective operation of sensors;**
- **Furniture and other components can cause shadow zones in monitored areas because IR energy cannot penetrate such materials. These shadow zones provide the potential for compromise of the system and should be minimized;**
- **A sensor can be neutralized if its optical devices are covered with IR blocking materials before the alarm is set. Most sensors do not contain supervision circuitry to detect this condition;**
- **Sensors can be bypassed and compromised with insulating clothing having a low emissivity. This allows an intruder to appear to radiate the same temperature as the background. Many of the sensors will detect a change in the IR signature of a room, even if the temperature corresponds exactly with that of an intruder. In such a case, the radiation pattern and intensity of a moving person will change. If the sensor stores information about the "normal" signature, then the difference will be detected;**
- **Sensors can be activated by flash flames, or by hot water being poured under a door.**



40_3.6.1.1 Defeat of Infrared and Other Heat Sensors

There are many ways to defeat, bypass, or circumvent these devices. The techniques are summarized below, for exterior and interior applications.

Heat Sensors

- Avoidance, use of non-heat producing methods of attack;
- Bypass sensor circuits while the system is disarmed;

Interior Sensors

- Avoid the sensor. Use the walk-test light to determine boundaries of detection patterns while the system is disarmed;
- Mask the generation or detection of infrared energy by using petroleum jelly, Vaseline, silicone, hairspray, paint, or other foreign substance such as white-out, or an energy absorbing material such as cardboard;
- Utilize mylar covering that will not transmit any body heat;

- Block the detection of IR by taking advantage of man-made or natural barriers in the field of view of the sensor in order to allow penetration into the protection area;
- Use a cardboard box that is allowed to reach room temperature and is placed in the field of view of the sensor, thereby creating a corridor to run past the detection pattern;
- Introduce a higher temperature into the protected area, thus making the sensor less sensitive to temperature changes;
- Use very slow movement by the intruder as he advances toward the detector, taking advantage of the mounting location of the sensor;
- Bypass the sensor circuit while the system is disarmed;

Exterior Sensors

- Avoidance of detection pattern;
- Tunneling under detection pattern;
- Bridging, two-man or pole vaulting over detection zone;
- Masking, by use of petroleum jelly, Vaseline, silicone, hairspray, paint or other foreign substance such as white-out or an energy absorption material such as cardboard;
- Blocking of the sensor, by taking advantage of natural or man made barriers in its field of view, to allow penetration past the detection area. Barriers such as washouts, depressions or snowfall will provide the required cover;
- Exploit detection sensitivity during high outside temperatures when the ambient temperature approaches skin temperature;
- Alarm stacking;
- Determine best intrusion path by walking directly into the sensor. This will reduce its detection capability.

40_3.7 Video Monitoring Systems

LSS401: Video logging and capture systems

LSS403: DOE on alarm assessment

Closed-circuit television can be effective for surveillance of a defined area. Local and remote monitoring of video images is now economically and technically feasible via the Internet. In the

photographs below, several wired (visible and covert) and wireless cameras are shown. Both monochrome and color cameras can be hidden virtually anywhere, and an image monitored at a remote location. Video can be stored on tape, hard drive, optical device, or solid state memory. Video surveillance systems are being employed to an ever increasing degree in public areas, transport, schools, and airports. Extremely sophisticated capture and logging systems have been implemented, especially at security check points, to allow for instant playback and transmission of images to law enforcement and security officers. See **chapter 39** for a more thorough discussion of video systems.

The inherent weakness of any video surveillance system is its operator, due to fatigue and monotony. Thus, an effective system must have the capability to direct the operator's attention to a specific camera display that is triggered by an alarm condition. An intruder must be easily recognized as a result of the image quality, field of view, and picture size. The system must be tamper-resistant, and alarm upon a loss of video. Recorders should operate in an automatic mode upon receipt of an alarm. All images must be buffered, so that there is no loss of data for pre-alarm, alarm, and post-alarm conditions.








ADEMCO
VIDEO
Quartz











40_3.7.1 Video Motion Detector

Images from video cameras, low light level devices, and those that function in the IR range are fed to motion detection sensors to provide for alarm notification in case of intrusion. The systems allow human evaluation of an alarm condition and also provide the means to document the event. These systems employ sophisticated processors to constantly compare a captured image and the "current" view, or compare images in sequence to detect changes in targeted areas. Any movement in the target field, or a

substantial change in lighting over a short period can trigger an alarm.

Video motion detection and analysis systems allow the manipulation of images in terms of zoom, pan, tilt, focus, and contrast, to permit the targeting of specified areas of a picture. Audio monitoring features may also be available. In some instances, cameras are secreted throughout a protected area; in other cases, they are visible and act as a deterrent.

Cameras must be properly installed, positioned, and set to protect the intended area and capture relevant images. Care should be taken to analyze lighting conditions to insure that the target area is sufficiently lit to insure the capture of a useable image.

The use of video as a monitoring system has many applications both overt and covert, and provides excellent redundancy to existing alarm sensors. Some examples of the use of video include:

- **Dead zones between two fences;**
- **Security check points;**
- **Gates;**
- **Fence lines;**
- **Outside storage lots;**
- **Interiors of warehouses (particularly at night);**
- **Approaches to "rear doors";**
- **Vehicle/pedestrian entry points;**
- **Loading docks;**
- **Guard posts where the CCTV system can be tied to a Duress Alarm;**
- **Secure internal areas, such as counting rooms, alarm centers, equipment storage, telephone and communications centers;**
- **Interview and interrogation rooms.**

Installation guidelines include:

- **Securely mount the cameras;**
- **Deny easy access to cameras and mounts, as well as video recorders that capture information;**
- **Maintain the field of view of the camera as open and uncluttered as possible;**

- **Reduce or eliminate vegetation and obstacles to visual observation.**

Unreliable or erratic operation will result under the following conditions:

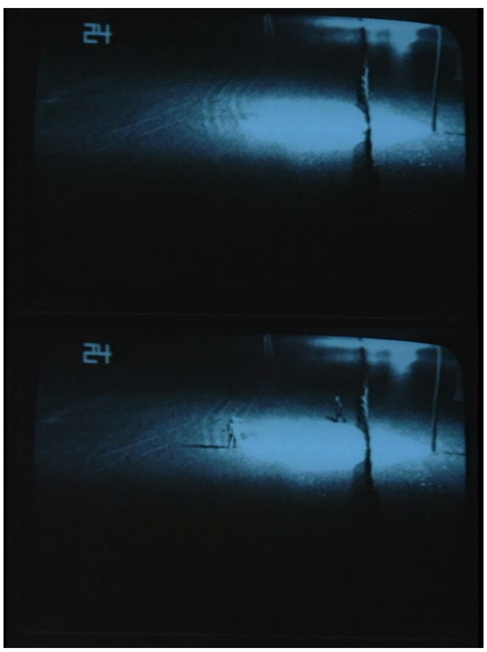
- **Camera pointed towards high intensity lighting;**
- **Poor lighting characteristics or extended periods of darkness in targeted zone;**
- **Improper hardware selection. In some circumstances, low light level or IR sensitive cameras may be better suited to the task;**
- **Improper placement of the camera that does not allow a full field of view of the target area;**
- **Changes in angle of lighting from the sun;**
- **Changes in brightness from movement of cloud motion;**
- **Wind-blown objects passing in the target area;**
- **Camera vibration due to wind;**
- **Light source interference, such as from reflected light, headlights, traffic lights, or security lights pattern change;**
- **Flying insects near the lens;**
- **Dirty or dust-covered lens.**

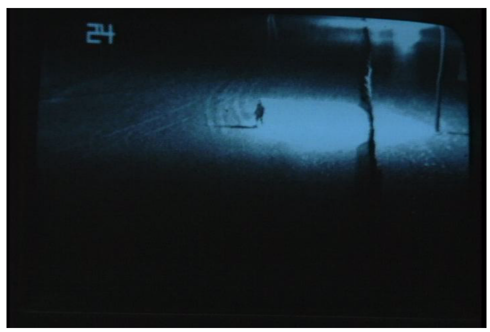
40_3.7.2 Defeat of Video Systems

Improperly installed or maintained systems can be bypassed or neutralized through a variety of techniques that are described in this section. If a knowledgeable intruder can determine the coverage area of the camera, he may be able to avoid detection by moving around, under, or over the field of view. Camera systems can be defeated by blinding, stacking, camouflage or concealment from view. Defense-in-depth, providing for supplemental systems such as motion sensing, should always be deployed to provide for reliable detection. Primary security issues that involve video hardware include:

- **Video multiplexers can be disabled, which will result in a failure to monitor any camera;**
- **Blinding of the camera through the use of infrared light sources;**
- **Stacking of alarms to distract the operator;**
- **Camouflage or concealment of intruders;**
- **Programming errors, either deliberate or inadvertant, may**

render the system insecure;
- **Monitors can be viewed by non-security personnel;**
- **Cameras can be destroyed or damaged. Lenses can be smashed or sprayed with material to make them unusable;**
- **Video recorders may not be properly maintained, resulting in dirty recording heads, erratic mechanical operation, or tape jams;**
- **Video recorder input settings may be tampered with;**
- **Tapes can be stolen;**
- **Failure to properly archive tapes;**
- **Storage of tapes near strong magnetic fields;**
- **Failure to maintain a retention policy;**
- **Use of poor quality or substandard tapes;**
- **Use of old time-lapse recording technology which is inherently unstable;**
- **Use of old tape with drop out errors or media failure;**





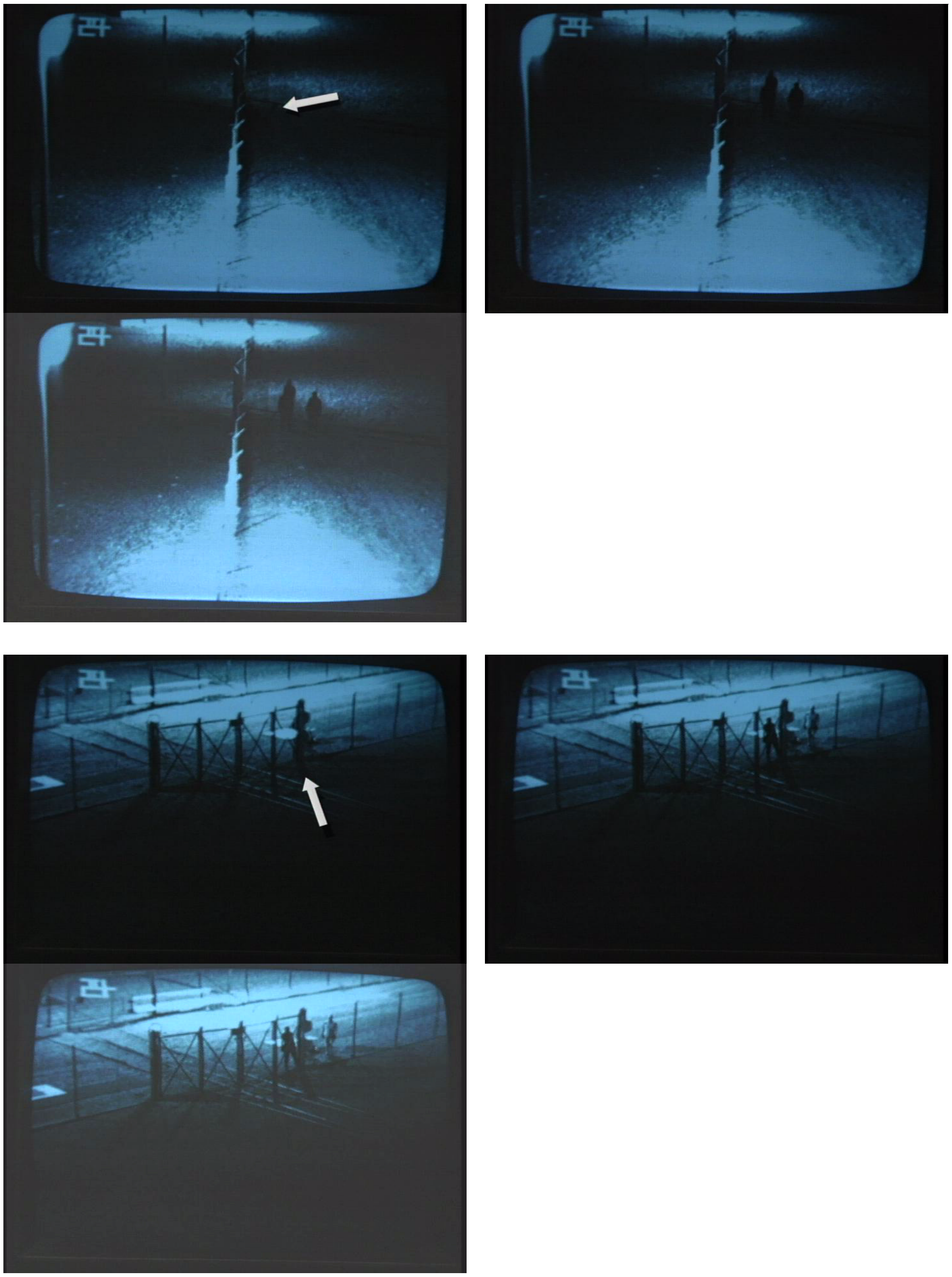
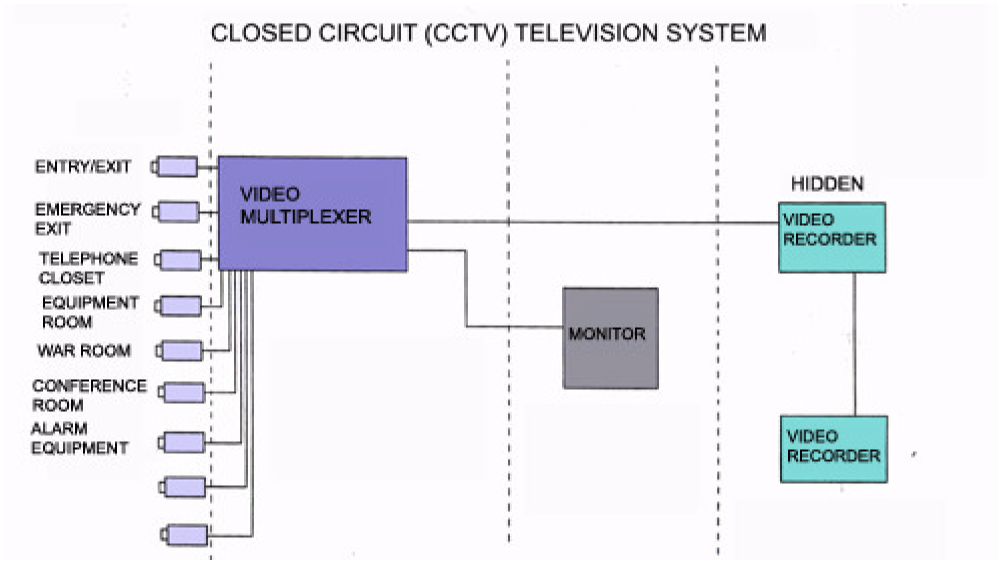


Figure LSS+4054 A camera is blinded by bright light in the photographs in the top and middle rows. Note the enhanced image (middle right) that shows the intruders. In the bottom row of photographs, the inruder is concealed, as shown in the enhancement (bottom right).
Courtesy of DOE Office of Security and Safety Performance Assurance.



40_3.7.2.1 Specific Defeat Techniques to Attack Camera Systems

There are a variety of means that can be employed to neutralize or destroy the effectiveness of a video surveillance system through attacks directed at cameras. These are summarized below. It is important for the security staff to analyze the potential methods to defeat the system, and to take corrective measures to minimize the risk. Reconnaissance by intruders will typically attempt to gather the following information:

- **Learn the territory and any unique characteristics;**
- **Become familiar with every segment of the area of intrusion;**
- **Explore the area to be breached by day and night;**
- **Every alley, bush, tunnel, tree, building, wall, railing, fence or other accesible point will be explored, tested for alarms, and climbed;**
- **Typically, intruders will be careful not to traverse well-used paths, streets, alleys, or other areas that would normally be subject to surveillance;**
- **Intruders will look for areas of cover, especially if aerial surveillance is utilized;**
- **Consider that flares and smoke bombs may be utilized to blind surveillance equipment.**

The following specific defeat techniques may be employed to reduce the reliability and effectiveness of any video

surveillance system, regardless of where the cameras are placed or mounted:

Plastic bag

A plastic trash bag filled with glue can be utilized to take a camera out of service. Cameras are often "bagged" if they are to be repaired. Thus, such action may not draw undue attention.

Sticker and tape

If the camera has been mounted so that it is accesible from the ground, then a sticker or tape can be placed over the lens to render it inoperative.

Paint gun

A paint gun, water pistol, or aerosol spray can be utilized to damage the lens. This is a highly effective method that can be carried out within a few seconds. The action can disable many cameras within a short period of time. Spray glue also works well and will be more difficult to remove from the lens. Effective range can be 5 meters above the ground. Paint splatter may be left on perpetrators, so criminal investigators should check for such evidence.



Laser pointer or infrared light source

A CCD or other video sensor can be disabled with a laser pointer or infrared light source. An emitter with an output of 5 milliwatts or greater can temporarily blind and may even permanently damage a video sensor. A threat from such devices has been recognized for their capability of damaging CCD and other pickup tubes, as well as the potential to cause eye damage or blindness to people up to several hundred feet from the

transmitter. Devices can be secreted in cameras with telephoto lenses or binoculars, and can be difficult or impossible to detect.

Cutting of coaxial cables

Fiber optic, twisted pair, and coaxial cables can be severed or damaged with either a sharp hand axe, fence cutter, or garden pruning tools. When cables are cut, their repair or replacement may be time-consuming and costly. Pins, or the application of heat may also be utilized to break the transmission path, or short circuit the center conductor to ground, thereby preventing any signal from reaching a remote monitoring site.



Block drop

Cameras can be damaged through the application of brute force by dropping weights, cinder blocks, or other objects from above their mounting location. Such action can completely destroy the housing and electronics.

High speed projectile

A camera may be taken out of service if it is penetrated with a projectile such as a bullet from a rifle or handgun.

RF Interference for wireless transmitters

Wireless cameras can be taken out of service by RF interference. Cameras will generally operate in the 900 MHz, 2.4 or 5.8 GHz bands, either on discreet frequencies, or utilizing spread spectrum. If the frequency band can be identified, the receiver can be jammed with a relatively high power signal, regardless of whether analog or digital transmission is employed. Spread spectrum and 802.11 protocol will not prevent this practice. Microwave ovens can also play havoc with 2.4 GHz receivers. This is a popular band for government covert operations, and is also utilized by the news media for remote pickups. Cameras operating with 802.11 protocol can also be received by computers equipped

with this technology. Most notebook computers incorporate WIFI. Inexpensive WIFI 802.11 sniffers are available to locate wireless networks.

40_4.0 Protection for Specific Types of Premises, Construction, or Fixtures

A survey of alarm devices that can be used to protect specific structures or fixtures is provided as a reference.

40_4.1 Windows

Windows and related components can be protected by the following devices:

- **Alarm glass;**
- **Alarm glass with embedded wires;**
- **Bolt contacts;**
- **Glass-breakage detectors. They cannot be used on panes with shatter-resistant films, since the propagation characteristics of the medium is altered;**
- **Laminated glass with wire inserts;**
- **Security alarm glass;**
- **Light barriers;**
- **Magnetic contacts;**
- **Spanned wire;**
- **Surveillance foil;**
- **Transducers sensitive to changes in pressure;**
- **Vacuum alarm glass;**
- **Vibration contacts;**
- **Volumetric protection devices.**

40_4.2 Walls

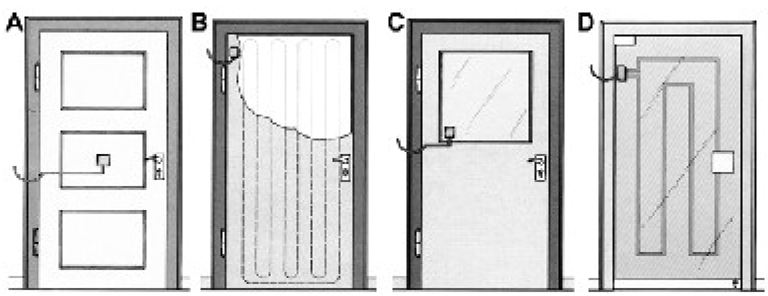
- **Seismic detectors;**
- **Wallpaper coverings with embedded closed-circuit wiring.**

40_4.2.1 Openings in Walls

- **Taut-wire trips;**
- **Trap loops, consisting of cables or wires placed across openings at narrow intervals. Pressure or severance will trigger an alarm.**

40_4.3 Doors

- **Magnetic contacts;**
- **Micro switch contacts;**
- **Bolt contacts;**
- **Light barriers;**
- **Vibration sensors;**
- **Surface surveillance systems (wires);**
- **Glass-breakage detectors;**
- **Sound detectors;**
- **Volumetric sensors;**
- **Foil.**



Doors should always be protected by more than just magnetic switches; otherwise, they are subject to compromise. If burglars know the precise position of the trip, they can often cut around it and fix the magnet to the door frame.

40_4.4 Small Openings and Confined Areas

- **Dome lights: contacts to prevent the dome from being raised;**
- **Ventilation openings: tubing and wiring;**
- **Showcases: capacitance field change detectors or ultrasonic sensors;**
- **Drawers and doors of cabinets: magnetic contacts;**

- **Locks and Locking Devices: bolt contacts;**
- **Furnishings: closed-circuit wiring in wallpaper.**

40_4.5 Enclosed Rooms

Entire rooms or specific areas or objects can be protected, depending upon exposure of property and character of the environment. The following devices can be utilized to protect enclosed rooms:

- **Volumetric sensors;**
- **Microwave detectors;**
- **Ultrasonic detectors;**
- **Passive infrared detectors;**
- **Proximity detectors.**

40_4.6 Interior Surveillance

Additional interior surveillance is usually necessary, regardless of the extent of protection and monitoring of the external shell. There are always exposed or vulnerable points of access that necessitate localized monitoring within the interior of a building. The following suggestions and guidelines are offered for the use and installation of internal trips:

- **Dead zones must be avoided in any scheme of protection;**
- **The operation of a detector must not be disturbed by external environmental influences;**
- **The risk of false alarms is high when traps are used for surveillance. They should only be installed in very controlled circumstances, as for instance in a small shop with few employees;**
- **Pressure mats can be placed under carpets and doormats;**
- **Large items or decorations can be monitored with magnetic contacts or micro switches;**
- **Contacts embedded within curtain rails will trigger whenever the curtains are closed;**
- **Current-sensing devices can be integrated into the electrical system to determine when interior**

lighting has been turned on or off or when power is drawn through the circuit;
- **Ultrasonic approach switches can be utilized;**
- **Alarm panels must be installed in protected rooms;**
- **Silent alarms should be used in the event of holdup;**
- **Visible and audible alarms should be used for protection against burglary.**

40_4.7 Alarms in Banks

Physical devices and other safeguards must be implemented to insure that a burglary is detected at the earliest possible moment. Monitoring and protection of the perimeter and interior areas is essential. These include approaches to the bank, roofs, and windows. Within the interior spaces, it is imperative to provide localized surveillance of strong rooms, ATMs, and night depositories.

40_4.7.1 Strong Rooms

Because of the prevalence of special forced entry materials and tools such as the thermic lance, diamond drills, and explosives, it is essential that strong rooms and safes be protected by many different physical barriers and alarm devices. These will include:

- **Sound sensors for doors, walls, floors, and ceilings;**
- **Volumetric protection;**
- **Bolt or frame contacts for doors;**
- **Capacitance and motion detection systems for interior areas and safes;**
- **Smoke detectors to sense the use of a thermic lance;**
- **Charged conductors, sunk into or attached to walls;**
- **Closed-circuit television cameras and video recorders;**
- **Proximity sensors.**

Interior safes and depositories may be further protected by an external casing that is alarmed. Automatic teller machines (ATMs) must also be specially monitored. Protection of the area around the ATM, as well as internal cash vaults, is essential.

40_4.8 Protection of Open Land

The reliable protection of open land is difficult because of changes in environmental conditions, animals, passers-by, and the ease of circumvention by experienced criminals. The following technologies may be utilized for monitoring open areas:

- **Closed-circuit television;**
- **Seismic detectors;**
- **Capacitance and pressure monitoring of fence lines;**
- **Microwave motion detection;**
- **Photoelectric sensors;**
- **Volumetric monitoring systems**
- **Fence systems.**

Techniques for exterior perimeter protection have been examined elsewhere in this chapter.

40_5.0 How to Steal $100,000,000 in Diamonds: A Case Study

This section provides an analysis of one of the largest and well executed diamond thefts in history, and demonstrates how vulnerabilities in security were discovered and exploited by a gang of career criminals over a two year period. The Antwerp diamond theft represents the real world of crime, and what lengths professional thieves will pursue in order to accomplish their goals.

This crime is illustrative of an extremely well planned penetration of an ostensibly secured area. In the author's opinion, many mistakes were made by building management and security staff with regard to protection of its perimeter, internal access, and stored valuables. A debriefing of senior case agents by the author offers an insight into the methods that were employed by perpetrators to steal the diamonds, the means that were utilized to catch them, and the chain of evidence that was developed for prosecution. An analysis of the perceived vulnerabilities of the security systems is presented to enhance the materials within this chapter, and to offer the reader a unique perspective of those that are intent on breaching security.

The material presented in this section represents the opinions of the author and other security experts, based upon information provided by law enforcement officials and others that were closely connected with the investigation. No statement of fact or assertion is made or intended with regard to the possible negligence of security staff or failure of security procedures within the Diamond Center. Certain actions of one or more criminal defendants cannot be ascertained as fact unless and until they provide a statement as to precisely how the crime was committed. Certain assumptions have been made by the author and others in reaching certain conclusions within this report. Counsel for the owners of the building in question have advised the author that any inference, suggestions or statements that the building management or staff was in any way negligent or in any way caused or allowed the theft to occur would be false. The author leaves it to the reader to make that determination.

Overview of the Diamond Exchange

Antwerp, Belgium processes and controls approximately eighty five percent of the world's rough cut diamonds. Every major company is represented and buys and sells their diamonds through Antwerp; the entire trade is centered within a square mile. Adjoining the district are hundreds of retail jewelry stores, mainly controlled by Georgians and Russians.

Within the core area, which spans just a few blocks, are all of the vendors, merchants, cutters, polishers, showrooms, banks, money exchange offices, insurance companies, secure couriers, storage vaults and brokers that are required to support the billions of dollars of business that annually flows through Antwerp. The High Council for Diamonds represents all of the companies within the district and is responsible for overall supervision of the diamond area and develops policy for the diamond trade worldwide. Diamonds from mines in Africa, Australia, Canada and elsewhere are all bought, traded and sold through the merchants in Antwerp. Their goods are exported to diamond centers throughout the world, but mainly to India, Thailand, Israel, and New York.


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The area is only accessible to authorized vehicles and pedestrians, and is patrolled continually by a special detachment of the Antwerp police. All vehicle traffic ingress and egress is controlled by pneumatic steel barriers at the three entry points to the district. Only those delivery vehicles that are authorized may enter, and all must remain on the street and in plain view. Armored cars are always escorted to their destination. Acts of terrorism in the 1980s, as well as daylight robberies and other crimes have necessitated the heightened state of security during the past few years. Constant video surveillance of the entire area is maintained.



Views of the Diamond area in Antwerp.

Summary of the Offense

During the weekend of February 15, 2003, one of the buildings in the district was burglarized. This facility houses many merchants and hundreds of millions of dollars of diamonds within its vault. There had never been a security problem in the building prior to this theft. It is typical of office buildings within the exchange; a multi-story secure structure with offices and a large strong room that contains hundreds of individual deposit boxes for its tenants.



The main entrance to the Diamond Center.

The burglary required two years to plan and execute, and a total of seven individuals were identified as being involved. At least five of the defendants are career criminals with extensive histories. The ring leader was arrested one week after the crime, and is currently scheduled for trial. The others are awaiting extradited from Italy. It is estimated that in excess of $100,000,000 was stolen from over one hundred boxes in the vault. Virtually none of the diamonds have been recovered. The maximum penalty in Belgium for theft is approximately five years.

Preparations and Planning by the Defendants

The defined target was the main vault in the basement of the Diamond Center in Antwerp. It is not known how this particular building was specifically chosen by the thieves, although the author suspects that information may have been provided to the defendants regarding the security system or the combination to open the vault, and this was the prime reason for the selection of the Diamond Center. With this knowledge, the building certainly would have been an attractive target. The author also suggests that information may have been obtained with regard to the individual tenants in the building and the amount of business that they may have been conducting. This could provide an insight into the value of diamonds that would have been stored within individual safes.

It is surmised by the author that the thieves had advance information with regard to the security system, vault combination, and the design of the safe deposit boxes for a number of reasons:

- **The Lips vault would have been difficult to penetrate by force;**
- **It is doubtful if the combination lock, requiring four digits, could have been manipulated or automatically opened with a robot dialer within a reasonable or predictable time frame;**
- **Becoming a tenant of the Diamond Center would only provide information and access to that building. It would not prove helpful if another building were to be penetrated. Having an ID badge for this specific building would not be particularly helpful for gathering detailed information about another location, although it would permit entry and exit into other facilities during normal business hours;**
- **It is highly unlikely that a gang of thieves would spend the time and expense to prepare for a burglary of this magnitude if there was any uncertainty that they could not successfully reach their target without delay or fear of detection. It is simply not logical that they would approach the vault without knowing the combination.**

In order to be successful in their operation, the thieves would need to develop a great deal of information regarding all aspects of building security and procedures. It was essential that they were able to gather this information over a period of time and in such a manner that they would not call attention to themselves.

This would require that they establish the following credentials:

- **Bona fide diamond merchant, meeting the requirements for doing business within the Diamond Center, supported by appropriate banking and business references;**
- **Establishment of their business as routine within the Diamond Center, and acceptance by both management and other tenants as legitimate merchants and which would not raise any suspicion;**
- **Obtain an identification card that would allow access through security sensors upon entering and leaving the building, and would allow recognition as an authorized tenant;**
- **Access to interior building areas, including offices, parking garage, and the strong room;**
- **Familiarity with the administrative and security staff, so that their presence would not be questioned, and it would appear to be in the normal course of business;**
- **Rental of safe deposit box;**
- **Routine access to a safe deposit box within the strong room;**
- **Ability to observe all aspects of the alarm and security system;**
- **Acquisition of rental space within the building over a long period of time, so that when the burglary occurred, they would have been evaluated as a long term tenant and not as a suspect;**
- **Establishment of banking and money exchange contacts within the diamond area, creating and confirming the illusion of doing business.**

The following information would have to be gathered, and was critical to the success of the operation:

- **Perimeter security of the building, and the level of surveillance provided by the Antwerp police;**
- **Identification of all entry and exit points to the building;**
- **Identification of non-secured access points to the building;**
- **Analysis of the adjoining parking garage, its access to the building, hours of operation, ability to open overhead gates, and monitoring of traffic;**
- **Identification of all access routes to the strong room;**
- **Physical access control systems;**
- **Access control procedures to enter and exit the building;**
- **Consistency of security procedures;**

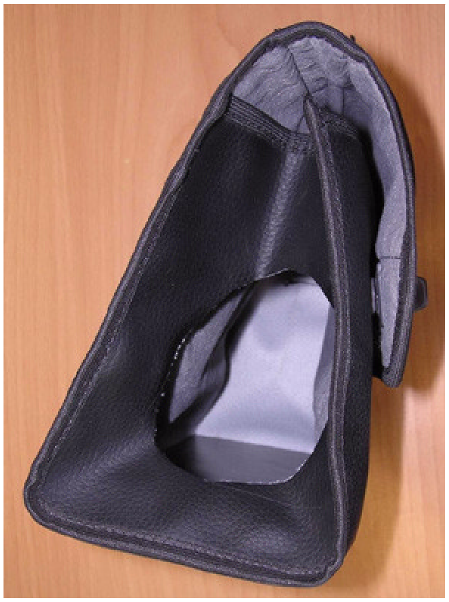
- **Traffic patterns into the building, and a correlation with hours of operation;**
- **Access procedures into the vault for building tenants;**
- **Alarm systems, both perimeter, internal, and strong room: blind areas in coverage and methods to bypass specific areas under surveillance;**
- **Identification of alarm system hardware, including each type of sensor that was employed and its location, approximate age and level of technology, the method that would be required to defeat it, and the level of sophistication of each sensor;**
- **Locks and keys, relating to doors, storage areas, master key systems;**
- **Identification of the types of locks, the method of master keying, the potential to compromise the master key system, and whether different types of locks were utilized in the area of the strong room and access doors into that area;**
- **Identification of the specific type of safe door and lock that was utilized for the entry to the strong room;**
- **Determination of whether the safe lock could be manipulated open, or opened with a robot dialer or automatic manipulation machine;**
- **Possible identification of the contract locksmith that performed routine maintenance on locks and safes within the building and the ability to compromise such information;**
- **Identification of specific information regarding the safe deposit vaults, including locking mechanism and the ability to force open the door with the use of a dent puller;**
- **Internal video surveillance systems: location of cameras, coverage, defeat, retention and storage of video tapes;**
- **Internal staffing procedures for all employees: number of staff, hours of work, job responsibilities, distraction level;**
- **Security staff complement: number of staff, duties, surveillance activities, work load, ability to monitor video surveillance systems;**
- **Monitoring procedures while tenants were in the vault.**
- **Observation of other building tenants while they were in the vault, and possible identification of target safe deposit boxes that may contain large amounts of diamonds;**

One of the defendants, identified as the ring leader, formed a diamond brokerage firm in Italy two years prior to the burglary in order to develop a business track record and paper trail.

Appropriate banking contacts were established in Antwerp to provide legitimacy to the newly formed company. He then utilized his credentials as a diamond merchant to begin negotiations with the management of the Diamond Center for an office within the building. This took some time, because appropriate checks have to be made on all tenants to verify that they were diamond merchants or otherwise legitimately involved in the trade, and qualified to be in the building.

After some discussion, an office was rented in the Diamond Center building. For the next two years, the thieves developed significant intelligence about the building, its staff, and its security, which enabled them to determine the precise plan of attack and optimum dates for its execution. They even shot covert videotape within the facility in order to review the layout, identify targets, and provide a working knowledge to all of the gang members. A video camera was secreted in a bag so that it could be utilized without notice.





**This leather case was utilized to hide a video camera that the thieves used for
covert surveillance and documentation within the Diamond Center.**

Security of the Diamond Center

The Diamond Center was thought to be a secure facility. As can be seen in the photographs, there is a guard post at the main entrance, as well as turnstiles that require the use of a proximity card issued to each tenant or visitor. The author was required to show his passport, even though he was escorted by a senior federal police official. The security officer at the desk has the responsibility to log all visitors into the building and issue ID badges. Tenants are provided with permanent identification.

Video surveillance was in operation both in the entry to the strong room and within the vault area only. Additional external video monitoring is maintained by the Antwerp Police. Audio, motion, and light level alarm sensors are in operation inside the vault area, both external to the vault door, and within the strong room. Dual-technology microwave/infrared devices were in use as motion detectors. There was no alarm monitoring on the first floor of the building, no surveillance of the main desk or control room area where video tapes were stored, and no electronic monitoring of the entry from the parking garage to the stairwell that led directly to the vault.

The entire facility utilizes Lips dimple pin tumbler locks for

all doors. These are a relatively low security mechanism that can be easily picked. The design of these locks indicates that a positional master key system was utilized. This type of system would be extremely difficult to decode for the top level master key, and thus would necessitate the picking of individual locks. There is no way to decode such a system without access to many individual keys for comparison and collection of data. They could not have utilized the lock on their office door within the Diamond Center to extrapolate the TMK. See **chapter 11** for a detailed discussion of positional master keying.

A Lips vault and four-wheel combination lock protected the strong room. The safe door was monitored by a balanced magnetic trip, audio, motion detection sensors, and vibration detectors. There was no proximity or capacitance sensor on the door, because it was set into the foundation of the building.

Access to the combination lock internal components for maintenance requires a metal cover with a lever lock to be removed from the back of the vault door. The key for this lock is believed to be standard to all Lips safes. The combination lock on the door had a spy proof dial which required direct vertical observation of the numbers. A high security lever lock is utilized together with the combination lock to secure the vault door. The key was stored in a locked key cabinet in an adjoining room; a low security wafer lock was utilized to secure this cabinet. An adjacent storeroom provided possible implements for the burglars to utilize. Each of the individual safe deposit vaults had a combination lock that utilizes three individually controlled wheel packs and a lever lock. The bolt mechanism is made of brass and can be easily warped out of a locked position.

In the view of the author, the security of the Diamond Center was typical of such facilities; multiple issues played a key role in failing to detect or prevent the crime. Management clearly believed that the building was secure: secure enough to protect $100,000,000 in assets. They had never experienced a problem, which leads to complacency. The insurance company, for their part, also believed that there was sufficient security to allow them to underwrite policies.

Management failed to install modern security hardware, which is also a common problem, following the maxim "if it works, don't fix it." The thieves were able to exploit several vulnerabilities in the overall security system to accomplish their mission. It is a classic problem, because the management believed that all

critical areas were protected with multiple layers of security. But a close review shows this was not the case. How much security is enough? That is always the question, and the answer, when dealing with high value targets and professional criminals is quite simple: there is never enough. Clearly, in this instance, more was needed to stop the thieves. Could management have anticipated the methodology of the criminals and taken effective steps to prevent the loss? Perhaps. If one considers the value of the target and the likelihood that professional thieves would plan such an attack, then certain breaches in security could have been foreseen and prevented, which very possibly could have thwarted this burglary.

This analysis should provide a model for other like installations, where the apparent security of the facility appears redundant, layered, and more than sufficient to prevent a successful attack. As shown in this case, experienced thieves will spend the time and effort required to analyze their target and devise a plan to exploit vulnerabilities. That is precisely what occurrred in this instance.

The Crime Scene

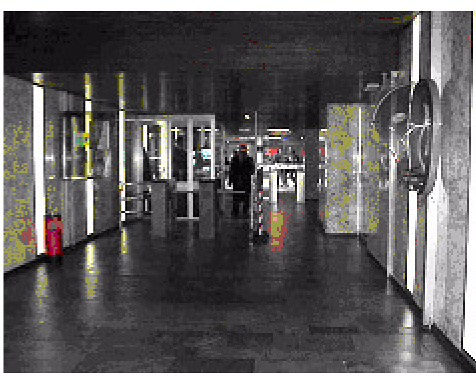
The Diamond Center building is a fifteen story structure with thirteen floors above ground and two subterranean levels. Approximately two hundred and twenty five diamond companies have their offices in the building. The theft took place in the strong room, situated on the lower level (-2), accessible by elevator or stairway. Within the strong room there are 189 individual deposit safes of various sizes, rented by the different diamond merchants who have their office in the building or in the diamond area. Note that each building has its own vault for the convenience and security of its tenants.



The strong room at the Diamond Center, the morning after the burglary.

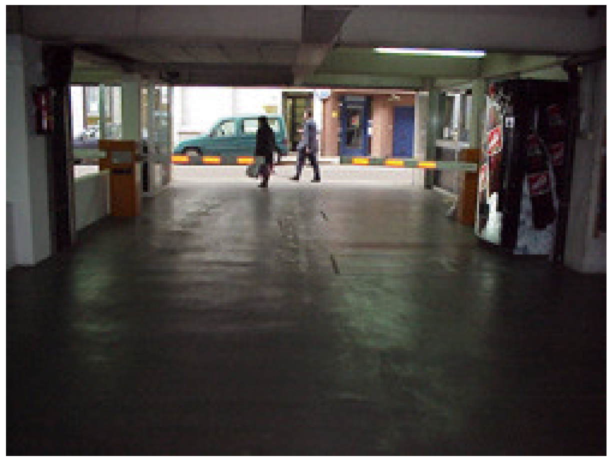
Access Points to the Diamond Center Building

The Diamond Center can be accessed via two entrances. The main entry is situated in the front side of the building along **X** Street. There is a second entrance in the back of the building in **Y** Street.









The garage adjoins the Diamond Center and can be accessed from the street, outside of the core area of the Diamond district. There are no security restrictions with regard to access to the street that leads to this parking garage.

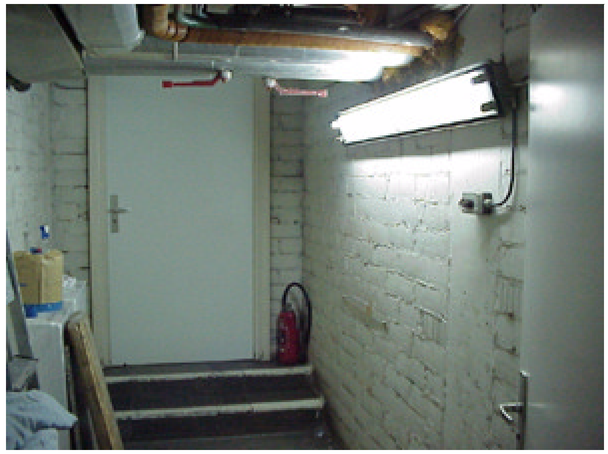
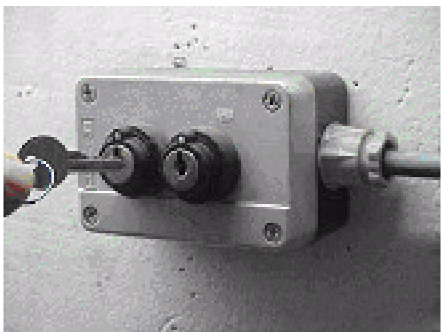
The main entrance in **X** Street is open Monday to Friday between 0700 and 1900. At all other times it is locked by means of an iron shutter. The second entrance on **Y** Street borders the inside parking area adjoining the building and is also open Monday to

Friday between 0700 and 1900. From 1900 and 0700, and every half an hour from 1900 until 2100, the building can be accessed and exited via **Y** Street only. The primary entrance is closed. After 2100 the security officer on duty can be contacted by phone in order for tenants to enter or leave the facility. During the week-end, **only** the second entrance is open on Saturdays between 0800 and 1300. On Sundays this entrance is open between 0900 and 1300. During the opening hours, each entrance is watched by a guard. There exists a third possibility to enter the building which is situated in **W** Street. It is an old emergency exit that has not been in use for the last eight years. This access is a garage door which is permanently monitored by an alarm.

Because the main entrance is only open on workdays between 0700 and 1900 and locked by means of a metal gate and controlled by cameras within the building as well as by those of the Diamond Council, it is nearly impossible to enter the building unseen along the front side, especially outside the normal workdays. The entrance along **Y** street however offers several possibilities to allow entry. During the weekend the garage doors along this entrance are kept open for several hours, which makes it possible to access the parking garage by car or on foot.

To enter the building following the usual procedure, one has to register to obtain a badge from the building security officer on duty. Nevertheless, the investigation has shown that on the same level inside the parking garage, a door offers the possibility to enter the Diamond Center and go directly to the elevators, which would make it possible to descend directly to floor -2 next to the strong room. A door next to the elevators also offers the possibility to descend to floor -2 via the stairways directly.

Within the parking garage, there is a switch box on the ground floor that controls the two overhead garage doors and would allow them to be opened.


The parking garage allowed access directly to the vault without any electronic surveillance. The control for the two steel garage doors could be easily accessed.

Electronic Access Control

In order to access the building via one of the entrances, each tenant or visitor is issued an electronic proximity identification card. There are four different kinds of access cards: visitors, federation, the access card of another building in the diamond quarter, and the access card of the Diamond Center itself. The card is read electronically and registers the time of entering and leaving the facility.



The main entrance into the Diamond Center.

Electronic Monitoring Systems

The building was not alarmed; only the area surrounding the main vault, and within the vault area itself. The following security systems were implemented to provide appropriate protection:

- **Video cameras to monitor the outside of the main vault;**
- **Video camera within the main vault;**
- **Video cameras in the area of the main vault;**
- **Shock and vibration detector on the door of the vault;**
- **Dual-technology (PIR/MCW) sensor within the main vault;**
- **Light level detector in the main vault;**

- **Audio sensor outside of the main vault;**

Access to the Strong Room

The strong room on floor -2 is only accessible Monday through Friday and never during Saturday, Sunday, or holidays. Hours are from 0700 until 1900. Every workday at 0700 the main vault door is opened by the guard on duty, after the alarm has been deactivated. The safe can only be opened by means of a four digit combination and a key. The key for the lever tumbler lock in the vault door is kept in a locked key cabinet in an adjacent room.

Behind the main vault door is a steel gate that presents another barrier to entry into the strong room and is always locked. Only tenants and authorized representatives may request access by calling for assistance with a button mounted on the frame of this gate. The guard on the ground floor main entry point will observe the person requesting access, via a video monitor. Only after he has recognized the person as one of the safe deposit owners will he release the electric lock. The gate will automatically return to the locked position after being opened.





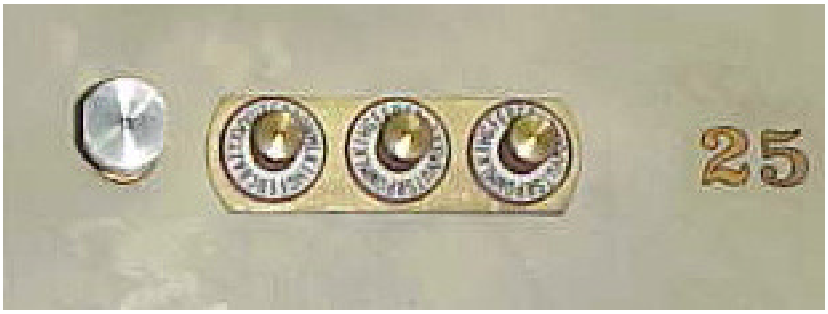


The Lips vault door and barrier gate into the strong room.

The strong room itself is secured with an alarm system consisting of motion sensors, thermal sensors and light detectors. The alarm is controlled by a keypad next to the vault door. A video camera system records all movement into and within the vault. The combination for the vault door is known by four persons, including building management and the guard. The individual safe deposit boxes can only be opened with one unique key and a three-digit code known by the tenant. The key is kept in the possession of the respective safe deposit owners.







Each safe deposit box had a three wheel combination lock and a lever key lock.

When police entered the strong room on the 17th of February 2003, the vault door and the gate were both wide open. Many individual deposit safes were broken into and several documents, bank notes, bags, boxes, jewelry, and other items were spread out on the floor. Physical evidence was gathered at the crime scene from items that were utilized or handled by the perpetrators. Forensic evidence related to the following specimens and types were developed from the crime scene.

Fingerprints and Glove Marks

Members of the technical laboratory detected and registered, by means of dactyloscopic powder, nine fingerprints on the main vault door. Each one of the individual deposit safes was dusted, but no latent fingerprints were discovered. However, technicians did find fragmentary impressions of three different glove marks.

Shoe prints

An envelope was found on the floor of the strong room that had an observable fragmentary shoe print, caused by one of the perpetrators walking over it.

DNA Evidence

A number of items yielded evidence that identified four different suspects from DNA profiles left in the vault. DNA was obtained from evidence within the vault, from the apartment of the ring leader, and from materials retrieved at Machelen. DNA evidence included:

- **Tape that was used on the plastic bags that were used to cover video cameras;**
- **Material that was in the sports bags that was left in the**

strong room;

- **Spare parts for dent puller. All were taped together, from which different DNA profiles were identified;**
- **Food (salami, cheese, wine, yogurt, and other items) at Machelen and at the apartment;**
- **Work gloves with DNA profiles of defendants were found at Machelen;**

In the strong room, a sports bag was found that contained crowbars, chisels, a putty knife, pliers, aluminum colored accessories, bolts, nuts, and miscellaneous implements. The crowbars and the chisels were wrapped in grey tape, and were matched to various defendants.

A panel of foam that was mounted on a metal handle was found, which apparently had been employed to mask the motion sensor. A multicolor work glove was also left just outside the strong room in the elevator hall on floor -2. DNA evidence was also developed from food left by the criminals at the apartment. It was matched to other food items that were found in trash bags left in the field at Machelen. Also, three different traces of gloves found at Machelen were tied to defendants inside of the vault.

Tool Mark Evidence

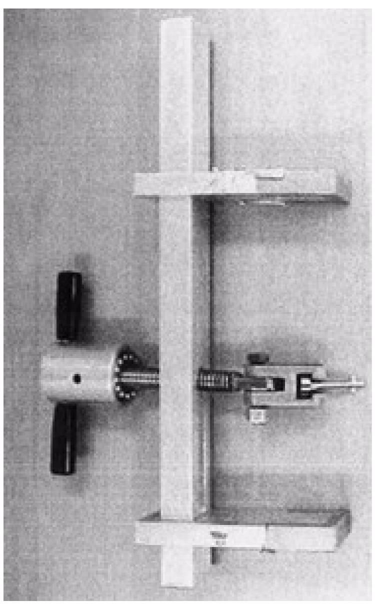
On floor -2 on the left side of the strong room, investigators observed that a door had been forced at the level of the lock. The door provides access to a room where, on the right-hand side, was located a metal key cabinet that contained the key for the lever lock in the vault door. This key cabinet was forced open and the key was removed.

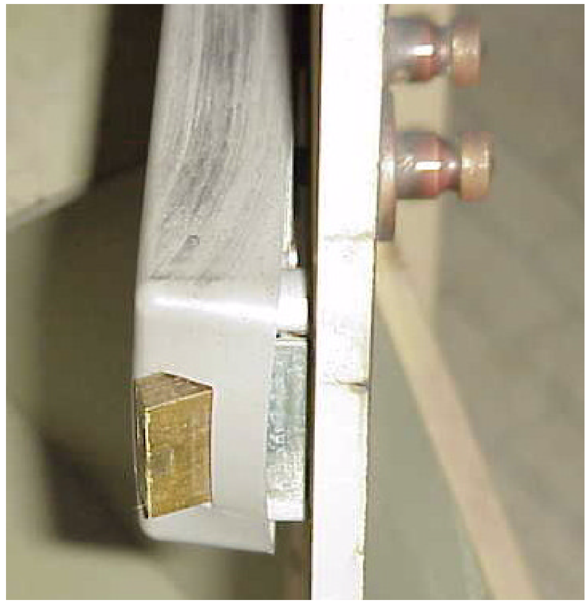


The key for the safe was kept in the small locked box on the wall. This key cabinet was easily opened with force.

In the strong room, approximately 110 individual deposit safes were forced open with a modified dent puller. This was comprised of a steel key that had been inserted into the lever lock of each safe, then reverse pressure was applied against an aluminum brace, causing the bolt for each lock to be bent to the extent that it would clear the strike.





A modified dent puller was utilized to apply reverse pressure to the door of each individual safe deposit box in order to bend the brass bolt. A steel key was inserted into the lock to allow the application of pressure. The dent puller required a number of components, which were found in the woods at Machelen.

Telephone Records

Cellular and other telephone records identified at least four suspects that were in the vault from 2300 until at least 0500 on the night of the burglary. The cell site was identified from where the calls originated.

Bypass of Alarm Systems and Sensors

Thieves entered the building through the parking garage, and used a stairway to get to the main vault on the lower level. There was no electronic monitoring of this route, and thus, the only alarm sensors that were of concern were on the vault door, the balanced magnetic trip to detect its opening, and the internal dual-technology sensor (motion and thermal) within the strong room. It appears that the light level sensor within the vault had been covered with black tape, and the video cameras that were located outside of the vault door and within the vault itself were covered with a plastic garbage bag by the thieves prior to the burglary. The control room that contained video tape recorders and stored media was also not alarmed. Although it is possible that the thieves worked in the dark prior to covering the cameras and sensors, it seems unlikely.

It is believed that a number of separate sensors and systems were bypassed prior to the burglary in order to allow undetected entry:

- **Light level detector;**
- **Dual-technology (motion/thermal) sensor;**
- **Balanced magnetic switch on vault door;**
- **Video cameras, located within and outside of the vault;**

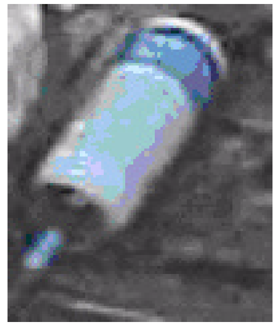
Investigators arriving on scene noted the following conditions immediately after they entered the strong room:

- **The alarm system that protects the strong room was still armed (on);**
- **The light level sensor in the vault has not activated the alarm;**
- **The light level sensor is covered with tape, masking the photoelectric detector;**
- **A cable in the ceiling has been completely stripped, without having been cut, thus indicating that a circuit may have been intercepted or tapped into, and that the burglars were aware of the function of this circuit and avoided tripping an alarm. The alarm circuits are supervised to protect against breaking or tampering;**
- **The balanced magnetic switch on the vault door is not mounted in its original position;**
- **The cameras in the vault, as well as the ones in the hall located on floor -2 are covered with dark plastic bags and sealed with tape.**



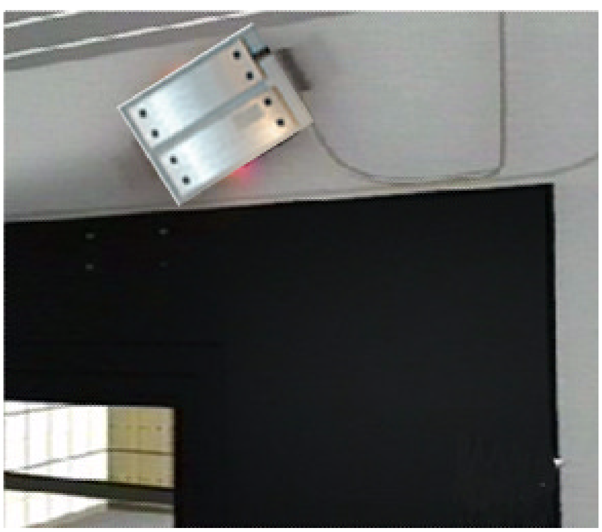
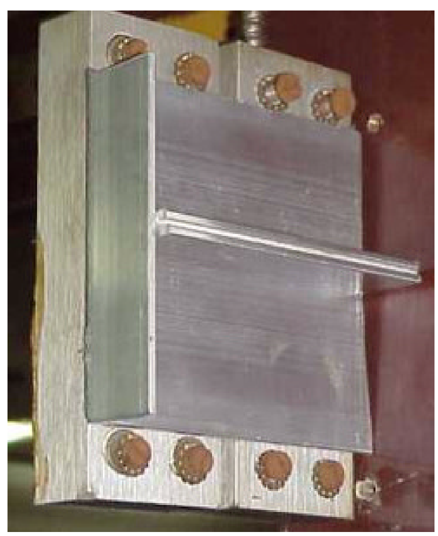
Cabling in an adjoining room were spliced into.

The motion sensor within the vault employs dual-technology and uses a combination of infrared and microwave for reliability. In order for the detector to function properly, body heat (infrared energy) and movement must be detected before an alarm condition is reported. If one of the sensors is disabled, then an alarm will not be detected or reported. An examination of the detector revealed that its housing and lens was covered with a greasy layer of material, believed to be silicone. The chemical will mask the infrared sensor, resulting in a failure to detect thermal energy. It appears that the thieves utilized a large panel of Styrofoam material to defeat the microwave circuitry of the dual-technology detector. It is believed that this material was contained within the storage room adjacent to the vault.

Dual-technology sensor, covered with silicone

The magnetic contacts on the vault door had been moved from their original position, and after making the bolts shorter, they were put back on the vault door with double-sided tape. It was not possible for staff to discover that the screws had been removed prior to the burglary, unless pressure would have been applied to the magnetic switch to insure that it was mounted securely. Prior to the burglary, the thieves removed the magnetic switch and actuating magnet as a pair. The two devices were slid sideways from their normal position. This was accomplished with a hand-made aluminum profile and double-sided tape. In this manner, the function of the switch was bypassed.



Simulation (left) of how the balanced magnetic switch was bypassed by removing both the sensor and actuating magnet and moving it above the vault door. The BMS was affixed to a piece of aluminum with double sided tape.

The light level detector module is a photoelectric cell to sense the presence of illumination. The sensor in the strong room was covered to block any light from reaching it. The sensor and associated alarm processor did not have anti-masking safeguards, so its failure to operate was not detected.



Light sensor, mounted in strong room.

A seismic detector was also mounted on the main vault door, which is designed to react to any mechanical vibrations. This sensor would not be affected by attacks on individual safe deposit boxes, and would not have been activated by normal opening of the

vault door.



Lips safe door, showing combination lock (left), bolt actuating handle (right) and lever lock (center)

BYPASS OF LOCKS AND SAFES

In order to open the vault door, both the combination lock and lever lock had to be compromised.

Lever lock on main vault door

The vault door could only be opened by the simultaneous entry of the combination and use of the key to turn the lever lock. With regard to the lever lock, this was not a problem because the key was kept in a key cabinet in an adjoining room. The thieves entered that room and opened the container with force. It is interesting that the simple wafer lock was not picked on this box.

Combination lock on main vault door

The Lips combination lock requires four numbers in sequence to properly align the wheel pack in order to open the vault. A spy proof dial restricts viewing of the entered code. It is clear that the thieves had the combination prior to approaching the strong room, given the amount of preparation before the crime. It would be highly improbable that two years of planning would all be jeopardized if the vault could not be unlocked.

As described elsewhere in this text, there are several ways that the combination could have been obtained by the burglars, although many procedures can be eliminated in this investigation. Section **36_2.1** details the known methods of compromising the combination of a lock. From this list, an analysis of the Diamond Center burglary can provide possible means that the Lips combination lock was opened.

- **Capture of combination;**
- **Capture of remote authorization or log in;**
- **Decoding the lock;**
- **Deduction of combination through physical means:**
    - **Paper marking;**
    - **Fingerprints;**
- **Audio capture;**
- **Employee compromise;**
- **Position of dial after entry of combination;**
- **Factory tryout combinations;**
- **Drilling;**
- **Removal of the access panel and cover plate of the lock and decode the wheel pack;**
- **Manipulation, using sound, feel, and touch;**
- **Radio frequency energy interception;**
- **Radio frequency interference or disturbance;**
- **Radiographic imaging;**
- **Reversal of day locking;**
- **Robot dialing;**
- **Simulated burglary or maintenance to secure information;**
- **Observation of combination through surveillance;**
- **Vibration;**
- **Wear of internal components;**
- **User negligence;**
- **Use of the Mas-Hamilton Soft Drill manipulation system.**

In this case one or more of the following modes of attack would appear most likely;

- **Inside information from an employee, vendor, contractor (the most likely);**

- **Covert recording of the combination during an authorized opening of the safe. This would require the placement of a video camera directly above the lock and a method to record the movement of the dial. This would be possible with a wired or wireless video link and a pinhole camera, which could have been stored within one of the safe deposit boxes within the strong room;**
- **Obtain the combination from the locksmith that services the vault;**
- **Compromise the database that is likely maintained by the locksmith that performs routine maintenance, or who recently reset the combination;**
- **The combination was compromised by a former employee. After the employee left the Diamond Center, the code was not changed;**
- **The combination was provided by a current employee. Extensive interviews by police failed to develop any leads with regard to this possibility;**
- **Use of a recording medium that is placed on the dial, and which would document the number of turns in each direction and stop position for each revolution. The combination could potentially be extrapolated from this raw data;**
- **Poor security procedures upon the part of one or more employees who had possession of the combination. It was determined by investigators that one of the authorized individuals having the combination at the Diamond Center kept the numbers written on a piece of paper in his wallet. It is possible that this information was obtained by someone having access to his wallet;**
- **Observance of the opening of the safe in order to determine the left-right-left pattern. This could be correlated with other information to make derivation of the combination simpler;**
- **Use of a known or probable sequence of numbers, which would be easy to determine by trial and error by thieves (highly unlikely);**
- **Failure to reset the original factory combination (did not occur);**
- **Radiographic imaging.**

The following entry possibilities would appear least likely:

- **Manipulation;**

- **Auto robot dialer;**
- **Access to the combination lock was obtained during normal business hours by the thieves. This could potentially have been possible if a tenant had direct access to the service panel of the vault door. Assuming that the key that allows removal of this panel is standard to all Lips vaults, then direct access to the lock and a viewing of the wheel pack would have been possible. It would then be a simple matter to determine the gate position of each of the four wheels;**
- **Use of sound recording device to derive rotational information from the dial. Potentially, the rotations could be correlated to provide a rough indication of the individual numbers of the combination;**
- **Observance of the opening of the safe in order to determine the left-right-left pattern for opening. This could be correlated with other information to make derivation of the combination simpler;**
- **Use of a known or probable sequence of numbers, which would be easy to determine by trial and error by thieves (highly unlikely);**
- **Failure to reset the original factory combination (did not occur);**





Four-wheel combination lock on Lips safe

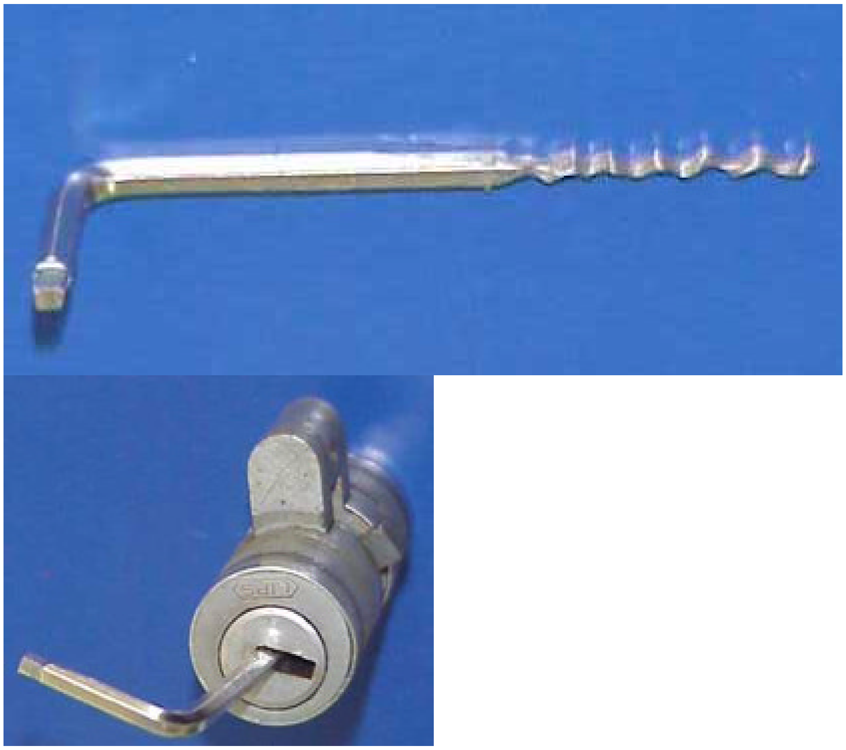
Individual safe deposit boxes

Individual safe deposit boxes were opened by using a modified dent puller, described in **chapter 32.**

A special steel key was manufactured that would fit into the lever lock on each box. This would provide the required link to the vault door that was needed to apply a pulling pressure against the lock and its bolt. Upon the application of sufficient force, the brass bolt could easily be bent inward to allow it to clear the strike and the edge of the enclosure. The thieves were able to open over 100 safe deposit boxes during the five hours that they were inside the main vault.

Lips Dimple Locks to Secure all Doors

Lips dimple pin tumbler locks are used on all doors within the facility. This system would utilize a positional master keying system and thus it would be very difficult to decode the top level master key. For this reason, picking of each lock was required. It is believed that individual locks were picked, using a modified rake picking tool that was found with the materials left by the thieves at Machelen. This tool, approximately 6.5 cm in length, was fashioned from an Allen wrench and would be quite easy to fabricate. The lock is relatively simple to bypass by using raking techniques with the tool.



Rake picking tool for Lips lock, fashioned from an Allen wrench

In the presence of the responsible person of the Diamond Center building, the rake pick was utilized by investigators to open several locks, including the door on the ground floor between the enclosed parking garage and the hall, and the lock to the storeroom on floor -2 that is adjacent to the main vault. Investigators believe that this tool was used to open all required locks within the facility, rather than a compromise of the master key system.

Key cabinet

The locked cabinet that contained the key for the lever lock on the main vault door was forced open without difficulty. It was secured with a wafer lock which could have easily been picked.

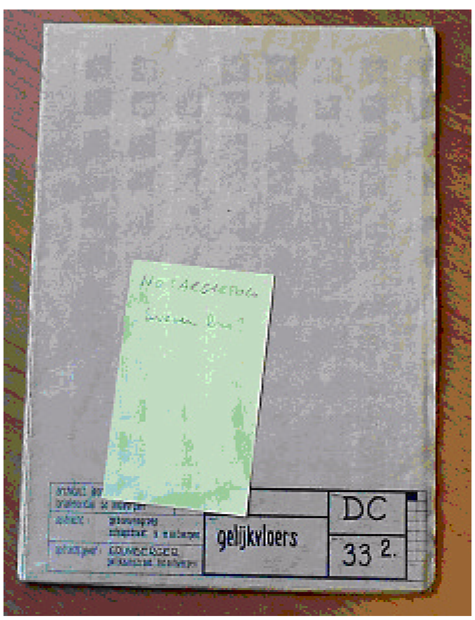
Security and Storage of Video Cassettes

Video recording equipment and tape storage is within the security control room at the main entry point to the building. No alarm system protects this area. Investigators noted that the video cassettes that were recorded from the 10th, 15th, and 16th of February were missing. It is believed that certain preparations

were made on February 10 by the thieves, which necessitated the removal of that tape. These dates could indicate that at least one of the video cameras had not been masked prior to the burglary, and/or that the thieves initially worked in the dark until all cameras were disabled. It is simply not known.


Control room of Diamond Center.

The criminals also took the video cassettes that would have contained images that were captured during the night of the burglary; thus, there was no record of the movements inside the building or the parking garage.



Videotape package and note.

Adjacent Storeroom Areas

An adjacent storeroom is located on floor -2 immediately opposite the main vault. The access door of this room has two ventilation grilles. Along the inner side of the door these grilles had been sealed with grey tape. The guard who discovered the burglary declares that, at the moment of his discovery, the access door of the storeroom stood open. Once inside the storeroom, investigators found several paint buckets that had been used to stop the iron gate at the entrance to the strong room from closing automatically. A pair of work gloves that do not belong to any employee of the Diamond Center were also found, as well as foam, tape and rubbish bags. It appears very likely that the thieves were hiding in this storeroom prior to the theft. The burglars may also have been using this storeroom while preparing for the burglary.

They may also have let themselves into the building and storeroom during the day on Saturday, and may have waited until Saturday evening before entering the strong room. This would have allowed the thieves to enter the vault area without worrying about tripping any alarm systems within other parts of the building, if sensors had been active.

Items Recovered at Machelen



Wooded area near Machelen.

Trash bags, boxes and other objects were hidden in a remote area approximately thirty miles from Antwerp. It is believed that the thieves left the items while on their way to Italy. Among the items that were secreted were empty cardboard jackets for Sony video cassettes, similar to the type that was used at the Diamond Center. Empty spools of video tape from cassettes were also found near the cardboard boxes. It is clear that the magnetic tape had been removed from the cassettes by the burglars. Portions of other rolls of magnetic tape were recovered near the hiding spot for the majority of items. All the recovered tapes were taken to SONY headquarters for analysis in an attempt to view the images. The results of this investigation were negative. A number of pieces of evidence from this location, including keys, tapes, receipts, documents, food, and DNA provided critical evidence that linked the perpetrators to the crime scene.

MISTAKES THAT WERE MADE: WHAT WENT WRONG

A review of the relevant issues involved in this case reveal a number of apparent failures in security, both physical and procedural. The analysis of this investigation can provide valuable insight for those charged with ensuring appropriate security for their own facilities. In this case, a number of problems contributed to the success of the burglary. Although many of the issues have been discussed throughout this text, it is important to summarize those factors that might have prevented this crime from occurring. The author has dealt with investigations involving theft for the past thirty years. In most instances, the opportunity to steal was created by a failure to establish and enforce appropriate operational procedures, as well as the failure to utilize the proper hardware to assure the requisite level of protection. At the end of the day, seven thieves were able to steal more than $100,000,000 in diamonds in part because of lapses in security that might have been prevented. The thieves selected their target, gathered information over a two year period, and executed their plan. They would not have been caught but for two mistakes.

Security Hardware: Locks and Keys

- **The Lips door locks are inadequate for critical areas. Their pick resistance is minimal. High security cylinders should have been installed;**

- **The key to the main vault should never have been left in a locked box adjacent to the strong room. There was essentially no security to protect this key. The result was that the main vault was less secure than if dual locking had been in effect. Proper procedure requires that one individual have the key, and another individual have the combination.**

- **The safe deposit vaults should have been analyzed for bypass and protected against the use of dent pullers;**

Security Hardware: Alarms

The bypass of alarm system sensors was critical to the success of the plan. Until one or more of the perpetrators provides a full statement of the crime, all of the facts will never be known. Some of the listed issues did not contribute to the theft in this case, but could have. The author believes that the following failures occurred:

- **The main vault door should have been protected by a shock and vibration sensor that is supervised;**

- **It appears that there was no smoke detector or rate of rise detector to protect access to the main vault door from a thermic lance or torch;**

- **The light level sensor was bypassed by masking the photoelectric cell. Evidently no anti-masking circuitry or software was operational, with the subsequent result that when the sensor was bypassed, nobody was aware of it;**

- **Failure to utilize anti-masking dual-technology sensors;**

- **Balanced magnetic switch was bypassed by physically removing it from the vault door;**

- **Failure to utilize anti-pry mounting plate with the balanced magnetic switch. When the sensor and actuating magnets were temporarily removed from the vault door, and then reapplied with double-sided tape, this movement would have been detected if the sensor had been supervised;**

- **Failure to mount the BMS with security screws, which would have**

made removal more difficult;

- **Failure to inspect, on a daily basis, all of the alarm sensors, and to test for proper operation. This likely would have revealed the bypass of all of the critical sensors.**

- **Failure of Operational Procedures;**

- **It appears that control room personnel failed to adequately monitor the video surveillance system. Personnel may have been detailed to other tasks and did not have time to watch monitors for unusual activity;**

- **Failure to maintain videotapes in a secure, off-site environment, so that critical evidence could not be removed, as occurred in this case;**

- **Failure to adequately assess and protect entry and exit points to the building, which allowed entry without tripping any alarms;**

- **Failure to properly alarm all access points to the vault. In this case, it appears that there was complete access to the vault entrance without detection. The thieves could enter directly from the parking garage, through two flights of stairs, without ever encountering an alarm sensor;**

- **There was no alarm system to protect the control room and critical systems control functions;**

- **There was no alarm to indicate entry or exit from the adjoining parking garage;**

- **There was no security in controlling the electric garage doors. Keys were openly available to the thieves;**

- **Storage rooms were located adjacent to the main vault. These rooms were not adequately secured and allowed access to the criminals for storage of implements, use of materials in the storeroom, and a hiding place for the thieves;**

- **There evidently was no standard procedure to conduct routine inspections of all areas to insure that no hardware had been**

tampered with;

- **No rigid cable runs were utilized to protect critical circuits in ceilings;**

Can it be said that the Diamond Center could have prevented this burglary? Maybe. It was their responsibility to provide adequate security to protect the valuables of its tenants in its vault. Even if the thieves had initially worked in the dark and used low light level binoculars to enter the vault and disable cameras and light sensors, there were four critical failures in the author's view which enabled the theft.

- **No alarm on the access route to the vault;**
- **Failure to adequately protect the balanced magnetic switch which was the primary monitor of the status of the vault door;**
- **Failure to remove and protect the vault key from unauthorized access;**
- **Failure to employ a motion detector in the vault which could not be masked.**

If the thieves had the combination to the vault, as the author speculates, then the single most critical issue was the BMS, and the failure of staff to detect or observe its movement prior to the crime. Unless the thieves were able to bypass this circuit, then this was the critical component which, if not compromised, would have signaled an intrusion. And, of course, if the circuit could have been bypassed, then this would have constituted another failure in security.

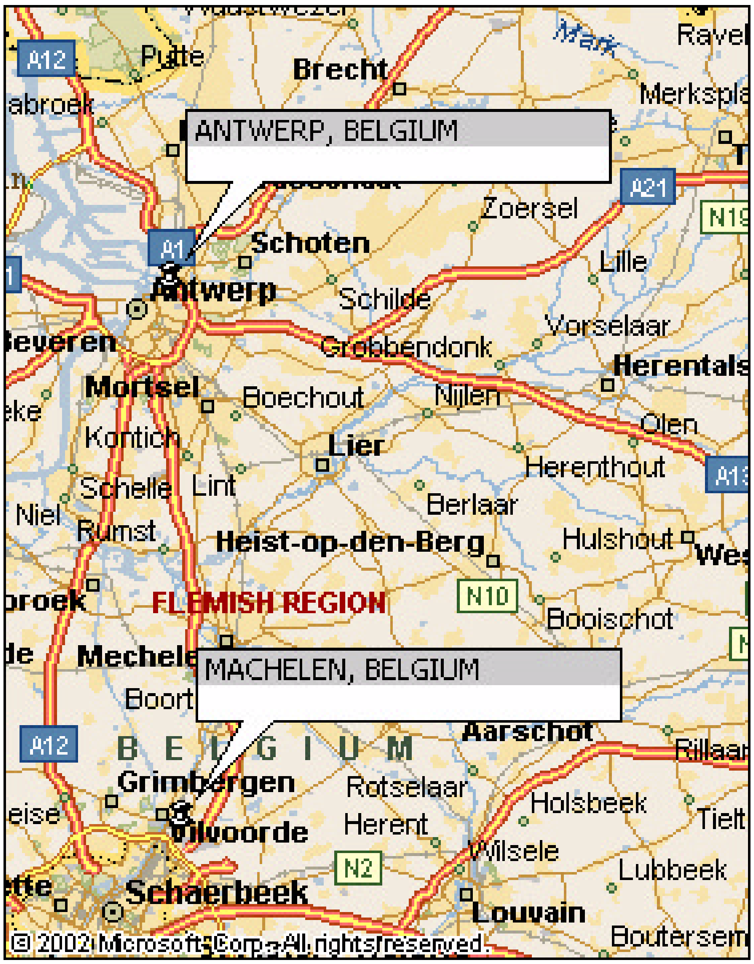
How They Got Caught

This theft would likely have remained unsolved but for two critical mistakes on the part of the thieves, which rapidly lead to their identification and the arrest of the gang leader. The burglary occurred late Saturday evening, when at least four thieves entered the main vault at about 2300 hours. They worked for more than five hours emptying over one hundred safe deposit boxes of their contents. They gathered up their tools and other items from the vault floor and placed the materials into trash bags and boxes, which they took with them.

It is estimated that they left the Diamond Center about 0600 on Sunday morning, and went to the apartment rented by one of the gang members in Antwerp. There, it is believed they presorted

their loot, had some food, wine, and cheese. They gathered some of the garbage in the apartment before they left and headed for Italy by car.

About thirty miles south from Antwerp, they stopped at a remote piece of property in Machelen, which was heavily wooded. They thought that because it was such a remote place that they would be secure in burying their trash there.



On Monday morning, the staff at the Diamond Center went to open the safe and found the contents strewn all over the floor. Almost at the same time, the landowner, Mr. Floordambos, found the trash bags and other materials that had been left by the thieves. It seems that he had had problems with others leaving garbage on his property, so he was especially vigilant. When the trash bags and other items were examined, the landowner noticed that there were diamond envelopes that were identified with the names of

merchants in the Diamond Center. He heard the news accounts of the spectacular theft and called police. They responded to the scene, and were able to rapidly determine that the material on his property was from the crime scene. Torn pieces of a receipt amongst the trash led police to identify one of the perpetrators (the ring leader of the gang). He was the individual that had rented an office in the Diamond Center. His associates were rapidly identified from the Italian police.

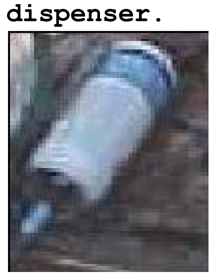
One week after the theft, on Friday evening, this individual returned to Antwerp and to his office at the Diamond Center, where security was on alert. They notified the Diamond Squad of the Belgium Federal police, who responded and arrested this individual. A search warrant was executed on his apartment, where incriminating evidence was found, including several diamonds in the carpeting which are believed to have come from the Diamond Center. It is thought that the gang leader returned to Antwerp for two reasons: to collect the remaining materials in the apartment, and to make an appearance at the Diamond Center so that there would be no suspicion that he was the only tenant missing after the burglary.

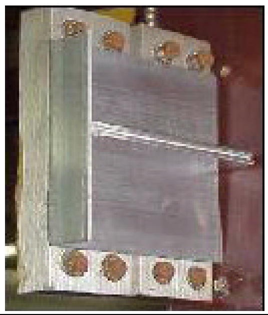
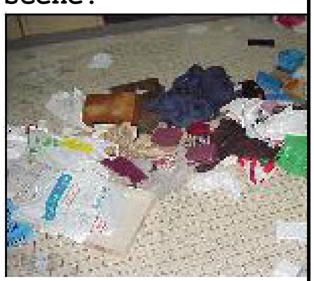
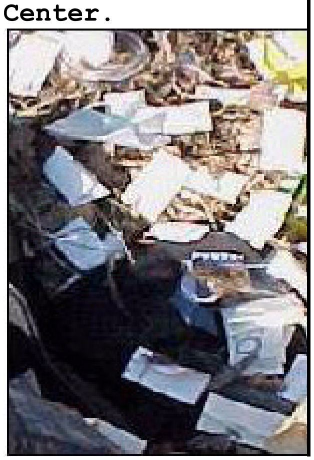
International arrest warrants were issued for the other gang members, who are awaiting arrest and extradition from Italy. Police estimate that more than $100,000,000 in diamonds were stolen. None have been recovered.

Evidence Links

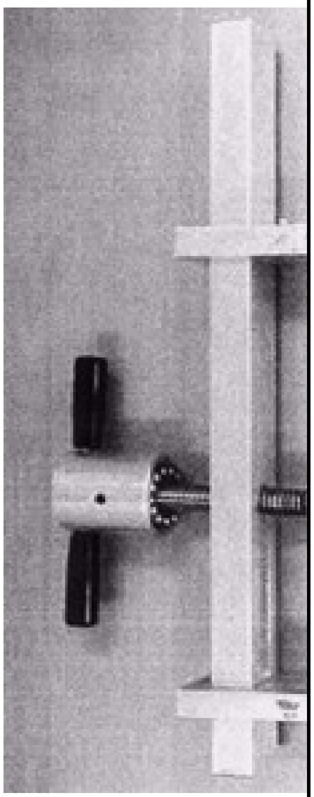
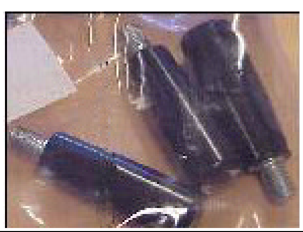
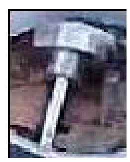
The following critical pieces of evidence were discovered at the crime scene, at the remote location near Antwerp, and at the apartment of one of the thieves. A full-size diagram of individual pieces of evidence and their relation to the crime scene is also accessible through the link.

ANTWERP DIAMOND CENTER BURGLARY: EVIDENCE LINKS			
EVIDENCE FOUND IN VAULT AT DIAMOND CENTER		**EVIDENCE FOUND OUTSIDE OF ANTWERP**	**EVIDENCE AT APARTMENT OF SUSPECT**
		Gloves	
	Sports bag.		
	Alligator clips for holding electrical wires, found in sport bag in vault.	**Alligator clips for holding electrical wires, found in garbage bags.**	

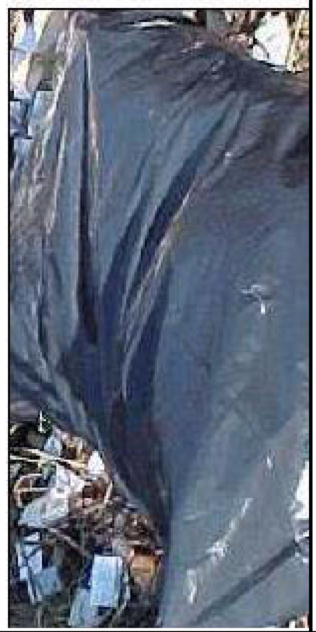
	Isomo (Styrofoam) sheets to defeat the microwave sensor.		
	Similar emeralds to those found in apartment and at Machelen.		**Vacuum bag, with diamonds and green emeralds.**
		Green emeralds in garbage sacks, which were from same lot as those in apartment.	**Diamonds and emeralds in carpet.**
		Food items matching those in apartment.	**Salami, wine, yogurt, cheese.**
	Black tape on light sensor and covered with trash bag. 		
	Greasy material on PIR alarm sensor, identified as silicone. 	**Silicone dispenser.** 	

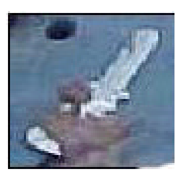
Balanced magnetic trip and magnet pair, mounted on vault door. 	**Balanced magnetic trip, which was removed from vault door, then held together as a pair with double-sided tape, and repositioned.** 	**Similar magnets.** 	
	Steel keys.	**Steel keys.**	
	Debris, wrappers, papers, empty and torn envelopes that were left at scene. 	**Several documents and folded notes, banknotes, related to the Diamond Center.** 	

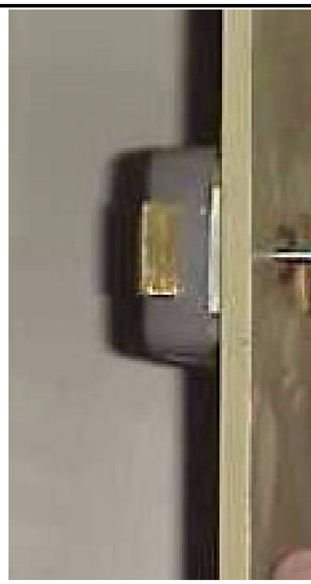
	Sony videotape used for surveillance of building. Missing cassettes from 2/10/2003 and 2/15/2003. 	**Empty Sony video cassette cases.** 	

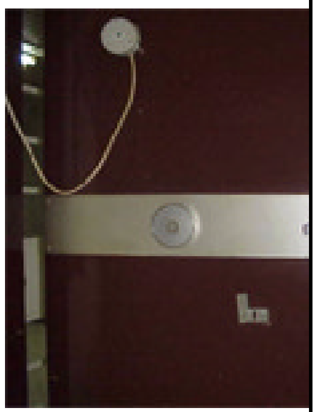
Model of dent puller, used to open safe deposit boxes. 	**Forced open safe deposit boxes.**  **Components of dent puller, handles.** 	**Components of a dent puller that can open safe deposit boxes.**    	
	Grey rubbish bag on cameras inside of vault and exterior to vault door.		

<table>
<tr><td></td><td>**Roll of grey tape, grey rubbish bag with grey tape, ventilation grilled access, door to storeroom sealed with grey tape.**</td><td>**Nearly empty roll of grey tape.**

</td><td></td></tr>
<tr><td></td><td>**Lips dimple locks in building.**
</td><td>**Picking tool for Lips lock.**

Lips keys.
</td><td></td></tr>
</table>

		**Steel keys for use in the dent puller.** 	

Locked key cabinet in room adjacent to vault. 	**Lever lock on vault door (in middle of the door).**  	**Bitting portion of lever key.** 	
	Shoe prints.		
	Fingerprints and glove marks.		
	DNA evidence.		
	Tool marks.		

MASTER PATENT BIBLIOGRAPHY

The following listing provides a master index of United States

and British patents that were researched, or cited within the text. The full text of all patents may be found at **www.security.org**. Organization is by chronological patent number, and by classification.

PRIMARY INDEX BY PATENT NUMBER

7917	SWIVEL TYPE KEY	2/1851
7918	HYDRAULIC RAM	1/1851
14958	LOCK AND KEY	5/1856
99013	DISC TUMBLER LOCK	1/18/1870
103837	LEVER LOCK	6/7/1870
135600	WARDED KEY IMPROVEMENT	2/1873
234057	WARDED KEY	11/1880
414720	P&F CORBIN RING SLEEVE	11/1889
457753	ANTI-PICK KEYWAY	8/11/1891
947913	LOCKING DEVICE	2/1910
1202019	REFERENCE	3/27/28
1254990	REFERENCE	1/29/18
1287882	PICK RESISTANT LOCK	12/1918
1345406	REFERENCE	7/6/20
1403753	REFERENCE	1922
1639919	PICK TOOL, IMPACT	8/23/27
1667223	PICK TOOL, IMPACT	4/24/28
1687649	REFERENCE	10/16/28
1775140	REFERENCE	9/6/50
1826337	REFERENCE	1932
1853525	PROGRAMMABLE LOCK	6/14/32
1860712	PICK RESISTANT LOCK	5/32
1863525	LOCK	6/14/32
1899739	REFERENCE	1933
1944006	IMPACT PICK	1/34
1965336	REFERENCE	1934
1977362	REFERENCE	10/16/34
1990972	REFERENCE	2/12/35
1991151	KEY DECODER	2/12/35
1994532	IMPACT PICK GUN	1935
2015322	CODE FINDING KEY	9/35
2023945	REFERENCE	12/10/35
2027009	REFERENCE	1936
2055129	REFERENCE	9/22/36
2059129	ANTI-PICK LOCK	10/36
2059376	PICK TOOL, TUBULAR	11/3/36
2064818	PICKING DEVICE	12/22/36

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2070233	CYLINDER LOCK	2/9/37
2070342	PICK TOOL, TUBULAR	3/14/36
2087423	PIN DECODER	7/20/37
2158501	TUMBLER LOCK	8/38
2194959	ANTI-PICK LOCK	3/26/40
2268654	REFERENCE	1/6/42
2279592	PICK TOOL, DOUBLE SIDED	4/14/42
2281714	ANTI-PICK LOCK	5/5/42
2283489	CYLINDER LOCK	5/42
2309677	PICK TOOL, IMPACT GUN	2/2/43
2338768	LOCK DECODER	1/11/44
2343041	BORESCOPE	2/29/44
2350250	CAR OPENER	1944
2424278	REFERENCE	7/22/47
2565254	POWER LOCK PICK	8/21/51
2575674	COMBINATION LOCK	3/49
2625032	COMBINATION SCRAMBLER	1/13/53
2629249	ANTI-PICK LOCK	2/24/53
2655808	PICK TOOL, TUBULAR	10/20/53
2673457	EXPOSED SHACKLE PADLOCK	3/30/54
2673458	PADLOCK	3/54
2674457	COMBINATION PADLOCK	3/54
2720032	LOCK DECODER	10/11/55
2727312	LOCK DECODER	12/20/55
2763027	IMPRESSION DECODER	1956
2775112	PROGRAMMABLE PADLOCK	12/25/56
2791840	REFERENCE	1957
2814940	COMBINATION PADLOCK	12/3/57
2830447	PROGRAMMABLE PADLOCK	4/15/58
2831447	PROGRAMMABLE LOCK	4/58
2852928	LOCK ACTUATOR	9/23/58
2907237	AUTOMOBILE UNLOCKING	1959
2974517	COMBINATION LOCK OPENER	3/61
3024640	X-RAY PROTECTIVE LOCK	3/13/62
3087050	BORESCOPE	4/23/63
3149487	PICK TOOL, BARREL LOCK	9/22/64
3206958	INTERCHANGEABLE LOCK CORES	9/21/65
3206959	INTERCHANGEABLE LOCK CORES	9/21/65
3251206	PICK TOOL, TUBULAR LOCK	5/17/66
3264908	VIBRATING PICK	8/9/66
3267706	PICK PROOF AXIAL LOCK	8/66
3270534	PADLOCK	9/6/66
3270538	TAMPER PROOF AXIAL LOCK	9/66

3330141	RESETABLE KEY	7/11/67
3367156	LOCK CYLINDER ASSEMBLY	2/6/68
3402581	TELEPHONE LEVER LOCK	9/24/68
3413831	ROTARY CYLINDER LOCK	12/3/68
3438290	AUTOMOBILE OPENING TOOL	4/15/69
3452562	LOCK PICK HOLDER	1969
3475934	LOCKOUT ASSEMBLY	11/4/69
3499302	MEDECO SIDEBAR LOCK	3/10/70
3499303	MEDECO SIDEBAR LOCK	3/10/70
3533253	CHANGEABLE COMBINATION	10/13/70
3541819	AXIAL LOCK	11/24/70
3572070	PROGRAMMABLE LOCK	3/23/71
3603123	PIN TUMBLER LOCK	9/7/71
3604231	PICK PROOF LOCK	9/71
3611763	MAGNETIC CARD LOCK	10/12/71
3633393	MAGNETIC LOCK	1/11/72
3664211	CAR LOCK RELEASE	1972
3722240	MEDECO CYLINDER LOCK	3/73
3738136	MASTER KEYING AXIAL LOCK	6/12/73
3762193	PICK RESISTANT LOCK	10/2/73
3813906	AXIAL LOCK	1/4/74
3819221	VEHICLE DOOR OPENER	1974
3827151	PIN DECODER	8/6/74
3834197	MAGNETIC CARD LOCK	9/10/74
3837197	DOUBLE BITTED LOCK	9/74
3868838	LOCK COMBINATION CHANGER	3/4/75
3916657	AXIAL PIN TUMBLER LOCK	11/4/75
3948065	CYLINDER LOCK	4/6/76
3983724	PROGRAMMABLE PADLOCK	10/5/76
3985010	MEDECO DECODER	10/12/76
3987654	MEDECO DECODER	10/26/76
3990275	TAMPER PROOF PADLOCK	11/76
4006613	LOCK PICK MECHANISM	2/8/77
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4047406	ANTIRAP LOCK MOUNTING	9/13/77
4056956	SAFE LOCK DECODER	11/77
4069407	UNDERWATER CUTTING ROD	1/17/78
4069694	RESETTABLE LOCK ASSEMBLY	1/24/78
4073166	MAGNETIC LOCK PICK	1978
4074548	LOCK CYLINDER ASSEMBLY	2/21/78
4078406	PICK RESISTANT LOCK	3/14/78
4094176	PICK TOOL TUBULAR LOCK	6/13/78
4133194	MAGNETIC LOCK	1/9/79
4144778	CAR OPENER	1979
4149394	CARD LOCK	4/79

4156375	PICK, IMPACT, ELECTRIC	5/29/79
4182947	UNDERWATER CUTTING ROD	1/8/80
4185482	DECODING MECHANISM	1/29/80
4186577	KEY BLANK PICK TOOL	2/5/80
4229959	MAGNETIC LOCK READER	10/28/80
4266488	RELOCKING DEVICE, SAFES	5/12/81
4300416	IMPRESSIONING TOOL	11/17/81
4375159	PROGRAMMABLE LOCK	3/1/83
4376382	RESETTABLE LOCK ASSEMBLY	3/15/83
4386510	KEY-CHANGEABLE LOCK CORE	6/7/83
4400956	IMPRESSIONING TOOL	8/30/83
4404823	VIEW LIMITING DIAL	9/20/83
4433563	ELECTRONIC LOCK DECODER	2/84
4444034	PULL RESISTANT LOCK CORE	4/24/84
4457191	PICK TOOL, LEVER LOCK	7/3/84
4462230	PROGRAMMABLE LOCK	7/31/84
4470275	SECURITY ENCLOSURES	9/11/84
4507944	MAGNETIC LOCK	4/2/85
4517746	WAFER DECODER	5/21/85
4535546	LOCK ELEMENT DECODER	8/20/85
4549176	INDUCED FIELD LOCK	10/22/85
4602253	TRANSDUCER LOCK	7/22/86
4606204	PICK GUN, VIBRATING	8/19/86
4608886	AUTO UNLOCK TOOL	9/2/86
4616491	ELECTRONIC LOCK	10/14/86
4617813	TUBAR PICK TOOL	10/21/86
4655102	AUTO UNLOCK TOOL	4/7/87
4667494	SIDEBAR DECODER	5/26/87
4669394	ELECTRONIC SAFE	2/87
4676083	LOCKING MECHANISM	6/30/87
4683783	AUTO UNLOCK TOOL	8/4/87
4684945	ELECTRONIC LOCK	8/4/87
4712398	ELECTRONIC LOCKING	12/15/87
4723427	MEDECO SIDEBAR LOCK	2/9/88
4730467	COMBINATION LOCK	3/15/88
4745784	ELECTRONIC DIAL LOCK	5/24/88
4766433	OPTICAL CARD READER	8/23/88
4802353	ELECTRONIC DOOR LOCK	2/7/89
4802354	HIGH-SECURITY AXIAL LOCK	2/7/89
4803860	COMBINATION LOCK DECODER	2/89
4817406	IMPRESSIONING TOOL	4/4/89
4836000	LEVER TUMBLER LOCK	6/6/89
4856309	PIN TUMBLER LOCK	8/15/89
4866962	ELECTRONIC KEY LOCK	9/19/89
4868409	VEHICULAR ANTITHEFT	9/19/89

4868559	OPTICAL KEY READER	9/19/89
4887445	ELECTRONIC LOCK	12/19/89
4891636	ELECTRONIC KEYLOCK SYSTEM	1/2/90
4901545	ELECTROMECHANICAL LOCK	2/20/90
4905490	ELECTRONIC DECODER	3/90
4966021	REPROGRAMMABLE LOCK	10/30/90
4972694	ELECTRIC STRIKE	11/27/90
4977767	EVVA WAFER LOCK	12/18/90
4977768	PICK RESISTANT AXIAL LOCK	12/90
5003801	PROGRAMMABLE KEY	4/2/91
5010750	MAGNETIC LOCK CYLINDER	4/30/91
5017851	COMBINATION LOCK DECODER	5/91
5020345	ELECTRONIC LOCK	6/4/91
5043593	OPTICAL THEFT SYSTEM	8/27/91
5058404	PUSH-BUTTON LOCK	10/91
5058465	IMPRESSION KEY HOLDER	10/91
5061923	ELECTRONIC COMB LOCK	10/29/91
5079936	HIGH-SECURITY LOCK	1/92
5083122	PROGRAMMABLE LOCK	1/21/92
5083362	VEHICLE ANTI THEFT	1/28/92
5086631	DISC CYLINDER LOCK	2/11/92
5094093	ELECTRONIC LOCK	3/10/92
5109684	CHANGEABLE PADLOCK	5/5/92
5133202	DECODING TOOL	7/92
5172578	DECODING TOOL	12/92
5224365	SIDEBAR LOCK DECODER	7/93
5325691	SIDEBAR LOCK PICK TOOL	7/94
5355701	METHOD OF DECODING	10/94
5402661	FORD SIDEBAR CYLINDERS	4/4/95
5454245	REMOVING SIDEBAR LOCK	10/3/95
5956984	LOCK PICKING APPARATUS	9/28/99
5987946	LOCK PICKING APPARATUS	11/23/99
6041629	LOCK PICKING APPARATUS	3/28/00
6082159	POCKET LOCK PICK	7/4/00
6134928	DECODING LOCK CYLINDERS	10/24/00
6138486	LOCK PICKING APPARATUS	10/31/00
6148652	DISC TUMBLER PICKING TOOL	11/21/00
6151936	APPARATUS FOR LOCK PICK KIT	11/28/00
6173595	LOCK PICKING APPARATUS	1/16/01
GB 2069589	SAFE LOCKING MECHANISM	1/30/81
GB 2112055A	ELECTRONIC LOCK	1982
GB 2114649	SAFE LOCKING MECHANISM	2/11/82
GB 2119011	SAFE LOCKING MECHANISM	4/8/83
GB 2151295	MAGNETIC LOCKS	12/3/84

GB 2153406	ANTI-DRILL BARRIER	8/21/85
GB 2155988A	ELECTRONIC LOCK	1985
GB 2158870A	ABLOY ELECTRONIC LOCK	11/20/85
GB 2172931	THERMAL RELOCKER	10/1/86
GB 2174452A	INDUCED FIELD LOCK	11/5/86
GB 2179094	SAFE LOCKING MECHANISM	2/25/87
GB 2197362	ANTI-DRILL BARRIER	5/18/88
GB 2214226A	MAGNETIC LOCK	9/31/89
GB 2241983	LEVER LOCK	2/91
GB 2252356	INDUCTIVE CODE TRANSFER	12/18/91
GB 2264531	LEVER LOCKS	2/24/93
GB 2273128	INDUCTIVE LOCK	12/18/91
WO 88/03594	INDUCED FIELD LOCK	5/19/88
JA0051298	MEDECO LOCK DECODER	4/25/77

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4056956	COMBINATION LOCK DECODER	11/77
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4803860	MANIPULATION MACHINE	2/89
4905490	LOCK COMBINATION DECODER	3/6/90
5017851	MANIPULATION MACHINE	5/91

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GB 2197362	CHUBB PLANET SAFE	1988
GB 1513609	CHUBB SAFE PATENTS	
GB 1427033	"	
GB 1103665	"	
GB 2231086	"	
GB 2233993	"	
GB 2196376	"	

ANTI-PICK LOCK MECHANISMS

14958	BANK LOCK	5/1856
24709	REFERENCE	7/1859
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1860712	PICK RESISTANT LOCK	5/32
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2673457	EXPOSED SHACKLE PADLOCK	3/30/54
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2814940	EXPOSED SHACKLE PADLOCK	12/3/57
2852928	COMBINATION LOCK ACTUATOR	9/23/58
3024640	X-RAY PROTECTIVE COMBINATION	3/13/62
3059462	CONSTRUCTION KEY SYSTEM	10/23/62
3270534	PADLOCK	9/6/66
3270538	TAMPER PROOF AXIAL LOCK	1966
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3402581	LEVER TELEPHONE LOCK	9/24/68
3499302	TWISTING TUMBLER	3/10/70

3499303	MEDECO	3/70
3533253	CHANGEABLE PADLOCK	10/13/70
3541819	AXIAL TUMBLER LOCK	11/24/70
3587081	PICK RESISTANT LOCK	6/22/71
3590615	ANTI PICK LOCK	7/6/71
3604231	PICK PROOF LOCK	1971
3633393	MAGNETIC CYLINDER LOCK	11/72
3656328	REFERENCE	4/72
3681955	REFERENCE	8/72
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3722240	MEDECO ROTARY TUMBLER	1973
3762193	PICK RESISTANT LOCK	10/73
3765199	ANTI PICK DEVICE	10/16/73
3768284	MAXIMUM SECURITY LOCK	10/30/73
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3813906	AXIAL	6/4/74
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3854311	PICK RESISTANT LOCK	12/17/74
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3882702	ANTI PICK KEY FOR LOCK	5/13/75
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3916657	DOUBLE KEY AXIAL	11/4/75
3928993	PICKPROOF CYLINDER	12/30/75
3959997	PICKPROOF LOCK	6/1/76
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4006615	AXIAL TUMBLER LOCK	2/8/77
4015458	SIDEBAR WAFER	4/5/77
4047406	ANTI-RAP PADLOCK MOUNTING	9/13/77
4068508	ANTIPULL PLUG	1/17/78
4069696	AXIAL SPLIT TUMBLER	1/24/78
4078406	ANTI-IMPRESSIONING LOCK	3/14/78
4083212	ROTARY DISC	4/11/78
4099396	AXIAL	7/11/78
4111019	PICKPROOF LOCK	9/5/78
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4151731	PICK RESISTANT CYLINDER	5/1/79
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4194379	PICK PROOF LOCK	3/25/80
4222252	REFERENCE	1980
4227387	AXIAL SPLIT PIN	10/14/80
4282731	ANTI-PICK PIN TUMBLER	8/11/81
4289000	PICK RESISTANT TUBULAR	9/15/81
4377940	IMPRESSION RESISTANT LOCK	3/29/83

4380163	TAMPER RESISTANT LOCK	4/19/83
4444034	PULL RESISTANT LOCK CORE	4/24/84
4462230	S&G PROGRAMMABLE LOCK	7/31/84
4577479	REFERENCE	1986
4580425	HIGH-SECURITY LOCK	4/8/86
4603565	ANTI PICK LOCK	1986
4616491	MAGNETIC LOCK	10/86
4619124	ANTI PICK LOCK	1986
4635455	MEDECO BIAXIAL	1987
4651546	ROTARY DISK PIN TUMBLER	3/24/87
4655063	PICK RESISTANT CORE	4/7/87
4683740	ANTI PICK LOCK	1987
4716749	HIGH-SECURITY LOCK	1987
4723427	SIDEBAR MEDECO LOCK	2/1988
4730467	DOUBLE LOCKING PADLOCK	3/15/88
4732022	MEDECO BIAXIAL	1988
4802354	HIGH-SECURITY LOCK	1989
4977767	EVVA MAGNETIC LOCK	12/18/90
4977768	PICK RESISTANT AXIAL LOCK	12/18/90
5001914	PICK RESISTANT LOCK	1991
5018376	AXIAL PIN TUMBLER	1991
5079936	HIGH-SECURITY CYLINDER	1/14/92

HIGH-SECURITY PADLOCKS

2625032	S&G 8088 PADLOCK	1953
2673457	S&G 8088 PADLOCK	1954
2775112	PADLOCK	12/56
2814940	COMBINATION PADLOCK	12/57
2830447	S&G HIGH-SECURITY	4/15/58
2852928	COMBINATION LOCK	9/1958
3533263	S&G 8077 HIGH-SECURITY	1970

SMART KEYS AND LOCKS

GB 2158870A	CHUBB/UNION	1985
GB 2174452A	CHUBB/UNION	1986
GB 2214226A	CHUBB UNION	1989

WO 88/03594 INDUCTIVE COUPLING OF CODE INFORMATION

US 2251453	INDUCTIVE COUPLING INFORMATION	1950
US 2252356	INDUCTIVE COUPLING INFORMATION	1950
US 3848229	INDUCTIVE COUPLING INFORMATION	1974
US 3787714	INDUCTIVE COUPLING INFORMATION	1974
US 4031434	INDUCTIVE COUPLING INFORMATION	1977

US 4549176	INDUCTIVE COUPLING INFORMATION	1985
US 4602253	INDUCTIVE COUPLING INFORMATION	1986

DIMPLE LOCKS

3413831	ROTARY CYLINDER LOCK	12/3/68
3367156	LOCK CYLINDER ASSEMBLY	2/6/68
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GB 2252356	LOCKS WITH INDUCTIVE CODE	12/18/91
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GB 2214226	MAGNETIC LOCK	8/31/89

3611763	MAGNETIC CARD	10/12/71
3633393	MAGNETS IN ROTARY TUMBLERS	10/15/68
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4133194	KEY OPERATED DOOR LOCK	1/9/79
4507944	MAGNETIC LOCK	4/2/85
4616491	MAGNETIC LOCK	10/14/86
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3402581	TELEPHONE LOCK	9/24/68
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GB 2241983	LOCKS	2/26/91
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3330141	RESETTABLE KEY	7/11/67
3572070	PROGRAMMABLE LOCK	3/23/71
3868838	PROGRAMMABLE AXIAL LOCK	3/4/75
3983724	COMBINATION PADLOCK	10/5/76
4069694	RESETTABLE LOCK ASSEMBLY	1/24/78
4149394	PROGRAMMABLE CARD LOCK	4/17/79
4375159	COMBINATION TUMBLER WHEEL	3/1/83
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4462230	PROGRAMMABLE LEVER LOCK	7/31/84
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5109684	ROTARY COMBINATION SHACKLE	5/5/92

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GB 2273128A	CHUBB ELECTRONIC LOCK	6/8/94
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4977767	LASER SIDEBAR LOCK	12/18/90
5086631	DISC CYLINDER LOCK	2/11/92

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MASTER PATENT ABSTRACTS FOR CLASS 70/394

The following listing provides abstracts for selected patents relating to lock picking and bypass. All of these patents are available in full-text format throughout this Infobase.

United States Patent 6,382,007 Wright May 7, 2002

Electro-mechanical system for determining key cuts for tumbler and wafer locks

A system for decoding locks having a sequence of spring-urged sliding members such as tumbler pins or wafers includes a probe device having the general contour of a key having a head portion and a straight shank fabricated of electrically insulative material and terminating in a tip portion having an oblique ramp surface. A series of spaced apart electrical conductors embedded within the shank in parallel relationship extend from the head portion to the ramp surface where they emerge as electrical contacts. An electrical circuit which includes an electronic monitoring and display apparatus detects when a given sliding member touches a most distant electrical contact, thereby representing a travel distance. The travel distance is correlated with a particular pin or wafer to produce the key code for the lock.

Inventors: Wright; Jesse M. (2929 S. Locust St., Denver, CO 80222)

United States Patent 6230529 Persson May 15, 2001

Tool for tubular key locks

A tool is disclosed for opening tubular locks in which a tubular key is receivable. The tool includes a plurality of probes that are releasably retained and secured in a given position to align the shear points in the lock in an opening position. The probes can be ergonomically and individually manipulated and have a course and a fine adjustment, such that the shear point of each tumbler can be easily and efficiently determined. Once the shear point is determined, the probe may be fixed in the position to maintain each tumbler driver.

Inventors: Persson; Kenneth E. (330 E. Elem St., East Rochester, NY 14445) Appl. No.: 365327 Filed: July 30, 1999

United States Patent 6173595 Hughes January 16, 2001

Lock picking apparatus

The method and apparatus for picking a lock which utilizes a single blade or pair of elongated thin, rigid, interchangeable blades which are to be inserted within the keyway of the lock. Each of the blades have an upper hiatused surface and can have an off-center sharpened edge so that the sharpened edge will contact the cylindrical lock pins of the lock spaced from the center of each of the lock pins. The off-center sharpened edge could be formed by beveling the side of the blade or by making a cut-out in the blade. The hiatused surface of the blades cause the "V" shaped tips of the cylindrical lock pins of the lock to move lineally with the sharpened edge causing the lock pins to pivot. Instead of a hiatused surface, there could be used one or more deflectable members, tufts of bristles or a brush. The blades are to be driven in a reciprocal manner with one blade moving in and the opposite blade moving out. The driving of the blades in an in and out linear motion can be accomplished either by an electrical motor or by a mechanical manually operated mechanism.

Inventors: Hughes; Donald R. (6120 W. Tropicana, Suite A-16-176, Las Vegas, NV 89103-4694) Appl. No.: 595062 Filed: June 16, 2000

United States Patent 6151936 Randall November 28, 2000

Method and apparatus for lock pick kit

A lock pick kit and method for opening a padlock without the padlock key, through the use of a conventional drill bit and a pair of specialized tools. The lock pick kit comprises a chisel having a shaft with first and second ends, a chisel handle attached to the first end, and a cylindrical protrusion attached to the second end. The second end of the shaft further includes a beveled cutting edge being positioned below and proximate a base portion of the protrusion. The kit further includes a pick having a shaft with first and second ends, a pick handle attached to the first end of the pick, with the pick handle configured to bend at a right angle to the longitudinal axis of the shaft, at its midpoint, an elongated tab extending from the second end of the pick at a right angle to the longitudinal axis of the shaft and a cylindrical protrusion extending from a free end of the elongated tab parallel to the axis of the shaft.

Inventors: Randall; Donald Lee (153 Redwood Ave., Hamilton Square, NJ 08610) Appl. No.: 390397Filed: September 3, 1999

United States Patent 6148652 Magini , et al. November 21, 2000

Picking tool for a disc tumbler lock

A lock picking tool for a high-security four-track disc tumbler lock, the tool probing all four tracks simultaneously.

Inventors: Magini; Mark A. (1021 E. Weldon, Phoenix, AZ 85014); Bradlee; Michael K. (1021 E. Weldon, Phoenix, AZ 85014) Appl. No.: 326323Filed: June 7, 1999

United States Patent 6138486 Hughes October 31, 2000

Lock picking apparatus

The method and apparatus for picking a lock which utilizes a single blade or pair of elongated thin, rigid, interchangeable blades which are to be inserted within the keyway of the lock. Each of the blades have an upper hiatused surface and can have an off-center sharpened edge so that the sharpened edge will contact the cylindrical lock pins of the lock spaced from the center of each of the lock pins. The off-center sharpened edge could be formed by beveling the side of the blade or by making a cut-out in the blade. The hiatused surface of the blades cause the lock pins of the lock to move lineally with the sharpened edge causing the lock pins to pivot. Instead of a hiatused surface, there could be used one or more deflectable members, tufts of bristles or a brush. The blades are to be driven in a reciprocal manner with one blade moving in and the opposite blade moving out. The driving of the blades in an in and out linear motion can be accomplished either by an electrical motor or by a mechanical manually operated mechanism.

Inventors: Hughes; Donald R. (6120 W. Tropicana, Suite A16-176, Las Vegas, NV 89103-4694) Appl. No.: 368920 Filed: August 6, 1999

United States Patent 6134928 Kang October 24, 2000

Method and apparatus for decoding lock cylinders

A method and apparatus for decoding locks having a guide member, an alignment member, a reader, and a recording medium, which a guide member is inserted into a lock to open the lock to receive an alignment member which aligns the tumbler members of a lock, thereby permitting a reader to be inserted into the lock, and withdrawn therefrom to cause a displacement of a pivotally connected reader arm which records an image of the lock profile on a recording medium.

Inventors: Kang; Samuel (863 Hyun Nae Ri Ha Bin Myun Dal Sung Goon, Taegu, KR) Appl. No.: 150711 Filed: September 10, 1998

United States Patent 6082159 Larsen July 4, 2000

Pocket lock pick

A compact lock pick assembly constructed and configured to be carried in a shirt pocket comprising the combination of a lock pick tool that is retractable into a generally tubular handle and a tension tool mounted on the tubular handle to act as a pocket clip is disclosed.

Inventors: Larsen; Ernest F. (2544 E. Holmes Ave., Mesa, AZ 85204) Appl. No.: 699262 Filed: August 19, 1996

United States Patent 6041629 Hughes March 28, 2000

Lock picking apparatus

The method and apparatus for picking a lock which utilizes a single blade or pair of elongated thin, rigid, interchangeable blades which are to be inserted within the keyway of the lock. Each of the blades have an upper hiatused surface and can have an off-center sharpened edge so that the sharpened edge will contact the cylindrical lock pins of the lock spaced from the center of each of the lock pins. The off-center sharpened edge could be formed by beveling the side of the blade or by making a cutout in the blade. The hiatused surface of the blades cause the lock pins of the lock to move lineally with the sharpened edge causing the lock pins to pivot. Instead of a hiatused surface, there could be used one or more deflectable members, tufts of bristles or a brush. The blades are to be driven in a reciprocal manner with one blade moving in and the opposite blade moving out. The driving of the blades in an in and out linear motion can be

accomplished either by an electrical motor or by a mechanical manually operated mechanism.

Inventors: Hughes; Donald R. (6120 W. Tropicana, Suite A16-176, Las Vegas, NV 89103-4694) Appl. No.: 354669 Filed: July 16, 1999

United States Patent 5987946 Watts November 23, 1999

Lock picking method and apparatus

Method and apparatus for non-destructively picking locks which normally are operated by keys, such locks capable of having twisting tumbler pins and sidebars. The method requires that: the pins be raised high in the keyway; the plug be axially bored by a thin drill which enters through a low portion of the keyway, the rear end of the drilled bore opening to the bolt cam operator; the drill bit be removed from the bore; and then the bolt cam operator be directly turned to shift open the bolt. This method does not decode the tumblers nor release any sidebar. The preferred apparatus comprises a pin raiser tool, which is self-retaining due to bias on the pins, which is transmitted to the handle of this tool; and a torquing tool, which is passed through the bore and has a blade which seats in the cam operator for turning the operator to shift open the lock bolt. A unique safety shield can be installed on the tailpiece to prevent picking by the method of this invention.

Inventors: Watts; James A. (2450 W. 82 St., Unit 201, Hialeah, FL 33016) Appl. No.: 911647 Filed: August 15, 1997

United States Patent 5956984 Hughes September 28, 1999

Lock picking apparatus

The method and apparatus for picking a lock which utilizes a single blade or pair of elongated thin, rigid, interchangeable blades which are to be inserted within the keyway of the lock. Each of the blades have an upper hiatused surface and can have an off-center sharpened edge so that the sharpened edge will contact the cylindrical lock pins of the lock spaced from the center of each of the lock pins. The off-center sharpened edge could be formed by beveling the side of the blade or by making a cut-out in the blade. The hiatused surface of the blades cause the lock

pins of the lock to move lineally with the sharpened edge causing the lock pins to pivot. Instead of a hiatused surface, there could be used one or more deflectable members, tufts of bristles or a brush. The blades are to be driven in a reciprocal manner with one blade moving in and the opposite blade moving out. The driving of the blades in an in and out linear motion can be accomplished either by an electrical motor or by a mechanical manually operated mechanism.

Inventors: Hughes; Donald R. (6120 W. Tropicana-Unit A16-176, Las Vegas, NV 89103) Appl. No.: 933128 Filed: September 18, 1997

United States Patent 5921122 Lin July 13, 1999

Device for preventing falling of upper pin tumblers of a lock during change of a lock core in the lock

A lock assembly includes a main body having a compartment defined in a lower part thereof for removably receiving a lock core therein. The main body further includes a number of upper chambers defined in an upper part thereof, each upper chamber including an upper pin tumbler received therein. The lock core includes a number of lower chambers defined therein, each lower chamber including a lower pin tumbler received therein. The main body further includes a number of longitudinally spaced holes defined in a periphery thereof each hole being communicated with a lower end of an associated upper chamber. A member has a number of branches, wherein each branch is removably inserted into an associated hole to support the associated upper pin tumbler during removal of the lock core.

Inventors: Lin; Jesse (Kaohsiung Hsien, TW) Assignee: Taiwan Fu Hsing Industry Co. Ltd. (Kaohsiung Hsien, TW) Appl. No.: 084382 Filed: May 27, 1998

United States Patent 5701773 Markisello December 30, 1997

Dual function apparatus for opening and removing automotive side-bar ignition locks

Apparatus for opening, or removing without damage, automotive side-bar type ignition locks, comprises a combination tool with a plurality of projections extending horizontally and forwardly

from the combination tool to engage the lock's keyway, at least one balanced pair of recesses in the lock's face, or, optionally, when the tool is used as a lock-remover, the inner walls of the lock's hollow wing-nut cylinder cap. When used as a lock-forcing opener, the combination tool is placed in position on the lock cylinder's face and a conventional wrench gripping the tool's hexagonally-shaped portion is turned to create torque applied by the tool's projections against the walls of the lock's recesses, forcing the lock cylinder to turn to its ON position and start the vehicle's engine. When the lock is to be removed without damage, the combination tool is used as a drill guide mounted on the lock by its projections, with its drill guide hole so positioned that an access hole drilled therethrough gives access for a side-bar pressure tool to be inserted and to exert inward pressure on the lock's side-bar, while at the same time a wafer pressure tool is reciprocated in the lock's keyway to urge the lock's wafer elements into lock-opening alignment, allowing the side-bar to be retracted. The lock can then be removed from its automotive mounting, a replacement key made, and the lock returned and reinstalled for continued use. Combination tool, matching drill bit, side-bar pressure tool and wafer pressure tool may be provided as a locksmith's kit.

Inventors: Markisello; Frank (91-10 Liberty Ave., Ozone Park, NY 11417) Appl. No.: 592892 Filed: January 29, 1996

United States Patent 5454245 Markisello October 3, 1995

Apparatus and method for removing side-bar automotive ignition locks without damage

Apparatus and method for removing side-bar automotive ignition locks without damage, a tool kit being provided containing a drill guide block, an adjustably molted drill bit, a side-bar pressure tool for insertion into the access opening created by the drill bit, and a wafer pressure tool for insertion into the keyway of the ignition lock to urge the lock wafer elements into alignment at the same time the side-bar pressure is being applied, causing retraction of the side-bar and consequent opening of the lock to permit its removal. Plugs are provided to reseal the drilled access opening.

Inventors: Markisello; Frank (91-10 Liberty Ave., Ozone Park, NY 11417) Appl. No.: 247577 Filed: May 23, 1994

United States Patent 5402661 Markisello April 4, 1995

Tool and method for turning on ford sidebar type ignition lock cylinders

A tool to start ignition side bar type lock cylinders in all Ford vehicles is provided and consists of using a tool which has a guide key to hold the tool in place, two tabs to cut into the face of the cylinder, a hexagonal shape at rear of tool to accept a wrench for turning the cylinder to the ON position and thus start the vehicle.

Inventors: Markisello; Frank (9-10 Liberty Ave., Ozone Park, NY 11417) Appl. No.: 850791 Filed: March 13, 1992

United States Patent 5355701 Tobias October 18, 1994

Method and apparatus for decoding a pin tumbler lock

Methods and apparatus for decoding pin tumbler locks, and more specifically, a mechanical key card lock. To determine the length and weight of a given pin tumbler, a probe is inserted within the lock, comprised of one or a matrix of many force sensing resistors. The probe will respond to variations in pressure and tension of each pin tumbler, and will thus provide a range of output resistances, directly related to the pressure exerted upon the sensor by a particular pin tumbler. The outputs of the sensors are then electronically sensed and recorded so that a duplicate key can be produced.

Inventors: Tobias; Marc W. (4317 Town Park Pl., Sioux Falls, SD 57105) Appl. No.: 024288 Filed: March 1, 1993

United States Patent 5325691 Embry July 5, 1994

Method and apparatus for use in picking and decoding sidebar locks

The present invention relates to lock picking and decoding tools and a method of using the same. The lock decoding tools comprise a torquing tool, a picking tool, and decoding tools. The method

comprises using the torquing tool to bias the locking bar out of a notch in the inner wall of the cylinder housing, picking the tumblers using the picking tool, turning the cylinder lock slightly so as to permit the torquing tool to be removed, turning the lock cylinder to the "ON" position, and decoding the cylinder lock using the decoding tools.

Inventors: Embry; Donald J. (Cloverport, KY) Assignee: HSL Marketing, Inc. (Atlanta, GA) Appl. No.: 006260 Filed: January 19, 1993

United States Patent 5224365 Dobbs July 6, 1993

Side bar lock decoder

A side bar lock decoder has a pair of guide plates laminarly arranged between a pair of side plates. Key portions of the plates have notches spaced for alignment with the lock wafers. Narrow passages between the guide plates extend from each of the notches to the edges of the base portions of the plates at approximately normal fingertip positions when the base portions are handheld. Wires slidably disposed in each of the passages extend from an outer end of each of the notches beyond the grip edges. One end of the wires abuts one of the wafers when the wafers and the notches are aligned. Springs, bias each of the wires toward a threshold reference position within the notches. Plungers, one connected to each of the wires, extend beyond the grip edges, are independently biased away from their respective edges by the springs. One or more housings secured to the laminar plates have at least one chamber therein for guiding the movement of each of the plungers during manipulation. Windows in the housings allow viewing of the depth of each plunger in its housing and at least one graduated scale on each housing, corresponding to the graduated scale of wafer depths of the lock, indicates the position of each plunger in relation to its threshold reference position when the wafers are shifted into the "open lock" condition. Pins extend from each plunger externally of its housing to facilitate simultaneous finger manipulation of each plunger.

Inventors: Dobbs; Jerry L. (Rte. 2, Box 411E, Sand Springs, OK 74063) Appl. No.: 927466 Filed: August 10, 1992

United States Patent 5172578 Bitzios December 22, 1992

Locksmith tool

An apparatus for determining lengths of locking elements in locks including a key head and wires maintained on the key head and extendable into the lock cylinder for measuring lengths of the lock pins. The distance that the wires will go into the depth of lock can be used to determine the depth of the furrows or the cuts of the needed key. The advantage of this invention is that one can duplicate a key which has been lost, without damaging the lock, or moving it out of the door. In addition to that this mechanism is also used as a "lock-picker" in order that one can lock or unlock a door when the keys have been lost. The invention operates in two different ways and for two different purposes. The first one is to duplicate a key which has been lost. The second one is to lock or unlock a door for different reasons, e.g. when the key has been lost, or when it is still inside the car or the house while the door is still locked.

Inventors: Bitzios; Spiridon A. (Kartall 11, Ioannina, GR) Appl. No.: 785240 Filed: November 1, 1991

United States Patent 5133202 Grant July 28, 1992

Disk tumbler lock decoder

A decoder is provided for disk tumble locks which is electrically rather than mechanically operated. A plurality of separate keys each has a blade sufficiently long to extend through all of the disks in the lock. At least one cut is provided in the blade of each key. The depth of the cut in each key is different, the cut of each key being coordinated to a different depth of disk from among the known alternative disk depths for the given tumbler lock to be decoded. The base surface of each cut contains discrete electrical contact connected by a discrete conductor to a point on the key which is externally accessible when the key is fully inserted into the lock. Each contact is positioned on its key so that, when the key is inserted into the lock keyway, an electrically conductive circuit is completed by the disk if the depth of the disk corresponds to or exceeds the depth of the cut. By alignment of the contact with a disk, a discrete electrical circuit will extend from the externally accessible positive point on the key when the contact is aligned with a disk of appropriate

depth. If keys are sequentially inserted into the keyway, beginning with the key of deepest cut and gradually progressing toward the key of shallowest cut, the key first completing the electrical circuit associated with any disk will complete a circuit indicating the depth of that disk, thus decoding the lock.

Inventors: Grant; Maurice (11390 N 209 E. Ave., Claremore, OK 74017) Appl. No.: 703195 Filed: May 20, 1991

United States Patent 4836000 Hirvi June 6, 1989

Lever tumbler lock

The present invention relates to a lever tumbler lock in which the scrape marks caused by the key bit as it displaces the various tumblers will not be completely informative of the configuration of the key bit. According to the invention the lock includes a device which as a key bit (13) inserted into the lock housing (1) is turned will scrape against at least a part of the cam surface (10) of at least one tumbler (2) such as to create on this cam surface or those cam surfaces scrape marks which cover the scrape marks caused by corresponding cams on the key bit when the key is turned, at least at the beginning and the end of these scrape marks.

Inventors: Hirvi; Jorma (Eskilstuna, SE) Assignee: AB Fas Lasfabrik (Eskilstuna, SE) Appl. No.: 199669 Filed: May 26, 1988

United States Patent 4817406 Martin April 4, 1989

Lock impressioning key

An impressioning key for making an impression of the tumblers of a lock comprises a key blank having a main portion of relatively hard material with a recess in an upper forward edge portion. A tumbler engaging portion consisting substantially wholly of lead is secured to the main portion in the recess, the tumbler engaging portion being a solid preshaped body of lead filling the recess.

Inventors: Martin; William E. (499 John Street N., Hamilton, Ontario, CA) Appl. No.: 082619 Filed: August 7, 1987

United States Patent 4667494 Joosten May 26, 1987

Tool set and method for opening and decoding locks

A tool set and a method of opening and decoding a side bar lock employing wafer type tumblers. A spring compressor tool configured for insertion into the lock mechanism keyway raises all the tumblers to a radially outward position and compresses the springs that normally bias the tumblers inwardly. A spring retainer tool inserted into the keyway with the spring compressor tool engages the tumbler springs to retain the springs in a compressed position but frees the tumblers for movement. A tumbler adjusting tool is inserted to grasp the tumblers, and move the tumblers to a position where the lock mechanism can be opened. A decoding tool is inserted to measure the radial position of each tumbler and provide a number which can be used to make a new key. A dust cover holding tool is provided to hold open the spring actuated dust cover.

Inventors: Joosten; Douglas W. (13513 Auburn NE, Albuquerque, NM 87112) Appl. No.: 818364 Filed: January 13, 1986

United States Patent 4617813 Christopher , et al. October 21, 1986

Lock-picking tool and method of use thereof

A picking tool adapted to open a cylinder lock of the axial pin tumbler type having its tumblers arranged in a coplanar configuration, includes a planar torquing core insertable into the lock keyway in a longitudinal direction, a plurality of longitudinal guideway channels formed on opposing faces of the core, and respective tumbler probes longitudinally reciprocable in the channels. A holder, which acts as a handle for manipulating the picking tool, also serves as a housing surrounding the core and the probes. The holder is formed with a pair of radial openings in opposite sides thereof which receive respective brake segments for exerting a frictional drag on the probes. An adjustable hoop clamp surrounds the brake segments for manually adjusting the frictional drag, so that the proper tumbler displacement action can be achieved. Setscrews are threaded into the body of the holder for clamping the probes in

their final tumbler-displacing positions. At the rear of the holder, the tail ends of the probes fan out circularly so that they can be more easily manipulated individually. The probes have indicia from which the lock code can be read out after the probes reach their final positions.

Inventors: Christopher; Walter S. (Park Ridge, IL); Kriskovich; Robert T. (Roselle, IL); Steinbach; Robert L. (Glendale Heights, IL) Assignee: Chicago Lock Co. (Chicago, IL) Appl. No.: 403094 Filed: July 29, 1982

United States Patent 4606204 Cooke, Jr. August 19, 1986

System and apparatus for opening cylinder locks

A lock opening method and mechanism for opening locks in minimum time while requiring very little skill on the part of the operator. The mechanism includes an adapter assembly, a tension arm and an oscillator unit. The assembly asserts rotary force to a lock cylindrical plug. This causes the lock pins to release and allowing the lock to be opened.

Inventors: Cooke, Jr.; Robert G. (Rte. 2, P.O. Box 29, Ahoskie, NC 27910) Appl. No.: 565403 Filed: December 27, 1983

United States Patent 4535546 Smith August 20, 1985

Locksmith tool apparatus for determining length of locking elements in locks

Locksmith tool apparatus determines the length of a locking element in a lock by engaging a locking element inside a lock and by moving the element to compress a compression spring to a known minimum length and by measuring the distance moved. By subtracting the distance the element is moved from known dimensions, the length of the locking element is determined.

Inventors: Smith; Rodney D. (6550 N. 2nd Dr., Phoenix, AZ 85013) Appl. No.: 583679 Filed: February 27, 1984

United States Patent 4517746 Easley May 21, 1985

Method and apparatus for decoding wafer combination locks

A probe for manually decoding a lock of the wafer combination type having an elongate body to slideably engage the keyway, the body comprising at least two hollow tubular members. Within the hollow members are rotatably disposed detecting members which detect, by means of physical contact, certain identifying portions of wafers therein which form the combination of the lock. An indicator on the outside of the probe, responsive to the detecting members, indicates the presence, type, and orientation of the wafers. The same method may be practiced without the use of the probe by viewing the interior of the lock slightly off center with a pencil beam of light to determine the same characteristic wafer portions.

Inventors: Easley; Thomas E. (1303 Fourth St., La Grande, OR 97850) Appl. No.: 499275 Filed: May 31, 1983

United States Patent 4400956 Martin August 30, 1983

Skeleton key kit

A key kit for opening tumbler locks has a key member with a shaft insertable into a tumbler lock, the shaft having a series of longitudinally-spaced recesses into which the tumblers in the lock can respectively enter. A foil of impressionable material is removably positionable on the shaft over the recesses, and a tumbler displacing member is insertable into the lock with the shaft and foil to displace the tumblers without the tumblers engaging the foil. The tumbler displacing member being removable from the lock after the shaft and foil have been inserted therein to enable the key member to be manipulated to cause the tumblers to make impressions in the foil corresponding to the key shape required to open the lock.

Inventors: Martin; William E. (Hamilton, CA) Assignee: Martin & Starchuk Limited (Dundas, CA) Appl. No.: 290037 Filed: August 5, 1981

United States Patent 4300416 Ross November 17, 1981

Key blank impressioning tool

A key blank impressioning tool has a pair of pivotally, interconnected parts for manipulation by the hands of the user. As one of the parts is grasped by one hand to apply torque to the key blank in the keyway of the lock to in turn tend to turn the plug of the lock, the second part of the tool is used by the other hand of the operator for the purpose of reciprocating a block so as to strike light blows of such nature as to create indentations in one edge of the blank to thereby identify the location and depth of the tumbler cuts to be made in the key blank.

Inventors: Ross; William D. (Kansas City, MO) Assignee: William D. Ross Manufacturing Corporation (Kansas City, MO) Appl. No.: 084620 Filed: October 15, 1979

United States Patent 4229959 Easley October 28, 1980

Method and apparatus for opening a lock

A novel method and apparatus for opening a magnetic cylinder lock of the type having an outer cylinder, a rotatable inner cylinder disposed within the outer cylinder, one or more magnetic pins disposed within chambers of one of the cylinders for engaging the other cylinder to prevent the inner cylinder from rotating, and a keyway within the inner cylinder for insertion of a magnetic key to displace each pin and release the inner cylinder, thereby opening the lock. A probe is provided for insertion within the keyway to determine the presence and polarity orientation of each magnetic pin by detecting its magnetic field. An indexing arm within the probe abuts the lock and provides a signal representative of the position of each pin chamber. Sensor circuitry correlates a signal from the probe representative of the presence and polarity orientation of each pin with a signal from the indexing arm representative of the position of each pin chamber and displays the "combination" of the lock. A selectively-actuable master key with a plurality of electromagnets imbedded therein is provided for insertion into the keyway and a power supply is used to actuate the electromagnets momentarily while turning the master key to displace each pin and open the lock.

Inventors: Easley; Thomas E. (1303 Fourth St., LaGrande, OR 97850) Appl. No.: 025402 Filed: March 30, 1979

United States Patent 4186577 Jarm February 5, 1980

Lock opening device

A device for opening a lock without the use of a key cut to the specific tumbler configuration of the lock, said device comprising a holder having a key blank corresponding to the key slot formed in the lock core mounted at one end thereof. A resilient member is secured to the key blank in such a position that it will engage the tumblers of the lock when the key blank is inserted into the key slot. In addition, a means is secured to the holder for engaging the lock housing in which said core rotates on the side thereof opposite the location of the tumblers and for urging the key blank and core against said engaged side in a manner such that the width of the shear line between the core and lock housing will be increased at the location of the tumblers. By adjusting the alignment of the key blank within the lock core, the spring-loaded tumblers will be caused to deform the resilient member at various depths until they are brought into the desired alignment along the shear line between the core and lock housing thereby permitting the rotation of the core within said lock housing.

Inventors: Jarm; Robert L. (Wauconda, IL) Assignee: Credit Industry Associates, Inc. (Arlington Heights, IL) Appl. No.: 924978 Filed: July 17, 1978

United States Patent 4185482 Nail January 29, 1980

Lock decoding mechanism

A mechanism for opening and/or decoding the bittings of a key for opening a cylinder lock. The mechanism comprises a housing having a forward projection shaped in the form of a key body and an abutment surface spaced from the forward projection disposed to abut the cylindrical plug of the lock when the forward projection of the housing is inserted in the keyway of the lock. A plurality of shims, including at least one shim associated with each lock tumbler, are supported in the housing, for longitudinal movement within the housing. Each of the shims have an elongated portion directed toward and supported in the forward projection of the housing and a tumbler actuating cam extending from the elongated portion. A plurality of actuators are associated with the

plurality of shims respectively. Each actuator is selectively shiftable for moving its respective shim with respect to the associated tumbler to position the tumbler for opening the lock. Indicia on the housing associated with the actuators indicates the positions of the actuators corresponding to the respective positions of each of the tumblers whereby the bittings of a key to move said tumblers to their respective positions to open the lock may be determined.

Inventors: Nail; William B. (247 Terrace Park, Rochester, NY 14619) Appl. No.: 880657 Filed: February 23, 1978

United States Patent 4094176 Hughes June 13, 1978

Pick for tubular cylinder locks

A pick for tubular cylindrical locks which includes a central substantially cylindrical member which has a plurality of grooves thereon, each groove to accommodate an elongated pin. The pins are capable of axial movement with respect to the cylindrical member against the action of a frictional brake in the form of rubber O-ring assembly. The very tip of the pins connect with a head which is adapted to be placed about the rotatable cylinder portion of a tubular lock. The head includes a series of axial slots and upon being moved axially into the cylindrical member, the head slightly deflects and frictionally secures to the cylinder portion of the lock. The head is moved axially by a fastener which connects between the rearwardmost end of the first member and the head.

Inventors: Hughes; Donald R. (2600 Brower Ave., Simi Valley, CA 93065) Appl. No.: 832279 Filed: September 12, 1977

United States Patent 4073166 Clark February 14, 1978

Magnetic lock pick

A device for opening locks with magnetically actuated tumblers or pins is provided with a housing of non-magnetizable composition and a plurality of interlocking gear wheels, pivotably retained in the housing, and also constructed from materials not susceptible to permanent magnetization. The gear wheels are pierced by a plurality of orifices across their thickness and

cylindrical permanent magnets are inset into each orifice with a substantially random distribution of their North and South poles with respect to the faces of the wheels. Means are provided to rotate the wheels simultaneously around their pivot axes, thereby generating a changing, random distribution of magnetic fields arising from the interaction of the inset permanent magnets. By holding the housing of the magnetic pick proximate to the usual placement of the coded magnet key of the lock, the magnetic pins, or tumblers, therein are exposed to a large combination of structured magnetic fields, one of which is likely to correspond to the key code.

Inventors: Clark; William H. (16521 Queenside Dr., Covina, CA 91722) Appl. No.: 756080 Filed: January 3, 1977

United States Patent 4006613 Zion February 8, 1977

Lock pick mechanism

A lock pick mechanism having a plurality of lock picks, a frame and housing members is disclosed. The lock picks, frame and housing members are connected together such that the lock picks may be contained within the frame and enclosed by the housing members when the lock picks are in their storage positions and such that an individual lock pick may be selected and pivotally moved from its storage to its operative position when the housing members are opened. After the selected lock pick has been moved to its operative position, the housing members may be closed to maintain the lock pick in its operative position.

Inventors: Zion; Westley (New York, NY) Assignee: Majestic Lock Co., Inc. (New York, NY) Appl. No.: 657193 Filed: February 11, 1976

United States Patent 3987654 Iaccino , et al. October 26, 1976

Method and apparatus for decoding twisting tumbler locks and locks resistant thereto

Methods and apparatus for decoding twisting tumbler locks and improvements in such locks to resist such methods and apparatus. To determine depth of cut of bit for a given tumbler, a blade is inserted into key way to position a wirelike probe at tumbler to

be decoded. Wirelike probe is advanced upwardly until it engages tit at top of tumbler. Depth of cut of key bit is function of length of tumbler and device can be calibrated to give direct readout of depth of bit cut. Angle of key bit can be measured by hooking a wirelike probe in side gate groove in tumbler and then twisting tumbler until tit engages key plug or shell. Amount of twist permitted is function of angular position required to register tumbler groove with side gate and device can be calibrated to give direct reading of such angle. To defeat depth of cut decoder, twisting tumbler lock wherein tits on tumblers are located at different distances from tops of tumblers is disclosed. Another form of modified twisting tumbler locks that will defeat decoding methods and apparatus herein is tumbler with side gates receiving grooves 180.degree. apart and with no tit.

Inventors: Iaccino; George V. (New Rochelle, NY); Idoni; Robert A. (New Rochelle, NY) Assignee: Lock Technology, Inc. (New Rochelle, NY) Appl. No.: 516465 Filed: October 21, 1974

United States Patent 3985010 Idoni October 12, 1976

Method and apparatus for decoding twisting tumbler lock and twisting tumbler lock resistant thereto

Method and apparatus for decoding twisting tumbler lock of the type wherein side bar is sole locking element and normally bridges shear plane unless radial apertures in twisting tumblers are all in vertical and horizontal register with complementary side bar protrusions. Decoding apparatus comprises three devices each with a blade insertable in keyway and having upwardly and rearwardly sloping front surface angulated at one of three angles to which tumblers must be twisted for horizontal registration of apertures. Each blade has indicia for indicating that front surface is at particular tumbler and further has indicia for determining amount of elevation of tumbler resulting from camming action between chisel shaped tumbler bottom and blade front surface when blade is advanced from initial engagement with tumbler to elevate tumbler. Method includes step of torquing blade during advancement to bias side bar toward tumblers and thus force protrusion into associated tumbler aperture when aperture registers with protrusion. This movement causes small but detectable resistance to further advancement and, thus, yields positive indication of registration. As angle of front surface is known and required tumbler elevation is known, tumbler is decoded. By repeating process with all tumblers, lock is

decoded.

Inventors: Idoni; Robert A. (New Rochelle, NY) Assignee: Lock Technology, Inc. (New Rochelle, NY) Appl. No.: 516466 Filed: October 21, 1974

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LOCKS AND SAFES: THE CONSTRUCTION OF LOCKS



Compiled from the papers of A. C. HOBBS
and edited by CHARLES TOMLINSON, ES
PHYSICAL SCIENCE KING'S COLLE

TO WHICH IS ADDED A DESCRIPTION OF MR. J. BEVERLEY I
A NOTE UPON IRON SAFES, BY ROBERT MALLET,

Reproduced and Printed in Great Br

Redwood Press Limited, Trowbridge ar
First Published 1868 by Virtue and Co.
Reprinted 1970 SBN 90157130

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THE first edition of this volume, though at the date of its appearance coordinating with the state of knowledge of the period, and containing matter well arranged and lucidly described, as must have been expected from the reputation of its author, had, through the lapse of the few intervening years,

inevitably become somewhat behind the state of the art of which it treats, one which is daily receiving the attentive consideration of many skilful men, and occasional marked improvements. Amongst those of later years none are more noteworthy than the locks patented by Mr. Fenby, of Birmingham; of these an account, with accurate illustrations, for which the drawings are supplied by the inventor, is now added, together with a brief essay upon the important but popularly ill-understood subject of iron safes.

April, 1868
ROBERT MALLET

In reference to Mr. Smyth's letter, which is given at pp. 130, 131, that gentleman is DESIROUS to state that it was in consequence of the defects there pointed out that Hr. Hobbs was enabled to pick the Bramah lock operated upon, which had been manufactured forty years previously, when the sliders were made of iron instead of steel as they now are, and yet, notwithstanding that and the other defects pointed out, it took Mr. Hobbs sixteen days to pick it.

In proof of the security of the Bramah lock, Mr. Smyth mentions that Mr. Hobbs's best workman failed in picking an ordinary 3" Bramah box lock; and that a person in the employ of Messrs. Johnson and Ravey, of Conduit Street, failed also in his attempt to pick a 6" cellar-door lock, though he had the look in his possession for twelve months, employing his evenings in making instruments and trying to pick it.

Mr. Smyth contradicts the statement that the new lock was removed from the window through any fear of its being opened. On the contrary, it was put up especially to afford an opportunity for Mr. Hobbs to make, if he thought fit, another trial, and it remained in the window four months. The sole cause of its removal was to stop the impertinent applications of men and boars, which interfered too much with the general business of the firm.



Alfred C. Hobbs

PREFACE

THE reader is entitled to know the origin of the small work which he holds in his hands.

In August 1852, being about to write a short article on Locks for a Cyclopedia of Useful Arts, of which I am the editor, I consulted my esteemed and lamented friend, the late Professor Cowper, of King's College, as to the desirability of explaining to the general reader the defects of some of our English locks, which, previous to the celebrated "lock controversy" of 1851, had borne a high character for skilful construction, beauty of workmanship, and undoubted security.

Professor Cowper expressed his strong conviction that by exposing the effects of our locks, the cause of mechanical science, as well as the public in general, would be benefited; that if our locks were defective, inventors would be stimulated to supply the defects, and the art of the locksmith would be raised accordingly.

He considered that Mr. Hobbs had made a considerable step in advance in the constructive details of his art, not only in having detected the weak points of some of our best English locks, but also in having introduced two or three new locks, which appeared to be more secure than any of those previously

produced.

Professor Cowper gave me an introduction to Mr. Hobbs, who placed at my disposal a variety of literary materials relating to the history and construction of locks, and stated his intention at some future time of bringing out a small book on the subject, if he could meet with a publisher. I recommended him to offer the work to Mr. Weale, for insertion in his series of Rudimentary Works. This was accordingly done, and I was invited to prepare the work; but as my engagements did not leave me sufficient leisure to write the book, I requested my friend Mr. George Dodd to put the materials together, and to search for more.

Mr. Dodd acceded to my request; and having completed his part of the work, I subjected it to a careful revision, and added various details which seemed to be necessary to completeness, at least so far as the narrow limits of a small rudimentary work would admit of completeness. The manuscript was then sent to press.

Each sheet as it was received from the printer was submitted to Mr. Hobbs, who read it with care, and made his annotations and corrections thereon. Mr. Hobbs and I then had a meeting, when the additions and corrections were read and discussed, and admitted or rejected as the case might be. The sheet having been thus corrected was sent to press.

It should also be stated that, during the progress of the work, Mr. Weale, at my request, wrote to Messrs. Bramah, and also to Messrs. Chubb, informing them that a Rudimentary Treatise on the Construction of Locks was being prepared, and requesting them to state in writing what alterations or improvements they had made in their locks since the date of the Great Exhibition. The communications which we have received from these celebrated firms are inserted verbatim, in their proper places, in the present work.

Such is the mode in which this small volume has been prepared. I have endeavored to perform an editor's duty conscientiously, without entertaining the feeling of a partisan in the matter. My chief object in superintending the production of this book (an object in which the Publisher fully participates) is to advance the cause of mechanical science, and to supply a deficiency in one of the most interesting portions of its English literature.

C. TOMLINSON.
July 1853.



The Bramah Lock Company was recognized by the Crown as a vendor with whom they chose to do business. The lock produced by Bramah is still made today, and was one of the driving forces for dramatic changes in the design of locking mechanisms during the middle of the nineteenth century.

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CHAPTER ONE: On Locks and Lock-Literature

THE manufacture of looks, and a consideration of the mechanical principles involved in their construction and security, have never yet been treated with any degree of fullness in an English work. Lock-making has occupied a large amount of ingenuity, and lock-patents have been obtained in considerable number, though

not always, we are satisfied, with a commensurate return for the expense incurred, but lock-philosophy (if so it may be designated) has not been largely attended to.

And yet it may safely be said that much which is both mechanically and commercially important is comprised in a lock. Every improvement in the manufacture of iron, steel, and brass, that is, in the tool-making and machine-making processes, may be made to reflect its light on the lock manufacture; the stamping, the casting, the planing, the slotting, the screw-cutting, the polishing of metals, all, in proportion as they are improved, impart some of their aid to the lock-maker.

Then, in the finer kinds of locks, the works are so delicate as to approach to the nicety of clockwork; thereby combining the manipulative skill of a talented artisan with the rougher mechanical work of the smith. The principles of mechanical science are also appreciated by many lock-makers. The lever, the inclined plane, the eccentric, the cam, the screw, the wheel and pinion, the ratchet, the spring, all are brought to bear on the internal mechanism of locks, frequently in many novel combinations.

The commercial importance of locks, though of course never seriously questioned when once fairly brought before one's attention, has been recently rendered so apparent as to have risen to the position of a public topic. If a strong room, containing gold and silver, notes and bills, books and papers, if such a room be necessarily shielded from intrusion, it becomes no less necessary that the shield should be really worthy of its name, trusty and reliable: a good lock is here nearly as indispensable as a faithful cashier.

And without dwelling on such an auriferous picture as a room full of gold, we shall find ample proof of the commercial importance of lock-making in the ordinary circumstances by which we are every day surrounded. Until the world becomes an honest world, or until the honest people bear a larger ratio than at present to the dishonest, the whole of our movables are, more or less, at the mercy of our neighbors. Houses, rooms, vaults, cellars, cabinets, cupboards, caskets, desks, chests, boxes, caddies, all, with the contents of each, ring the changes between *meum* and *tuum* pretty much according to the security of the locks by which they are guarded.

A commercial, and in some respects a social doubt has been

started within the last year or two, whether or not it is right to discuss so openly the security or insecurity of locks. Many well-meaning persons suppose that the discussion respecting the means for baffling the supposed safety of locks offers a premium for dishonesty, by showing others how to be dishonest. This is a fallacy. Rogues are very keen in their profession, and know already much more than we can teach them respecting their several kinds of roguery.

Rogues knew a good deal about lock-picking long before locksmiths discussed it among themselves, as they have lately done. If a lock, let it have been made in whatever country, or by whatever maker, is not so inviolable as it has hitherto been deemed to be, surely it is to the interest of honest persons to know this fact, because the dishonest are tolerably certain to apply the knowledge practically; and the spread of the knowledge is necessary to give fair play to those who might suffer by ignorance.

It cannot be too earnestly urged that an acquaintance with real facts will, in the end, be better for all parties. Some time ago, when the reading public was alarmed at being told how London milk is adulterated, timid persons deprecated the exposure, on the plea that it would give instructions in the art of adulterating milk; a vain fear, milkmen knew all about it before, whether they practiced it or not; and the exposure only taught purchasers the necessity of a little scrutiny and caution, leaving them to obey this necessity or not, as they pleased.

So likewise in respect to bread, sugar, coffee, tea, wine, beer, spirits, vinegar, cheap silks, cheap woolens, all such articles as are susceptible of debasement by admixture with cheaper substances, much more good than harm is effected by stating candidly and scientifically the various methods by which such debasement has been, or can be produced.

The unscrupulous have the command of much of this kind of knowledge without our aid; and there is moral and commercial justice in placing on their guard those who might possibly suffer therefrom. We employ these stray expressions concerning adulteration, debasement, roguery, and so forth, simply as a mode of illustrating a principle, the advantage of publicity.

In respect to lock-making, there can scarcely be such a thing as dishonesty of intention: the inventor produces a lock which he honestly thinks will possess such and such qualities; and he

declares his belief to the world. If others differ from him an opinion concerning those qualities, it is open to them to say so; and the discussion, truthfully conducted, must lead to public advantage: the discussion stimulates curiosity, and the curiosity stimulates invention. Nothing but a partial and limited view of the question could lead to the opinion that harm can result: if there be harm, it will be much more than counterbalanced by good.

The literature of lock-making is, as we have implied, very scanty, both in England and America. The French and Germans, though far below our level as lock-makers, are very superior to us in their descriptions of the construction and manufacture of locks. Take, for instance, the French treatise published more than eighty years ago by the *Academie des Science'*, and forming part of a folio series of manufacturing treatises, illustrated very fully by engravings. It is worth while to examine this work, to see how minutely and faithfully the writers of such treatises performed their task nearly a century ago. The *Art du Serrarier***, with the distinguished name of M. Duhamel du Monceau as the author or editor, was published in 1767.

It occupies 290 folio pages, and is illustrated by 42 folio plates. The first chapter gives us an introduction and general principles, in which the choice and manipulation of materials are touched upon; the different qualities of iron and steel; and the processes of forging, founding, welding, stamping, filing, polishing, etc.

In the copper-plates representing these smiths' operations and the tools employed, there is a smithy, with about a dozen smiths engaged in all these various occupations, with stockings down, and a due amount of workshop slovenliness. The next chapter takes us into what may perhaps be called "smith's work in general," or at least it treats of the manufacture of various kinds of ironmongery for doors, windows, and house-fittings generally.

Then the third chapter treats of "smith's work which serves for the security of houses," consisting of railings, palings, bars, and gates of various kinds, such at least as are made of iron. In chapter four we have a notice of such kinds of smith's work as relate to the fastenings for doors, windows, closets, chests, etc.; such as hinges, hasps, latches, bolts, and other contrivances less complex than an actual lock.

This brings us, by a natural transition, to locks in general, which form the subject of chapter five, to which is attached the

illustrious name of M. de Reaumur as the author. Here are given a hundred folio pages of description, illustrated by twenty folio plates relating to locks, lock-making, and locksmiths. The sixth chapter relates to the iron-work of carriages, or the labors of the coach-smiths; while chapter seven, to wind up the work, relates to bell-hanging.

That chapter of the work which has reference to locks is the only one with which we have to do here. It is arranged in a systematic manner, beginning with the simpler locks, without wards or tumblers, and proceeding thence to others of more complex construction. The period at which the work was written was too early to lead us to expect to find a tumbler-lock described and delineated: there are, however; numerous examples of single tumbler-locks, many of them of great ingenuity.

The use of multiple bolts, that is, of many bolts shot at once by one action of the key, seems to have been familiar enough to the locksmiths of those days. One lock represented is remarkable; it is attached to a strong and ponderous coffer or chest. The chest is open; and the whole under or inner surface of the cover is seen to be occupied by a lock of intricate construction; there are no less than twelve bolts, three on each long side, one on each short side, and one in each corner; these bolts are so placed as to catch under a projecting rim fixed round the top of the coffer. The collection of keys, exhibited on a separate plate, is remarkable for the great variety of forms given to them. We shall by and by copy some of the drawings of this curious work.

It was to be expected that in the *'Encyclopedie Methodique'* published in the same country and in the same century, the locksmith's art would be treated at some such length as in the work just described. Among the two hundred volumes of which the *cyclopedie* consists, several are devoted to arts and manufactures; and one of them contains the article in question.

It occupies 168 quarto pages, and is illustrated by 35 copper-plate engravings, showing in detail not only the parts of various locks, but the tools used by the lock maker. It is proper, however, to remark, that much of the letterpress and many of the plates relate to smith's work generally, and not exclusively to lock-work; the French name *serrurerie* being applied not only to lock-making, but to most of the smith's work required in dwelling-houses.

This affords, indeed, a striking illustration of the fact that until lately a lock-maker has been regarded rather as a smith than as a machinist; rather as a forger and filer of pieces of iron, than as a fabricator of delicate mechanism. One of the most curious features in this treatise is a vocabulary, containing in alphabetical arrangement, a minute account of all the French technical terms employed in the locksmith's art. This vocabulary alone occupies 38 quarto pages.

The Germans, like the French, bestow great attention on the treatises relating to the manufacturing arts. Some of these are, indeed, worked up to a degree of minuteness which would seem superfluous, where little distinction is drawn between the importance of fundamental principles and that of mere technical details. Locks have had their due share.

The article on locks in Prechtl's *Technological Encyclopedia* written by Karmarsch, and published in 1842, occupies about 140 pages. Locks are very minutely classified by the author, according to the purposes and their modes of action, and are illustrated by many plates. One of his classifications is into *German, French,* and *Bastard* locks, referring in part to the extent to which the key turns around in the lock; and the last of the three having an intermediate character between the other two.

After treating of the ordinary warded locks, he comes to the combination principle; and it is profitable here to notice how well the works of our machinists are understood on the continent, when they have anything to recommend them; there are a dozen closely printed pages devoted to a minute description of Bramah's invention, with all the separate parts illustrated by copper-plate engravings. After this comes a more general account of the details and manufacture of locks, similarly illustrated by engravings.

Whatever may be the merits of the different articles relating to locks in the various English cyclopedias, there are none approaching in length to the article in Prechtl's work. But when we consider that Prechtl devotes twenty large volumes to technological or manufacturing subjects, he is of course able to devote a larger space to each article than is given in English works. Both in England and in America, men are more disposed to do the work than to describe it when done.

In the *Encyclopedia Britannica,* in Rees' *Cyclopedia,* in Hebert's *Engineers' and Mechanics' cyclopedia,* in the *Encyclopedia*

Metropolitana, in the *Penny Cyclopedia,* and in other similar works, locks are described as well as can be expected within the limits assigned to the articles. Mr. Bramah's essay on locks, and on his own lock in particular, is one of the few English pamphlets devoted expressly to this subject.

An excerpt from the proceedings of the Institute of Civil Engineers, in 1851, gives an interesting paper on locks by Mr. Chubb; and shorter reports of papers and lectures have been published in various ways. Perhaps the best account of locks which we have, considering the limited space within which a great deal of information is given in a very clear style, is that contained in Mr. Tomlinson's “Cyclopedia of Useful Arts.”

CHAPTER TWO: Ancient Locks: Grecian, Roman, Egyptian

MASTER EXHIBIT LIST

LOCKS and door-fastenings have not, until modern times, been susceptible of any classified arrangement according to their principles of construction. They have been too simple to require it, and too little varied to permit it. That some such fastenings must be employed wherever doors of any kind are used is sufficiently apparent; and there is a little (though only a little) information obtainable, which shows the nature of the fastenings adopted in early times.

The bolt, the hasp, the chain, the bar, the latch, the lock, all were known in one or other of their various forms, in those ages which we are accustomed to consider classical. Travelers, generally speaking, do not descend to locks, or rather they do not think about them; otherwise they might have collected much that would have been novel and applicable to the present work; and indeed, there is some ground for the assertion, that a notice of the door-fastenings of all nations would reveal to us something of the social and domestic habits of various members of

the great human family. Be this as it may, however, we may profitably make a little inquiry into the locks of ancient times.

In the volumes of Lardner's *Cyclopedia* relating to the "Manners and Customs of the ancient Greeks and Romans," we do not find any mention of the kinds of locks used by those nations; but the author, while describing the houses, says: "Doors turned anciently upon large pivots in the center let into sockets in the lintel and threshold, so that one of the sides opened inwards, the other outwards; and Plutarch gives the following curious reason why persons were to knock and alarm the porter, viz. lest the visitor entering unawares should surprise the mistress or daughter of the family busy or undressed, or servants under correction, or the maids quarreling." As the visitors had thus the power (if permitted so to do) to open the outer door of a house, it would appear that very little in the nature of a lock was employed under ordinary circumstances, unless indeed it were a mere latch.

In respect to Roman houses it is stated, that "the doors revolved upon pivots, which worked in a socket below, and were fastened by bolts which hung from chains." There is no mention of locks here. Mr. St. John, in his work on the same subject, says: "The street-door of a Grecian house, usually, when single, opened outwards; but when there were folding-doors, they opened inwards, as with us."

"In the former case it was customary, when any one happened to be going forth, to knock, or call, or ring a bell, in order to warn passengers to make way." After describing the various kinds of wood of which the doors were made, he proceeds: "The doors at first were fastened by long bars passing into the wall on both sides; and by degrees smaller bolts, hasps, latches, and locks and keys succeeded. For example, the outer door of the Thalamos in Homer was secured by a silver hasp, and a leather thong passed around the handle, and tied, perhaps, in a curious knot.

Mr. Yates, in a learned article on this subject in Smith's ***Dictionary of Greek and Roman Antiquities,*** collects numerous details scattered through various early writers. We will string together a few of these details, so far as they have any relation to the fastenings of doors. The outer door of a Roman house was generally called ***janua;*** whereas the inner doors were called ***ostia.*** The doorway, when complete, consisted of four indispensable parts: the threshold or sill, the lintel, and the two jambs. The threshold, on which the feet trod, was often

regarded with a kind of superstitious reverence; the lintel, which crossed the doorway at the top, having a considerable superincumbent weight to bear, was usually made of one piece of timber or stone of great strength. The jambs, or side uprights, were also made in one piece each.

The **doorway**, in every building of the least importance, contained two doors folding together; even the internal doors had their **bi-valve** construction. But in every case each of the two valves was wide enough to allow persons to pass through without opening the other; in some cases even each valve was double, so as to fold like our window-shutters.

These doors, or valves, were not hinged to the side-posts, as with us, but were, as has already been stated, pivoted to the lintel above and the threshold below. The fastening usually consisted of a bolt placed at the base of each valve or half-door, so as to admit of being pushed into a socket made in the sill to receive it.

The doorways in some of the houses at Pompeii still show two holes in the sill, corresponding to the bolts in the two valves. At night, the front door of the house was further secured by means of a wooden and sometimes an iron bar placed across it, and inserted into sockets on each side of the doorway; hence it was necessary to remove the bar in order to open the door. Chamber-doors were often secured in the same manner.

In the ***Odyssey*** there is mention of a contrivance (adverted to by Mr. St. John) for bolting or unbolting a door from the outside; it consisted of a leather thong inserted through a hole in the door, and by means of a loop, ring, or hook, capable of taking hold of the bolt so as to move it in the manner required.

*We have here evidently the elements of a more complete mechanism; for the bolt was a crude lock in the same degree that the thong was a crude key. That the Romans afterwards had real locks end keys is clear; for the keys found at Herculaneum and Pompeii, and those attached to rings, prove that a kind of warded lock must have been well known. There are the remains of a tomb at Pompeii, the door of which is made of a single piece of marble, including the pivots, which were encased in bronze, and turned in sockets of the same metal; it is three feet high, two feet nine inches wide, and four and a quarter inches thick; it is cut in front to resemble panels, and thus approaches nearer in appearance to a modern wooden door; and it was fastened by some

kind of lock, traces of which still remain.

The same facts frequently become more clear when described in different words by different writers. We shall make use of this circumstance. Mr. Donaldson, in his ***Essay on Ancient Doorways,*** presents us with details that illustrate many of the foregoing remarks.

Homer describes the treasures and other valuable objects (mentioned in the *Odyssey)* as being kept in the citadel, secured merely by a cord intricately knotted. This, of course, was soon found to be a very insufficient protection, and therefore a wooden bar was adopted inside the doors of houses, to which it was attached by an iron latch, fastened or removed by a key adapted to it; this key was easily applied from within; but in order to get at it from without, a large hole was made in the door, allowing the introduction of the hand, so as to reach the latch and apply the key.

The lock, called the Lacedemonian, much celebrated by ancient writers, was invented subsequently; it was especially fitted for the inner chambers of houses, the bar fastenings continuing to be employed for closing the outer doors of dwellings and the entrance-gates to cities. The Lacedemonian lock did not require a hole to be made in the door, for it consisted of a bolt placed on that side of the entrance-door which opened, and on the inside of a chamber-door.

When a person who was outside wished to enter, it was necessary for him to insert the key in a little hole and to raise the bolt; and in time this species of fastening was improved by the insertion of the bolt in an iron frame or rim permanently attached to the door by a chain, and fastening the door by the insertion of the hasp, through the eye of which was forced the bolt inside the lock by applying the key.

After quoting a Latin sentence from Varro in elucidation of his subject, Mr. Donaldson proceeds to observe, that for the most part the locks of the ancients were different in principle from those of modern days, not being inserted or mortised into the doors, nor even attached except by a chain; they were, in fact, padlocks.

One of the passages in the *Odyssey* alluding to the primitive mode of fastening the valves or folding-doors of a house runs thus:

"Whilst to his couch himself the prince addressed, The duteous nurse received the purple vest: The purple vest with decent care disposed, The silver ring she pulled, the door reclosed: The bolt, obedient to the silken cord, To the strong staple's inmost depth restored, Secured the valves."

Most of the other great nations of antiquity resembled either the Egyptians or the Greeks and Romans, more or less closely, in their domestic and domiciliary arrangements; or, at any rate, so far as such humble matters as locks and keys are concerned, we need not seek far from those nations for examples.

The Nineveh and other Assyrian explorations have, however, revealed many curious and unexpected facts; from the temples and the palaces we may by and by penetrate into the houses and rooms of the citizens sufficiently to know how their doors were fastened. In the meantime, ancient Egypt awaits our notice.

Sir J. Gardner Wilkinson, in his ***Manners and Customs of the Ancient Egyptians,*** gives the following information concerning the doors and door-fastenings of that remarkable people, on the authority of models, sculptures, and paintings, still existing. The doors were frequently stained so as to imitate foreign and rare woods. They were either of one or two valves, turning on pieces of metal, and were secured within by a bar or by bolts. Some of these bronze pins have been discovered in the tombs of Thebes; they were fastened to the wood with nails of the same metal, the round heads of which served also as ornaments.

In the stone lintels and floors behind the thresholds of the tombs and temples are still frequently to be seen the holes in which the pivot-pins turned, as well as those of the bolts and bars, and the recess for receiving the opened valves. The folding-doors had bolts in the center, sometimes above as well as below; a bar was placed across from one wall to the other.

In many of the ancient Egyptian doors there were wooden locks fixed so as to fasten across the center at the junction where the two folds of the door met. It is difficult, by mere inspection of the bas-reliefs and paintings, to decide whether these locks were opened by a key, or were merely drawn backwards and forwards like a bolt; but if they were really locks, it is probable that they were on the same principle as the Egyptian lock still in use.

For greater security, these modern locks are occasionally sealed with a mass of clay; and there is satisfactory evidence that the

same custom was frequently observed among the ancient inhabitants of that country. Sir J. G. Wilkinson gives a representation of an iron key, now in his possession, which he procured among the tombs at Thebes, and which looks very much like a modern burglar's pick-lock.

In relation to keys generally, and after mentioning the use of bronze for their manufacture, he says: "At a later period, when iron came into general use, keys were made of that metal, and consisted of a straight shank about five inches in length, and a bar at right angles with it, on which were three or more projecting teeth. The ring at the upper extremity was intended for the same purpose as that of our modern keys; but we are ignorant of the exact time when they were brought into use; and the first invention of locks distinct from both is equally uncertain; nor do I know of any positive mention of a key, which, like our own, could be taken out of the lock, previous to the year 1336 before our era; and this is stated to have been used to fasten the door of the summer parlor of Eglon, the king of Moab."

The description here adverted to is that contained in Judges iii. 23-20:

> **"Ehud went forth through the porch, and shut the doors of the parlor upon him, and locked them .... his servants .... took a key, and opened them."**

The curious and ingenious wooden lock of ancient Egypt is still in use in Egypt and Turkey. In Eton's ***Survey of the Turkish Empire,*** published towards the close of the last century, the locks then and there in use are thus described:

> "Nothing can be more clumsy than the door-locks in Turkey; but their mechanism to prevent picking is admirable. It is a curious thing to see wooden locks upon iron doors, particularly in Asia, and on their caravanserais and other great buildings, as well as upon house-doors. The key goes into the back part of the bolt, and is composed of a square stick with five or six iron or wooden pins, about half an inch long, towards the end of it, placed at irregular distances, and answering to holes in the upper part of the bolt, which is pierced with a square hole to receive the key. The key being put in as far as it will go, is then lifted up; and the pins, entering the corresponding holes, raise other pins which had dropped into these holes from the part of the lock immediately above, and which have heads to prevent them falling lower than is necessary."

"The bolt, being thus freed from the upper pins, is drawn back by means of the key; the key is then lowered, and may be drawn out of the bolt. To lock it again, the bolt is only pushed in, and the upper pins fall into the holes in the bolt by their own weight."

Mr. Eton, probably seeing how well the tumbler-principle is here understood, says: "This idea might be improved on; but the Turks never think of improving. The locks on the doors of modern houses in Cairo seem to be of this long-established form, except where iron locks have been imported from Europe."

A letter was inserted in the ***Journal of Design*** for July 1850, from Mr. W. C. Trevelyan; in which, after adverting to the Egyptian lock, he says:

"It is remarkable that the locks which have been in use in the Faroe Islands, probably for centuries, are identical in their construction with the Egyptian. They are, lock and key, in all their parts made of *wood;* of which material, if I mistake not, they have also been found in Egyptian catacombs; and so identical with the Faroes in structure and appearance, that it would not be easy to distinguish one from the other."

The construction of this remarkable Egyptian or pin-lock (pin tumbler) will be understood from the accompanying engravings. The quadrangular portion, in figure 1, is the case of the lock, screwed or otherwise fastened to the door, having a wooden bolt, passing horizontally through a cavity in it. In the part of the case above the bolt are several small cells containing headed pins, arranged in any desired form; and in the top of the bolt itself are an equal number of holes similarly arranged.

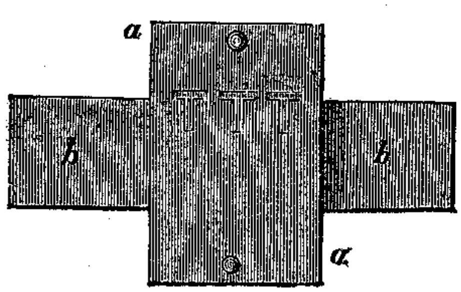


Figure 1

The effect of this arrangement is such that, when brought into

the right position, the lower ends of the headed pins drop into the corresponding holes in the bolt, thereby fastening the bolt in the lock-case. A large hollow, or cavity, is made at the exposed end of the bolt; the cavity extending as far as and beyond the holes occupied by the pins.

The key consists of a piece of wood (shown in two positions, (figures 3 and 4,) having pins arranged like those in the lock, and projecting upwards just to a sufficient distance to reach the upper surface of the bolt. This being the arrangement, whenever the key is introduced and pressed upwards, its pins exactly fill the holes in the bolt, and by so doing dislodge those which had fallen from the upper part of the case.

The bolt may, under these circumstances, be withdrawn (as shown in figure 2), leaving the headed pins elevated in their cells, instead of occupying the position shown by the dotted lines in figure 1. The cavity in the bolt must of course be high enough to receive the thickness of the key, and also the length of the pins protruding from the key.

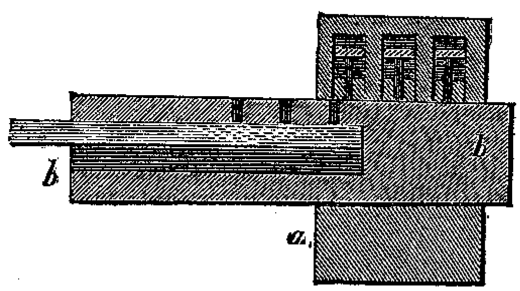


Figure 2

This primitive lock comprises many of the best features of the tumbler or lever-locks of later days, as will be seen in a future chapter. There will also be opportunities of showing how the pin-action has been applied in other ways in some of the modern locks.

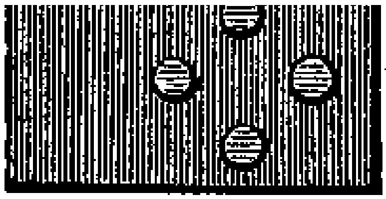


Figure 3



Figure 4

CHAPTER THREE: Lock Classification; the Puzzle-Locks and the Dial-Locks

MASTER EXHIBIT LIST

Figure 5 Puzzle look of the seventeenth century.

In approaching the subject of modern locks, it becomes necessary to decide upon some method of treating the widely-scattered and diverse materials which are presented to our notice. One plan would be to trace the subject chronologically, by describing, in the order of their invention, the most important locks that have been presented to public notice. But this would be attended with some disadvantages: the peculiar characters of the several locks would not be brought out with sufficient distinctness; and the result, so far as the reader is concerned, would rather tend to confusion than to a clear appreciation of the subject.

There are more advantages belonging to a classification of locks under certain headings, according to some marked peculiarities in their modes of action. This is a convenient plan, but it is not an easy one to put in execution; for inventors have not sought to place their locks in any particular class, but rather to call attention to their merits.

Moreover, many locks embody two or three distinct principles so equally, that it will often be difficult to decide in which class to place them. This, nevertheless, may be done with an approach to correctness. It is necessary first, however, to explain certain technical terms by which locks are distinguished one from another.

Locks, in truth, admit of an immense variety, which, however important to be known to locksmiths, carpenters, and others employed by them, need only be glanced at very cursorily by the

general reader. Some locks are named according to the purposes to which they are to be applied; others according to their shape, or the principles of their construction.

In the first place, there is the distinction between *in-door* and *out-door* locks. Of in-door locks, one principal kind is the *draw-back* lock, for street-doors, in which the bolt is capable of maintaining any one of three positions: it may be locked by the key, or left half-way out by the pressure of a spring, or be drawn back by a handle.

In the first position, it can only be withdrawn by the key; in the second, it closes the door, but can easily be withdrawn by the handle; and in the third, it leaves the door unfastened. If these locks are made of iron and carefully finished, they are further called *iron-rim;* but if made of wood, suitable for back-doors and inferior purposes, they are *spring-stock.* For the doors of rooms, there are the *iron-rim,* the *brass-case,* and the *mortise* lock; the second supplants the first, and the third the second, as we advance in the elegance of the door-fittings.

Other designations for room-locks depend on the number of the bolts: thus, if there be only one bolt, it is a *deadlock* or *closet lock;* if there be a second bolt, urged by a spring and drawn back by a handle, it is a *two-bolt lock;* and if there be also a third, a private bolt acting only on one side of the door, it is a *three-bolt lock.* Again, according to the kind of handle employed, it may be a *knob-lock* or a *ring-lock.* According to which edge of the door it is to be fixed, it becomes a *right-hand* or a *left-hand* lock.

If the wards of the lock are of somewhat superior quality, and bent round nearly to a circle, the lock is *one-ward round, two ward round,* and so forth. If the lock has no wards at all, it *is plain;* if the wards are of common character, they are often called *wheels,* and then the lock becomes *one-wheel, two-wheel, etc.* Sometimes the lock is named from certain fancied resemblance in the shape of the ward, as the *L-ward, T-ward,* or *Z-ward.* If the wards are cast in brass, instead of being made of slips of iron or copper, the lock is termed *solid ward*

Of the numerous but smaller varieties known by the collective name of ***cabinet locks,*** there are the *cupboard,* the *bookcase,* the *desk,* the *portable desk,* the *table,* the *drawer,* the *box,* the *caddy,* the *chest,* the *carpet-bag,* and many other locks. All these

locks are further called *straight,* when the plate is to be screwed flat against the wood-work; *cut,* when the wood is to be so cut away as to let in the lock flush with the surface; and *mortise,* when a cavity is excavated in the edge of the door for the reception of the lock.

Out-door locks are usually *wooden stock locks,* for stables, gates, etc.; comprising many varieties of *Banbury bastard, fine, etc*. There are D *locks* and P *locks,* for gates, designated from their shapes; and there are the numerous kinds of *padlocks.*

The above terms are employed chiefly between the makers of the locks and the persons who fix them in their places; but there are other terms and names, more familiarly known, which will come under notice in future pages.

It is scarcely worthwhile to descant upon the "middle age" of lock-making, to impart to the subject so much of dignity as to be susceptible of regular historical treatment. True, we know that *wards* were employed before *tumblers* (unless, indeed, the pins of the Egyptian lock be considered as tumblers (a character to which they present considerable claim), and that wards may be taken as the representative of the medieval period of lock-making; but it may be more profitable to proceed in our notice of the different kinds of locks in an order which will in itself partake somewhat of the historical character.

Apart from all the warded and tumbler locks are the very curious *puzzle* or *letter-locks;* a construction which we propose to dismiss out of hand in the present chapter, before treating of those which have more commercial importance.

The puzzle-lock is generally in the form of a padlock, which is opened and closed without the use of a key, and which has certain difficulties thrown in the way of its being opened by any one who is not in the secret of the person who closed it. It is, in fact, one of the locks in which the doctrine of permutation is made to contribute to the means of security.

The key to open it is a *mnemonic* or *mental* one, instead of one of steel or iron. Two centuries ago, the puzzle-lock attracted far more attention than any other. It has always certain moveable parts, the movement of which constitutes the enigma. Some of these very curious and out-of-the-way locks are so formed as to receive the name of *dial-locks;* but the chief among them are *ring-locks,* a name the meaning of which will be presently

understood.

The puzzle or letter-lock of the ring kind, then, consists essentially of a spindle; a barrel, encompassing the spindle; two end-pieces, to keep the spindle and barrel in their places; and the shackle, hinged to one of these end-pieces. To unfasten the lock, one of the end-pieces must be drawn out a little, to allow the shackle or horseshoe to be turned on its hinge; and the question arises, therefore, how this end-piece is to be acted upon.

This is effected in a very ingenious way: there are four studs or projections in a row on the spindle, and as the spindle fits pretty closely in the barrel, the former cannot be drawn out of the latter unless there be a groove in the interior of the barrel, as a counterpart to the studs on the exterior of the spindle.

Four rings fit on the barrel, on the interior of each of which is a groove; unless all these four grooves coincide in direction, and even lie in the same plane as the groove in the barrel, the studs will not be able to pass, and the spindle cannot be drawn out. Each ring may be easily made to work round the barrel by means of the fingers, and to maintain any position which may be given to it. There are outer rings, one over each of the rings just described, with the letters of the alphabet (or a considerable number of them) inscribed on each; and these outer rings, by means of notches on the inside, govern the movements of the inner rings.

The action is, therefore, as follows: when the padlock is to be locked, the rings are so adjusted that all the grooves shall be in a right line; the spindle is thrust in, the end-piece is fixed on, and the shackle is shut down. The padlock is now fastened; but a reverse order of proceeding would as easily open it again, and therefore the "safety" or "puzzle" principle is brought into requisition.

The outer rings are moved with the finger, so as to throw the various interior grooves out of a right line, and thus prevent the withdrawal of the spindle. As each ring may be turned round through a large or a small arc, and all turned in different degrees, the variations of relative position may be almost infinite.

The letters on the outer rings are to assist the owner to

remember the particular combination which he had adopted in the act of locking; for no other combination than this will suffice to open the lock. There may, for instance, be the four letters L O C K in a line, which line is brought to coincide with two notches or marks at the ends of the apparatus; and until all the four outer rings are again brought into such relative position as to place the letters in a line, the lock cannot be opened.

There are many allusions to locks, apparently belonging to the letter or puzzle principle, by authors who flourished two or three centuries ago. Thus, in Beaumont and Fletcher's play of the *Noble Gentleman,* written in the early part of the seventeenth century, one of the characters speaks of "a cap-case for your linen and your plate. With a strange lock that opens with A M E N" and in some verses by Carew, written about the same time, there is an analogy drawn, in which one of the things compared is:

"A lock that goes with letters; for till every one be known,
The lock's is as fast as if you had found none."

In the *Memorabilia* of Vanhagen von Ense, written about the middle of the seventeenth century, a commendatory notice is given of a letter-lock, or combination lock, invented by M. Regnier, Director of the *Musee d'artillerie* at Paris. "Regnier," we are told, "was a man of some invention, and had taken out a patent for a sort of lock, which made some noise at the time. Everybody praised his invention, and bought his locks. These consisted of broad steel rings, four, five, or eight deep, upon each of which the alphabet was engraved; these turned round on a cylinder of steel, and only separated when the letters forming a particular word were in a straight line with one another.

The word was selected from among a thousand, and the choice was the secret of the purchaser. Anyone not knowing the word might turn the ring round for years without succeeding in finding the right one. The workmanship was excellent, and Regnier was prouder of this than of the invention itself. The latter point might be contested.

I had a vague recollection of having seen something of the sort before; but when I ventured to say so, my suspicions were treated with scorn and indignation, and I was not able to prove my assertion; but many years afterwards, when a book, which as a boy I had often diligently read, fell into my hands, Regnier's lock was suddenly displayed.

The book was called *Silvestri a Petrasancta Symbola Heroica,* printed at Amsterdam in 1682. There was an explanation at p. 254, attached to a picture; these were the words: *Honorius de Bellis, Serulae innescae orbibus volubilibus ac literatis circumscripsit hoc lemma—Sorte ant labore.* However, neither luck nor labor would have done much more towards discovering the secret of opening Regnier's locks, from the variety of their combinations; and their security seemed so great, that the couriers' despatch-boxes were generally fastened with them."

This curious extract, which was brought forward by Mr. Chubb, in a paper on locks and keys (read before the Institution of Civil Engineers in 1850), seems to take away the credit from one (Regnier) with whose name the letter-lock has been most intimately associated. We shall presently explain, however, what it was that Regnier effected towards perfecting the letter-lock. In the meantime it may be interesting to note that the British Museum contains a copy of the work mentioned by Vanhagen.

At the page indicated there is an engraving (a facsimile of which is given in **Figure 5**) containing a drawing of a veritable puzzle or letter-lock; the lock consists of a cylinder or barrel, on which seven rings work; each of these rings is inscribed with letters, and the ends of the cylinder are grasped by a kind of shackle.

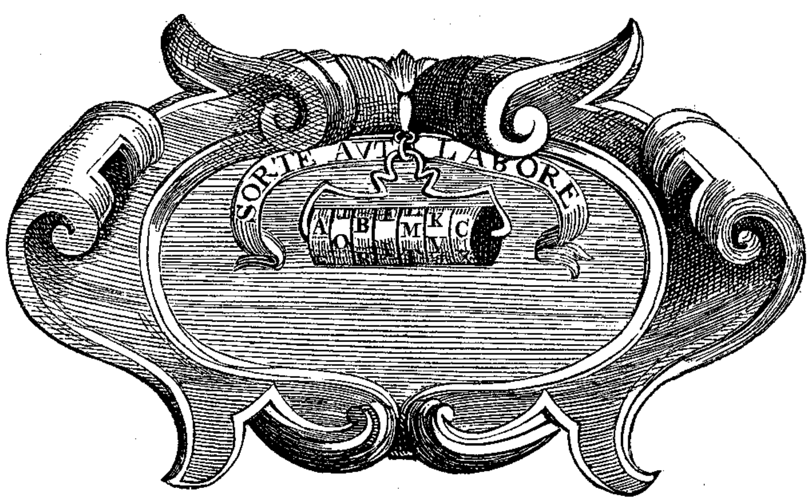


Figure 5 Puzzle look of the seventeenth century.

It was a natural result of the arrangement of the letter lock, as invented (conjecturally) by Cardan, that only one particular word or cipher or key could be used in each lock; and it was to

increase the puzzle-power of the lock that Regnier doubled all the rings, making each pair concentric, and enabling the user to vary the cipher at pleasure.

The principle of the letter-lock, when applied to **doors**, requires that sort of modification which renders it what is termed a *dial-lock.* There are to such a lock one or more dials, with a series of letters or figures stamped on them; there is to each dial a hand or pointer connected by a spindle with a wheel inside the lock; on the wheel is a notch which has to be brought to a certain position before the bolt can be moved. There are false notches, to add to the difficulty of finding the true notch in each wheel.

To adjust the notches to their proper position, a nut on the back of the wheel is loosened, and the pointer is set at any letter or figure chosen by the user. The pointers and the dials perform the part of the outer rings, the wheels that of the inner rings; and it is easy to see that the same leading features prevail in the two kinds of lock, however they may differ in detail.

These dial-locks have not been numerous; they require wheel and pinion work within the body of the lock, which gives delicacy and complication to the mechanism. The letter padlock, be its merits great or small, is strong and durable, not liable to get out of order; and insofar as it requires no key or keyhole, it occupies rather a special position among locks. One of our great "merchant-princes" has been a letter-lock inventor, as the following will show.

Early in 1852, Mr. William Brown, the distinguished member for South Lancashire, read a paper before the Architectural and Archaeological Society of Liverpool, of much interest in relation to our present subject. His object was to describe a letter-lock that he had invented, and which had up to that time given high satisfaction. We cannot do better than transcribe the paper, as reported in one of the Liverpool Journals, with a few abridgments.

"As your society are desirous of seeing any improvements **or** attempts at them, I send you a stock-lock for inspection. The idea for its construction I took from a letter-padlock. I had a lock of this description. made by Mr. Pooley twenty-five years ago, which has been in use ever since on Brown, Shipley, and Co.'s safe.....

"Its advantages I conceive to be as follows: First, it cannot be picked, for there is no keyhole. Second, it cannot be blown up by gunpowder, for the same reason. Third, you cannot drill through the door so as to reach the lock, for you are intercepted by a steel plate on which your tools will not act: thus you cannot introduce gunpowder that way to force the lock off. Fourth, you cannot bounce off the wheels in the interior with a muffled hammer, for vulcanized India-rubber springs resist this. Fifth, you cannot drill the spindles out, as their heads are case-hardened. Sixth, you cannot drive them in, for they are countersunk in the door about half-way through.....

"Now let us set the lock to the word WOOD (any other four letters might be used). When you set the lock, make a private record of them, so that you may not forget them. If parties do not know your letters, nothing but violence, applied by some means or other, can enable them to get into your safe; for the lock will not open to anything but its talisman. Take off all the large wheels and open the lock: you will see that the large wheels have a number of false chambers; if you get the spurs of the bolt into three real chambers and one false, you are as fast as ever, for all four must be right.

"Having placed your key and pointer outside the door to point to **W** on brass-plate No. 1, the small wheel inside **obeys** the same impulse; then maintain your small wheel steadily on this point, and the large wheel No. 1 will only fit on at the right place, the true opening compartment being opposite the spur of the bolt. It being necessary at the time you set your lock that it should be open, proceed with Nos. 2 and 3 in the same way, your pointer, standing steadily at **O**. No. 4 is the same, the pointer being held steadily at **D**.

You should then shoot your lock two or three times, to be sure you have made no mistake. Every time you shoot your bolts out, turn your wheels away from the true chamber, and see when you again turn your pointers to **WOOD** that your lock opens freely; it is the proof that you have made no mistake, and you may now venture to lock your safe.

When you unlock the door, and find it necessary to leave it open for a time, you should shoot the bolts as if locked, and turn the wheels, so that no one may find what your real letters are; and again adjust them to their proper places, in order that the bolt may go back and enable you to relock. Once having locked the door and turned the wheels from your real letters, you need not

trouble yourself with carrying the key, but leave it in any place beside the lock.

"I believe two wheels would make a perfectly safe lock; three would be quite so. I adopted four to make security doubly sure, as it would be impossible in any given time to work the changes. On two wheels by chance the lock might open; you can, however, calculate the chances against this; and also three or four, the false compartment on the outer rim being taken into calculation.

"If this lock is of any value, it should be known; if it has weak points, let them be pointed out, and they may admit of a remedy; for we ought not to be led to believe a lock is safe which is not so."

In relation to the "first advantage" which Mr. Brown not unreasonably supposed to be possessed by his lock, viz. that "it cannot be picked, because it has no keyhole," we shall have something to say in a future page, where certain fallacies on this subject will be noticed. In the meantime we may remark, that it is not a little credible that a leading Liverpool merchant should have invented a lock worthy of occupying a position on his own safe for a quarter of a century; for we may be quite certain that he would not have allowed the lock to maintain that post of honor unless it had really (so far as experience had then gone) served worthily as a safeguard to his treasures.

And if it were possible to collect all the bygone specimens of lock-oddities, we should probably find among them many highly-ingenious letter-locks; for supposing a man to have a mechanical turn of mind, a lock is by no means an unworthy medium for displaying it; the pieces of metal are so small as to be easily manageable at a small workbench in a small room. The fondness for this sort of employment evinced by the unfortunate Louis XVI of France led to the common remark, "He is a capital locksmith, but a very bad king."

In an amusing article in the *Observer*, during the progress of the "lock controversy," was the following paragraph relating to combination locks of the letter or puzzle kind: "The French, in their exposition of 1844, availing themselves of the permutation principle, produced some marvels in the art; but the principle has not been adopted in this country. The *Chariwari* had an amusing quiz upon these locks when they first came out.

It said the proprietor of such a lock must have an excellent memory: forget the letters, and you are clearly shut out from your own house. For instance, a gentleman gets to his door with his family, after a country excursion, at eleven O'clock at night, in the midst of a perfect deluge of rain. He hunts out his alphabetical key, and thrusts it into his alphabetical lock, and says AZBX. The lock remains as firm as ever. 'Plague take it!' says the worthy citizen, as the blinding rain drives in his eyes. He then recollects that that was his combination for the previous day. He scratches his head to facilitate the movement of his intellectual faculties, and makes a random guess BCLO; but he has no better success.

In addition to his being wet, his chances of hitting on the right combinations and permutations are but small, seeing that the number is somewhere about three millions five hundred and fifty-three thousand five hundred and seventy eight. Accordingly, when he comes to the three-hundredth he loses all patience, and begins to kick and batter the door; but a patrol of the National Guard passes by, and the disturber of the streets is marched off to the watch-house."

CHAPTER FOUR: Warded Locks, with their various Appendages

MASTER EXHIBIT LIST

The more ordinary locks are of an oblong quadrangular shape. In nearly all of them, either a bolt shoots out from the lock, to

catch into some kind of staple or box, or a staple enters a hole in the edge of the lock, and is there acted upon by the bolt. A common room-door lock will illustrate the first of these kinds, a tea-caddy lock the second. The key, as is well known, enters a receptacle made for it; and the shaft of the key generally serves as a pivot or axis around which the web or flat part of the key may move in a circular course.

During this movement the web acts directly or indirectly on the bolt, driving it in or out according to the direction in which the key is turned; the key impels the bolt one way, certain springs act upon it in another, and the balance between these two forces determines the locking and unlocking of the bolt. *Wards,* or *wheels,* are contrivances for rendering the opening difficult without the proper key; and it is of warded locks that we shall chiefly treat in this chapter.

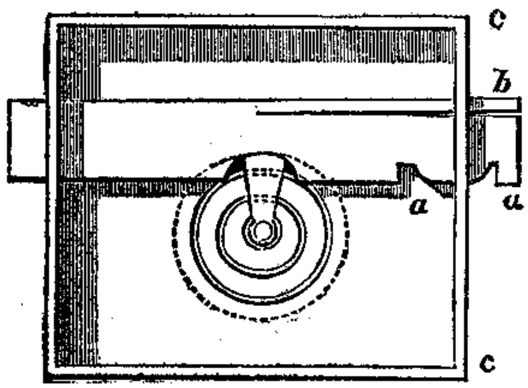


Figure 6 Interior of a back-spring warded lock.

The annexed cut, **figure 6**, represents the interior of an ordinary back-spring lock, without tumblers.

Such a lock may usually be known from a tumbler-lock by this simple circumstance, that it emits a smart snapping noise during the process of locking, occasioned by the pressure of the spring when the bolt is in a particular position. In the woodcut, the bolt is represented half out, or half shot. At **aa** are two notches on the underside of the bolt connected by a curved part; **b** is the back spring, which becomes compressed by the passage of the curve through a limited aperture in the rim ***cc*** of the lock.

When the bolt is wholly withdrawn, one of the notches **a** rests upon the rim ***cc;*** and the force with which the notch falls into this position, urged by the spring **b**, gives rise to the snapping

or clicking noise. When the bolt is wholly shot, the other notch rests in like manner upon the edge of the aperture in the rim.

It must be obvious at a glance, that this back-spring lock is objectionable on the score of security, on account of the facility with which the bolt may be forced back by any pressure applied to its end, a pressure which may often easily be brought to bear. At the center of the lock is seen the end of the key acting on a notch in the bolt, and surrounded by wards.

It is not at a first glance that the relation between the clefts in a key and the wards of a lock can be duly appreciated; because the wards present themselves to view as portions of circles to which nothing in the key seems to correspond but if it be borne in mind that the key has a rotary motion within the keyhole around the pipe or barrel as an axis, the circular form of the wards will be accounted for, and their *section will* be regarded as exhibiting the looked-for relation to the wards of the key.

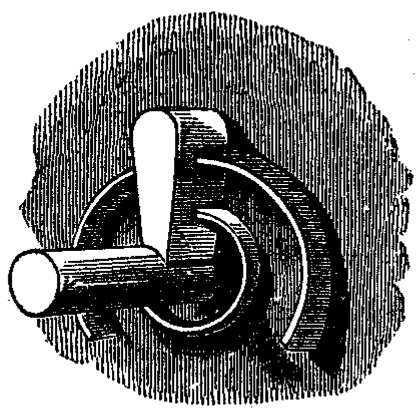


Figure 7 Section to show the action of wards.

In the annexed cut, for example (**Figure 7**), which represents a portion of the interior of a warded lock, the curved pieces of metal are the wards (two in this case); and there are two clefts in the bit of the key to enable the latter to take its circular course without interruption from the wards. If the clefts were other than they are, either in number, position, or size, this freedom of the key's movement could not be obtained.

When once the opinion became established that a lock is rendered secure by virtue of its wards, (a theory which we shall have to discuss in a later page), much ingenuity was displayed in varying the wards of the lock, the clefts of the key, and the shape of the keyhole. Even if the two former were unchanged, a change in

the latter might add to the puzzlement of the arrangement.

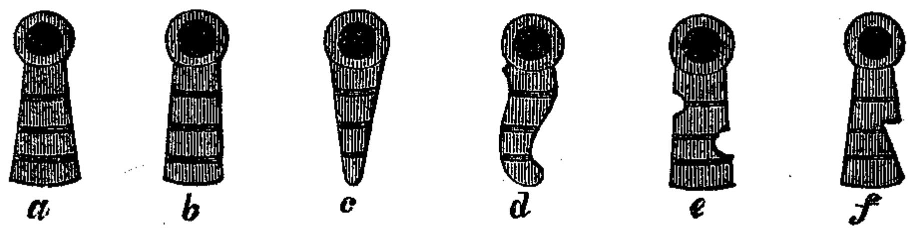


Figure 8

For instance, in the annexed cut (**figure 8**), all the six keys represented may have clefts or cuts exactly alike, all adapted to the wards of one particular lock; yet the differences in the *thickness* of the web are such, that if the keyholes were shaped in conformity therewith, each keyhole would be entered by one of these keys; **b** and **c** differing from **a** in the relative thickness at different points, and **d**, **e**, and **f** having certain curvatures and cavities not to be found in the other three.

But without waiting for the detailed examination of the relative security and insecurity of locks, we may at once show how simple is the principle which renders the warded system fallacious. In **figure 9** we shall be able to illustrate this.

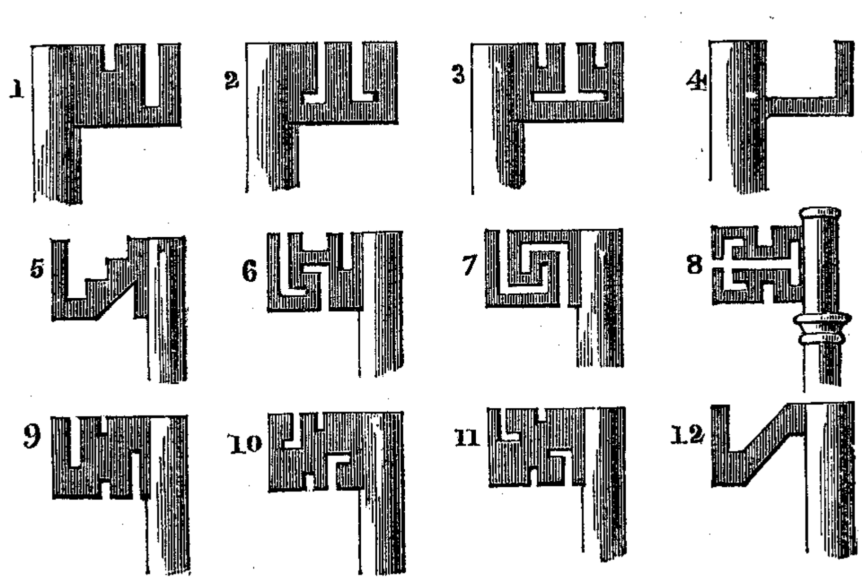


Figure 9 Examples to show the action of "master," or "skeleton keys."

Numbers 1, 2, and 3, all appear very different keys and it is quite true that neither one would open a lock adapted for either of the other two; and yet the very simple arrangement No. 4 would

open all three. This No.4 is called a ***skeleton key;*** and the relation which it bears to the others may be expressed in the form of a proposition thus: at any point where there is solid metal in *all* the keys, there must (or may) be solid metal in the corresponding part of the skeleton key; but at any point where there is a vacancy or cavity in any of the keys, there must be a cavity in the corresponding part of the skeleton key.

If Nos. 1, 2, 3, 4, be examined, this proposition will be found to be borne out; there is so much cavity in No. 4 that it avoids the wards in all the three locks, nothing being required but the tongue of metal to move the bolt. Sometimes to add to the safety, wards are attached to the front as well as the back plate of the lock; and then there may be a double series of notches required in the key, such as in No. 5; but if this be compared with Nos. 9, 10, 11, it will be found that although no one of the four would open a lock adapted for either of the other three, yet the skeleton key No. 12 would master them all, having cavities wherever any of the others have cavities.

This is the theory of the *master key,* by which one key may be made to command many locks. Nos. 6 and 7 have complicated wards; but the key is so much cut up as to be weakened more than is desirable. No. 8 enables as to point out the difference between two distinct **classes of** keys.

Keys with pipes or barrels fitting on a pin or pipe shaft can only open a lock on one side of the door or box; but a key with a solid stem, as No. 8, has the clefts so cut as to open the lock from either side, as in a street-door lock: it is, in fact, two warded keys fixed end to end, only half of which is employed at one time in opening the lock.

Some of the warded locks of the last century are curious. While the idea prevailed that a complicated ward gave security, there was room for the exercise of ingenuity in varying the shape of the wards. **Figure 10** is copied from the great French work. It represents the cuts in the key, and also (seen from a perspective) the complicated forms of the pieces of metal which constitute the wards corresponding with those cuts.

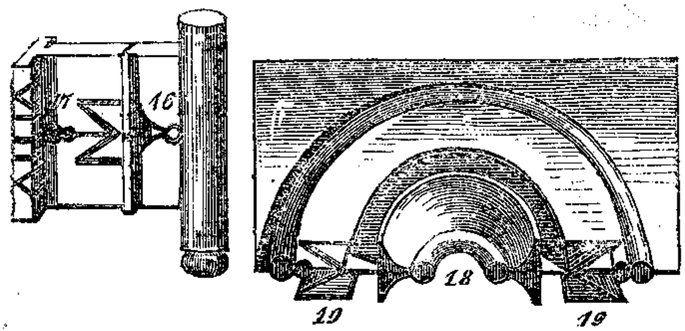


Figure 10 Cuts of a French key.

The aperture in the key at 16 fits upon the metal surrounding the keyhole at 18; and the M-shaped cuts at 17 fit in like manner upon the similarly-shaped metal pieces at 19.

Another example of a similar kind is shown in figure 11, where an anchor appears to have been the favorite form. The anchor-cuts in the key are shown at 26; while in the wards the bottom of the anchor is near the keyhole at 28, and the top at 29.

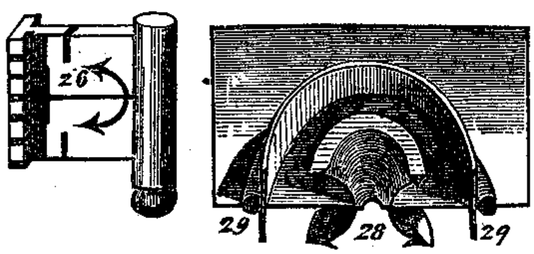


Figure 11 Wards of an old French lock.

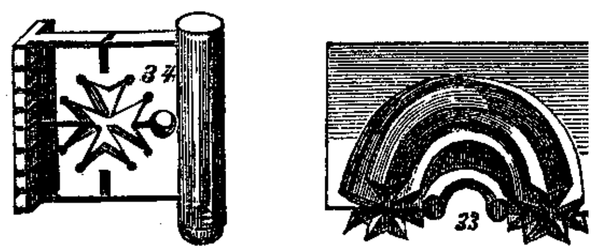


Figure 12 Wards of an old French look.

A similar illustration occurs in figure 12, where the star-like cuts at 34 on the key correspond with the star-like wards at 33.

From the fifteenth to the eighteenth centuries, locks were made in France, on which a vast amount of care and expense was bestowed. They were, in an especial degree, decorative appendages as well as fastenings. They were of three kinds: room-locks, buffet-locks, and chest-locks; they were fixed on the outside of the door or lid, so as to be fully visible.

The key had a multitude of perforations which bore no particular relation to the wards of the lock, but which were regarded as tests of the workman's skill. The honorary distinctions awarded to apprentices and aspirants in the art depended very much on the number and fine execution of these perforated keys. The locks,

considered as fastenings, had slender merit; although usually throwing four bolts, they were not very secure.

Figure 13 represents the exterior of a lock made about the year 1730, by Bridou, a celebrated Parisian locksmith. It was a lock belonging to a coffer or strong chest; all the works being sunk below the level of a carved architectural molding or ornament. There is a secret opening near the part **c**, forming a portion of the ornamental design; it allows a bolt, shown at **D**, figure 14, acted on by the spring **E**, to be touched, by which a doorway opens upon the hinges at **B B A A** are a sort of pilasters, which aid in forming a hold for the bolts.

The little ornament at **c** is drawn down by the hand, opening the secret door and revealing the keyhole **G. S S. O O. z z**, are ornaments fastened on at **b c d**, figure 14, by nuts and screws, intended to display the skill of the workman The lock itself, access to the keyhole of which is obtained within the secret door, has nothing very remarkable about it.

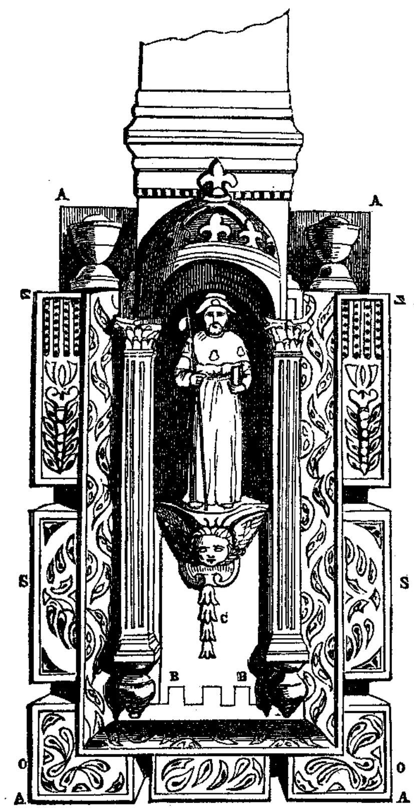


Figure 13 Exterior of an old secret lock.

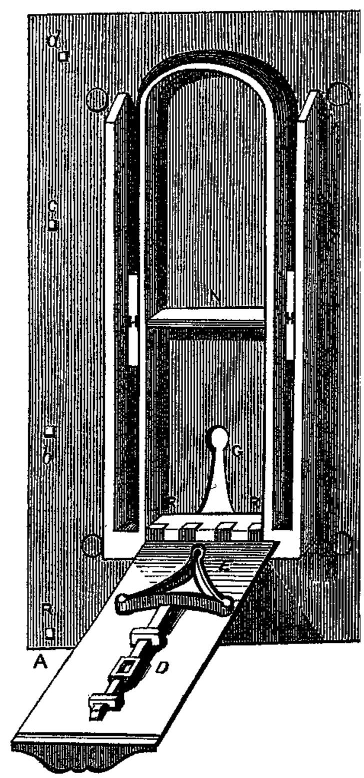


Figure 14 The same with a portion of the front letdown showing the keyhole.

Mr. Chubb, in his paper read before the Institute of Civil Engineers, illustrated the insecurity of the warded lock by the example of one which had actually been placed in the strong room of a banking house, and which is represented in the annexed cut (figure 15).

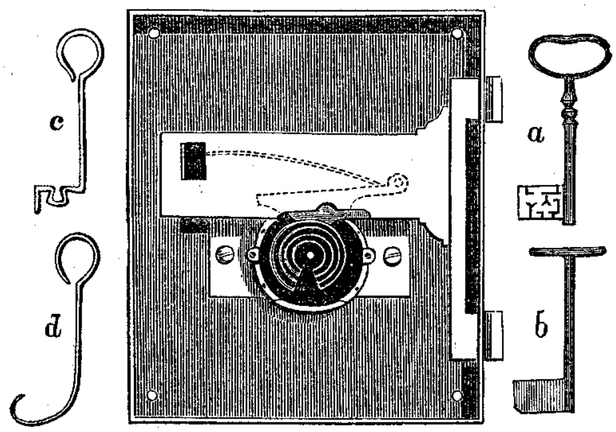


Figure 15 Examples of true and false keys.

The wards are here shown, surrounding the central key-pin; and from the appearance of the key, shown at **a**, it is evident that these wards must have been rather complex. But the uselessness of the wards was proved by the result. A burglar employed an instrument, shaped like that at **b** having on one of its faces, or sides, a layer of wax and yellow soap; this instrument, being introduced through the keyhole and turned a little way round, brought the soft composition in contact with the ends of the wards, and these ends thus left their impress on the composition.

A false key was then made, as at **c**, which, however clumsy it may appear, has a cavity, or vacuity, where there is a cavity in the true key; and by such a surreptitious instrument was the lock opened. Even so crude an instrument as **d**, by passing round the wards, might open such a lock. We are somewhat anticipating the full consideration of this subject; but it is desirable at once to explain how and why an improvement on the warded lock was sought for.

In connection with the fanciful eighteenth-century locks, lately adverted to, we may remark that no less a man than Louis XVI was an amateur workman in this department of mechanical art. or at least in smith's work, which in France is generally considered to include lock-making. Sir Archibald Alison says, in his *History of*

Europe: "He had an extraordinary fondness for athletic occupation and mechanical labor; insomuch that he frequently worked several hours a day with a blacksmith of the name of Gamin, who taught him the art of wielding the hammer and managing the forge."

"He took the greatest interest in this occupation, and loaded his preceptor in the art with kindness; who returned it by betraying to the Convention a secret iron recess which they had together worked out in the walls of the cabinet in the Tuileries, wherein to deposit his secret papers during the storms of the Revolution." There are not wanting indications that the unfortunate monarch wrought upon locks, as well as upon safes and strong rooms.

Besides wards, there have been numerous other contrivances far adding to the security of locks, including screws, escutcheons, spiral springs, wheel-and-pinion work, alarms, and multiple bolts. As these are not of sufficient importance to be treated in separate chapters, we shall here give just so much notice of them as will illustrate their general character. Some of them are found combined with the "tumbler" principle, presently to be described; but all of them, it is now well known, were employed in various ways when the tumbler lock was but little understood, and when the warded lock was held in esteem.

The Marquis of Worcester, whose curious *Century of Inventions,* written nearly two hundred years ago, contains so many suggestions which ingenuity has since developed into practical completeness, gives four of his inventions in the following words:

69. "A way how a little triangle-screwed key, not weighing a shilling, shall be capable and strong enough to bolt and unbolt, round about a great chest, a hundred bolts, through fifty staples, two in each, with a direct contrary motion; and as many more from both sides and ends; and, at the same time, shall fasten it to the place beyond a man's natural strength to take it away; and in one and the same turn both locketh and openeth it."

70. "A key with a rose-turning pipe and two roses pierced through endwise the bit thereof, with several handsomely contrived wards, which may likewise do the same effects."

71. "A key, perfectly square, with a screw turning within it, and more conceited than any of the rest, and no heavier than the triangle-screwed key, and cloth the same effects."

72. "An escutcheon, to be placed before any of these locks, with these properties: First, the owner, though a woman, may with her delicate hand vary the ways of causing to open the lock ten millions of times beyond the knowledge of the smith that made it, or of me that invented it.

Second, if a stranger open it, it setteth an alarm, which the stranger cannot stop from running out; and besides, though none shall be within hearing, yet it catcheth his hand as a trap cloth a fox; and though far from maiming him, yet it leaveth such a mark behind it as will discover him if suspected; the escutcheon or lock plainly showing what money he hath taken out of the box to a farthing, and how many times opened since the owner had been at it."

Mr. Partington, in his edition of the Marquis's singular work, makes a few comments on these lock-and-key contrivances. He says that the lock is evidently intended to operate on the principle of applying a *screw* for the purpose of moving the bolt, instead of using a key as a lever for this purpose. That such a plan might be applied to locks generally, he observes, there can be no doubt; and by a similar contrivance the large keys at present in use for outer doors, iron chests, etc, might be advantageously reduced by this means. By employing the escutcheon mentioned by the Marquis, much additional security would be obtained. It must be confessed, however, that many of the marquis's statements are difficult to credit.

The escutcheon has been a favorite resource with lock makers. Mr. Mordan's escutcheon, for instance, introduced before the Society of Arts in 1830, is a contrivance to be placed temporarily over the keyhole of a door, to prevent the picking of the lock during the owner's absence. The escutcheon, or "protector," has a short pipe which, after the door has been locked, is thrust into the keyhole.

Attached to the pipe is a small lock, on Bramah's or any other convenient principle, so contrived that, on turning its key, two lancet-shaped pieces fly out laterally and bury themselves in the wood. The escutcheon cannot be removed until the small key has reacted upon the small lock; and until this removal has taken place, the large key cannot reach the keyhole.

A curious application of the escutcheon principle attracted some attention among locksmiths about seventy years ago. One of the

first premiums awarded by the Society of Arts, after the commencement of their "Transactions," was to Mr. Marshall, for a “secret escutcheon," in 1784. In his description of his new invention, he adverts to the Marquis of Worcester's wonderful escutcheon, and to the many attempts which have since been made to produce an apparatus which should realize the Marquis's description.

He supposes that the letter padlock originated as one among many varieties of these imitative inventions; but this may be doubted. Mr. Marshall's contrivance, however, was in effect an endeavor to improve upon the letter-lock. He considered it an objection that, in ordinary locks of this kind, the letter-rings admit of no variation of place; and he sought to remedy this defect.

It is not so much a new lock, as an escutcheon for a lock which he produced. There is a studded bar passing through a barrel; there are five rings which work concentrically on this barrel; there are letters on the outer surfaces of the rings, and notches on the inner surface; but when, by the usual puzzle-action of the rings, the notches in them have been brought into a right line with the studs of the bar, the result is, not that the hasp of a padlock is raised, but that the escutcheon is removed from the keyhole of an ordinary lock. Mr. Marshall’s contrivance, therefore, is not so much a ring padlock, as a puzzle-ring security for the escutcheon of a fixed lock.

Some locks work by a screw and a spiral spring, instead of an ordinary key. Mr. W. Russell received a silver medal from the Society of Arts, about thirty years ago, for a new mode of locking the cocks of liquor-casks. Under ordinary circumstances, as is well known, the cock of a barrel or cask is in no way secure from the action of any one who can approach near enough to touch it; and different methods have been adopted of obtaining this security or secrecy.

One plan is to employ a perforated cap, soft-soldered to the barrel of the cock, immediately over the grooved plug, the top of which plug is formed to the shape of the perforation, and a socket-key of the same form is introduced to turn the plug or open the lock. Another plan is to employ an iron saddle or staple, passing over the plug and below the bottom of the cock, through which a bolt is put, and a pendent padlock attached.

The first method is very inefficient; the second is much superior, and has been largely adopted for locking the cocks of

coppers, stills, vats, and other large vessels. But Mr. Russell thought some further improvement was needed. He caused a hole to be bored through the barrel, and to some depth into the plug when the latter is in the position for closing the cock. A stud works into this hole in such a way, that when the stud is driven home, the plug cannot be turned or the lock opened.

The stud is attached at its other end to a spiral spring connected with a screw; a key is employed, the hollow pipe of which has an internal screw; and when this key is inserted in the cock-barrel and turned twice round, it draws back the stud, and allows the plug to be turned round in the proper way for opening the cock.

It is not often that wheel-and-pinion work is introduced into locks; the delicacy, the cost, the weakness, and the tendency to get out of order would all militate against the frequent adoption of such a course. It is, however, adopted occasionally. Mr. Friend's secret-lock, introduced to the notice of the Society of Arts in 1825, had a train of wheels which acted upon the bolt, driving it out whenever the circular arcs of three wheels moved against it, but allowing a spring to force it back again whenever a deep cleft in each of the wheels locked into a stud on the bolt.

There were certain numbers on a guide-plate, and a power of combining these numbers in great variety; and a provision that the bolt could be unlocked only by the same combination of numbers that had locked it. The guide-plate was a separate piece of apparatus, carried in the pocket of the user as a companion to the key. The key was of no use without the guide-plate, nor the guide-plate without the key.

The user 'set' the numbers on the guide-plate, then applied it to the face of the lock, then introduced the key into the keyhole, and turned the key partially round; the bolt was now shot, and the guide-plate removed. If the key were used without the guide-plate, the bolt might be locked, but it was always unlocked again by the time the key had made a complete circuit. There was considerable ingenuity in the idea of this lock; but we believe it never went further than a model. Indeed many of the locks elaborately described in books have never had an existence as acting working locks.

A very ingenious principle has been occasionally introduced in which clockwork regulates the interval of time that must elapse

before a lock can be opened, even with its **proper** key. The object is to ensure the safety of the lock during a journey, or until a particular person be present, or until the locked article is conveyed to a particular room. A patent was taken out in 1831 for a look on this principle by Mr. Rutherford, a bank agent at Jedburgh.

Against the end of the bolt of the lock is placed a circular stop-plate, so adjusted that the bolt cannot be withdrawn until a particular notch in the rim of the circular plate is opposite the end of the bolt. The plate is put in rotation by clockwork. As the notch can be set at pleasure to any required distance from the end of the bolt, the lock may be secured against being opened, either by its own or any other key, until any assigned number of minutes or hours after it has been locked; for the plate may be made to revolve either slowly or quickly, by varying the number of wheels in the clockwork.

When the lock is used for boxes or portable packages, the clockwork must be moved and regulated by a spring; but when it is applied to closets or safes, a descending weight and a pendulum may be employed. It is manifest that this system is susceptible of being greatly varied in its mode of application; and it has many points of interest about it. That a man cannot open his own lock with his own proper key until the lock gives permission by assuming a particular state or condition, certainly strikes one as being susceptible of many useful applications, where time is an element taken into the account.

A curious alarm lock was invented by Mr. Meighan, in 1836, in which the bell or alarm is not placed behind a door, as in many alarm contrivances, but within the **lock** itself. Two or more studs are placed on the bolt, which press against the lower end of a small tumbler. The movement of the tumbler elevates a hammer; but as soon as the point of the tumbler becomes released from the stud, a spring presses the hammer down forcibly, and causes it to strike against a small bell placed near it. This sounding of the bell will be repeated, during the shutting of the bolt, as many times as there are studs to act upon the point of the tumbler.

Much of the ingenuity that has been displayed in locks depends on the employment of multiple bolts, there being all the additional strength that results from the use of two or more bolts instead of simply one. Ordinary doors seldom afford us examples of these double bolts; but they may be frequently seen in cabinets and desks, where two staples fixed to the lid fall into two holes in

the lock, and are retained by two bolts.

The most remarkable and complicated varieties, however, are those in which the bolts, instead of shooting parallel and nearly together, shoot in wholly different ways; one up, one down, one to the right, one to the left, and so on. It is on safes, strong boxes, and the doors of strong rooms containing valuable treasures, that such locks are usually placed. The mechanism is such that the key acts upon all the bolts at once, through the intervention of levers and springs of various kinds.

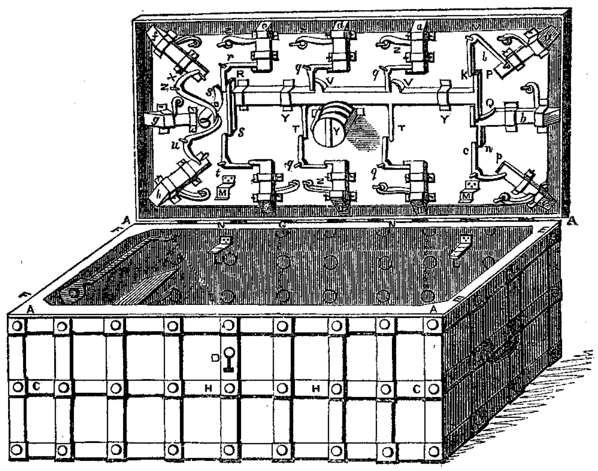


Figure 16 Multiple bolts of an old chest look.

The above woodcut represents a very curious specimen of these multiple-bolt locks. It is copied from the great French work; and the ponderous chest to which it is attached is, we are told by Reaumur, "known at Paris by the name of the strong German coffer." He further says, "nothing is wanting in these coffers on the score of solidity. They are made entirely of iron; or if of wood, they are banded both within and without with iron; and can only be broken open by very great violence." "Their locks are almost as large as the top of the coffer, and close with a great number of bolts. The one which we have engraved has twelve fastenings; they have been made with twenty-four, or more."

His next remark on the subject is a sensible one: "Notwithstanding the large size of these locks, and all the apparatus with which they are provided, they correspond but ill with the solidity of the rest of the coffer. If we have given a representation of one, it is chiefly to show how little confidence one could have in such a lock, and what are its defects, in order that we may avoid them."

It is not difficult, by tracing the action of the several levers, to see how one movement of the key, in the center of the lid, would act upon all the bolts. In the engraving (Figure 16) ***a,f,h,c*** are the four corner bolts; six others, ***ace, ace,*** are on the long sides, three on each; and two, ***bg,*** on the short sides.

Every bolt is provided with a spring, of which three or four are shown at **zzz**. There is no staple or box to receive each bolt; but all shoot or snap beneath the raised edge **E** running round the top of the box just within the exterior at **AA**. The keyhole in the front of the box at **D** is a deception or mask; the real keyhole is in the middle of the lid concealed by a secret door opened by a spring.

When the key has moved the great central bolt, this acts upon the other bolts **P Q R S T** etc.; **v v** are studs which act upon two of the bolts; **yy** are staples confining the great bolt; ***k,l, c,p,x,*** *are* small levers which transmit the action to the corner bolts; ***q,r,s,t,n,*** are the small levers which render a similar service to the side and end bolts; **LL** within the chest, and **MM** on the lid, are contrivances for limiting the movement of the latter; **CH, UC** are iron straps or bands by which the interior of the chest is strengthened. After all, this is not so much a lock as a series of spring latches.

If a lock can be picked, the picking is as effective whether the lock has one bolt or twelve bolts. This fact led Mr. Duce, in 1824, to construct, instead of a four-bolt lock, four distinct one-bolt locks, fixed in the same frame and opened by the same key; the bolts to be moved in succession instead of simultaneously. It would require four times as long to pick this as a four-bolt lock of similar action.

There have been many other varieties of the multiple bolt, but we need not stop to describe them.

CHAPTER FIVE: On Tumbler or Lever Locks

MASTER EXHIBIT LIST

SECURITY being the primary object in all locks, any considerations as to mechanical ingenuity and graceful decoration give place to those which relate to safety. A spring lock may be ingenious and even beautiful in its construction, but an imitative key will easily open it. Hence arose the invention of wheels or wards; and as wards failed in trustworthiness, they in their turn yielded to something better.

We have already explained how the insecurity of mere warded locks arises; and we shall have something more to say on the subject in a future chapter. It is sufficient here to remark, that wards, springs, screws, alarms, wheel-work, escutcheons, all, however useful for particular purposes, are wanting in the degree of surety which we require in a lock. Hence the invention of *tumblers, levers,* or *latches,* which fall into the bolt and prevent it from being shot until they have been raised or released by the action of the key.

We have been unable to ascertain at what time, or in what country, or by whom, tumbler-locks were invented. The invention has been claimed by or for persons subsequently to the year 1767, when the celebrated French treatise *(Art du Serrurier)* already referred to was published; and yet this treatise contains numerous examples of simple tumbler locks of ingenious construction, as will presently be shown.

One of the most elementary forms of tumbler-lock is shown in **figure 17**. In this case the bolt, instead of having two notches in the bottom edge, like those in the back-spring lock, **figure 6**, has two square notches or slots in the upper edge; and as the key acts upon the bolt, these notches must of course share in whatever movements the bolt is subjected to.

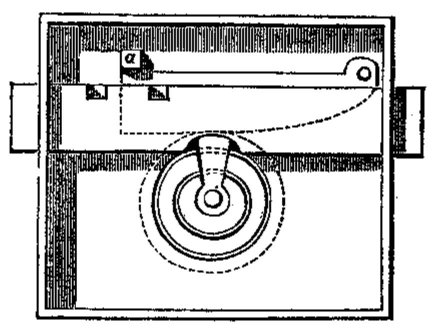


Figure 17 Simple tumbler lock.

Behind the bolt is a kind of latch or tumbler (the lower part of which is shown by dotted lines), with a stump or projecting piece of metal at **a**; the tumbler moves freely on a pivot at the other end, and is made to rise through a small arc whenever the key acts upon the bolt. When the bolt is wholly shot, the stump falls into one notch and prevents the motion of the bolt; when wholly withdrawn, the stump falls into the other notch, and equally prevents the motion of the bolt.

It is not, therefore, until the key, by elevating the tumbler, has raised the stump out of the notch, that the bolt has freedom of movement. If the shape of the key does not enable its web to effect this elevation to a sufficient degree, the bolt remains immovable; and to this extent a certain additional security is obtained by making the shape of the key significant as well as the wards.

The tumbler principle, as we have said, is difficult to trace to its origin on account of the various aspects that it presents; but the great French treatise proves that the locksmiths of France were familiar with tumbler locks a century ago. The plates of that work represent the details of numerous locks, on the upper edge of the bolts of which were notches called *encoches,* as at figure 18; into these notches sank a small iron stud or stump called the *arrest du pene,* or bolt-stop, shown in **figure 19**, attached to the upper portion of the *gachette* or tumbler, which, for the sake of economy of metal, is made in the form of a triangular spring in front of the bolt ***ki;*** and not until the key, by its circular action, had raised this stud out of one or other of the notches, could the bolt move to the right or left.

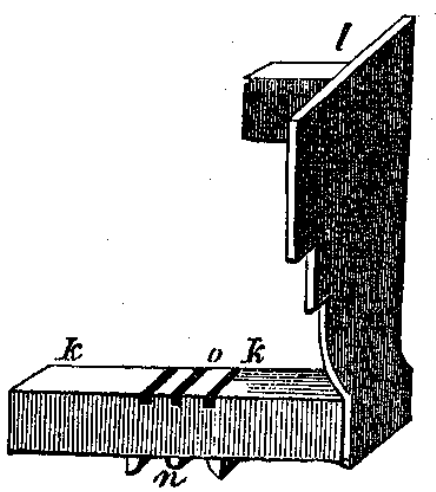


Figure 18 French pin tumbler lock.

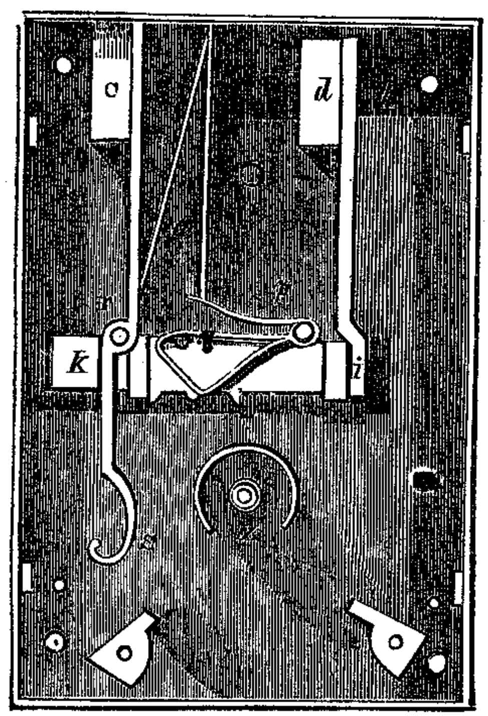


Figure 19 Old French lock.

The stud was generally fixed to a spring that forced it down

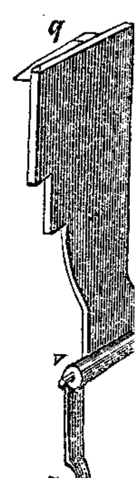
again into the notch as soon as the action of the key had ceased. Sometimes, however, the stud was fixed to the bolt, and the notches were in a separate tumbler or *gachette* (see **E E**, **figure 21)***;* and in other instances, again, the stump was fixed to the case of the lock and caught into notches in the bolt.

It will be seen, when we come to treat of tumbler locks of later date, that there was much in these early locks to point out the way. **Figure 19**, copied from the French work, represents a lock of the box or casket kind. Two staples, fixed into the cover, fall into two cavities or receptacles at **cd***;* and a short bolt in each receptacle catches into each staple, one near **g** and one near ***h.***

The small bolt **q** is attached to the upper extremity of the lever ***qrs, F*****igure 19**, and shown separately in **Figure 20***;* and by the pressure of a spring **a** (**Figure 19**) upon this lever, the bolt ***q*** is kept locked in the staple. The vertical portion of this spring presses at its lower end on another spring **p** (**Figure 19**) of singular curvature*;* and attached to the horizontal part of this second spring is the stud, which falls into a notch in the top of the bolt.

The action of these parts, then, is as follows: when the key is placed upon the key-pin at **z**, and turned round in the direction in which the hands of a watch move, the bit presses against the tail **s** of the lever, moves it upon its center **z**, **Figure 19**, **v**, **Figure 20**, to the left, and consequently moves the upper part ***q*** to the right, ***Figure 20,*** drawing it out of the receptacle and liberating the staple within **c**.

Thus it will be seen that the lever **q r s**, held in one position by the spring **a**, forms in itself a simple kind of spring catch-lock, and was, in fact, formerly used as such, without any other appendages except the staple in the lever, into which the catch ***q*** fitted on shutting down the lid.



So also we may regard the other portion, **Figure 18**, or ***k i p h*** (**Figure 19**), as forming a separate lock*;* for the key after having passed **s** comes in contact with the triangular spring, which it raises thereby, lifting the stud out of the bolt, and exerting pressure against the barbs of the bolt **n Figure 18** shoots the bolt ***k,*** and also the short bolt **l**, which passes through the staple

also the short bolt I, which passes through the staple in the cavity **d, Figure 19.**



Figure 2

The lock represented in the four following figures is also from M de Reaumur's chapter on locks in the work referred to. In this lock, the tumbler principle is carried out in a very elaborate manner, for not only is the stump or stud **H** (**Figure 23**) attached to a very strong spring (best shown at **H, Figure 22**), which holds it with considerable force in one of the three notches of the principal bolt **r S** (**Figure 24**); but there is also a second set of notches EE in the *gachette* **GO** (**Figure 21**), and a pin attached to one of the plates of the lock fits into one of these notches, thereby preventing the bolt from being moved until the *gachette is* lowered by the revolution of the key; so that in attempting to pick this lock, not only must the spring **H** be raised so as to release the stud from the notches of the great bolt, but the *gachette* must be lowered to disengage the fixed pin from the notches.

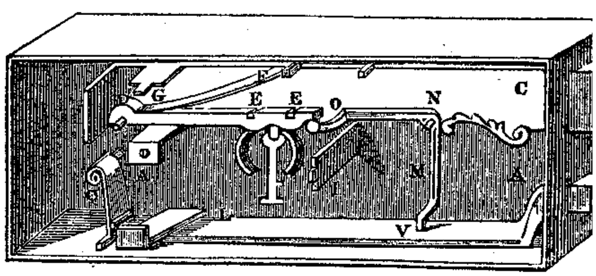


Figure 21 Details of an old French lock.

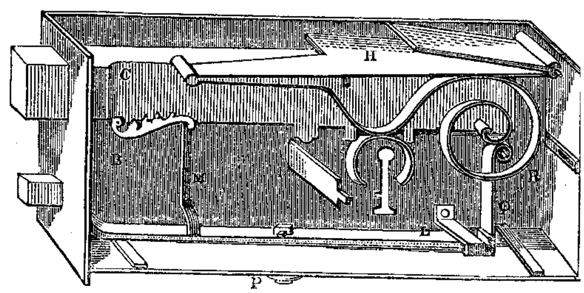


Figure 22 Another view of the same.

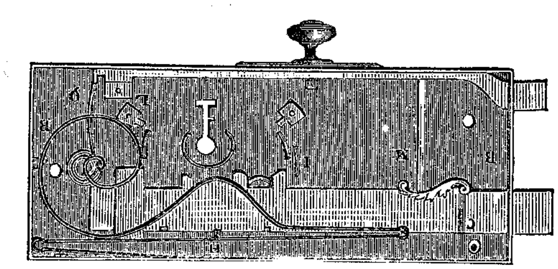


Figure 23 Another view of the same.

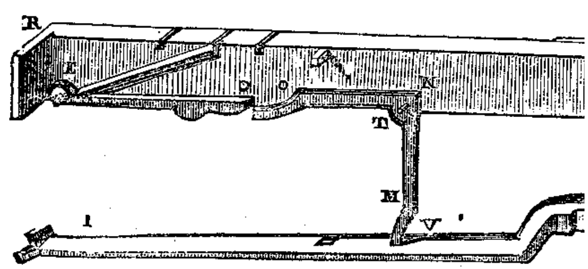


Figure 24 The two bolts detached.

There is yet a third source of security. Attached to the large bolt are short projecting pins **F** (**Figure 21**), against which an arm or detent, **GF**, of the *gachette* projects, thus preventing the bolt from being shot back by any pressure applied to its

extremity **s**.

There are a few details relating to this remarkable lock that may as well be introduced here in order to complete the description. The principal bolt can be shot twice, or be *double-locked;* hence it is furnished with three barbs for the key to act against, and with three notches for the spring-stud. The lower bolt **I E**: can be shot by the horizontal pressure of the button **P** (**figures 22, 23**), which is situated on the inner side of the door to which this lock is attached, so that a person inside the room can secure the door against any one on the outside who is not furnished with the proper key, for it must be remarked that the small bolt as well as the large one is acted upon by the key.

Suppose that the small bolt to be shot or locked is kept so by the pressure of the coiled spring **Q** (**figures 21, 22**). But this small bolt is connected with the large one by means of the bent lever **ONM** (**figures 21, 24**), which turns on a pin **N** attached to the main bolt. Now, when both bolts are either fully shot or upshot, the arm **ON** lies flat against and parallel with the main bolt; but when the large bolt is unshot and the small one not moved, the arms **ON**, **NM**, fall into an inclined position, and the arm **ON** passing a little below the main bolt comes within the range of the web of the key, which in its revolution causes the bent lever to move upon its center **N**, thereby restoring **ON** to its horizontal position, and at the same time causing the arm **N M** to move from right to left, or in the direction for unshooting the small bolt. The end of this arm thus catches into a mortise **v** (**figures 21, 24**) in the small bolt, and immediately unlocks it.

Let us return to the subject of tumbler-locks. About the year 1778, Mr. Barron introduced that species of double-action (as it may perhaps be termed) which so greatly increases the security of the simple tumbler, **Figure 17**. In the tumbler-locks previously made, if the tumbler was raised sufficiently high, the lock could be opened: there was no such possibility as raising it *too* high; but Mr. Barron, by his invention, patented 31st October, 1778, rendered it absolutely necessary that a limit should be put to the height to which the tumbler should be raised, by rendering the bolt equally immovable whether the tumbler were too much or too little raised.

Another important improvement was the introduction of two tumblers instead of one. The bolt has in its middle a slot or gating notched on both edges, the notches being fitted for the reception of studs fixed to the tumblers. If the studs or stumps

of the tumblers are at rest in the lower notches, they require to be elevated to the general level of the gating before the bolt can he moved. Whereas, if the tumblers were raised ever so little too high, the studs will enter the upper notches, and prevent the shooting of the bolt.

The lower edge, or belly, of each tumbler is acted upon by the steps of the key during its circular movement; the leverage of the key being so exactly adjusted as to raise the tumbler to the desired height and no further. The tumblers are made unequally wide, so that steps or inequalities in the bit of the key are requisite to lift them both to the proper height. There are thus two improvements introduced: there are two **tumblers** instead of one, and each tumbler has a double instead of a single action.

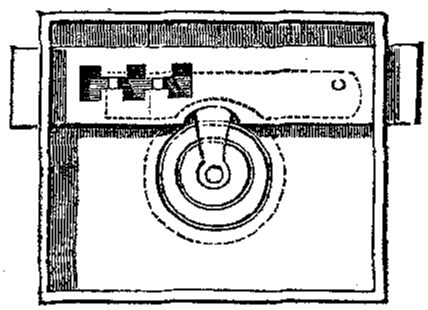


Figure 25 Action of Barron's tumbler-look.

This ingenious and very useful lock is represented, so far as regards its governing principle, in **Figure 25**. The bolt is here seen to have a peculiar slot or hole cut in it, consisting of a narrow horizontal passage or gating, with three notches above it and three below it. These double notches might be available even for one tumbler only; but Barron used two or more for the sake of additional security. In **Figure 25**, there are two tumblers shown, expressed by dotted lines. Both are hinged to one pivot, both are raised by the same action of the key, but the stump on the one tumbler does not coincide in position with that on the other.

It will be seen that if the studs of the tumblers were to rest in the lower notches, they would be required to be elevated to the level of the gating before the bolt could be moved; while, on the other hand, if lifted too high, the stumps would be caught in the upper notches, and would equally prevent the passage of the bolt. The tumblers are unequally wide; and the bit of the key is stepped or notched in a corresponding way, that there may be one step fitted to act upon each tumbler.

Mr. Barron also adopted the reverse arrangement of having the stump on the bolt, and the openings in the tumblers; so that the principle of his patent may be concisely expressed as being "an arrangement to allow a stump on the tumbler to pass through an opening in the bolt, or a stump on the bolt to pass through an opening in the tumbler."

A very elaborate tumbler-lock, patented 23thd February, 1790, by Mr. Rowntree, contrasts remarkably with the simplicity of Barron's lock. Mr. Rowntree's lock consisted of tumblers combined with revolving discs or wheels. Its mechanism may be understood from the following description and engravings. The same letters refer to the same parts in the several figures.

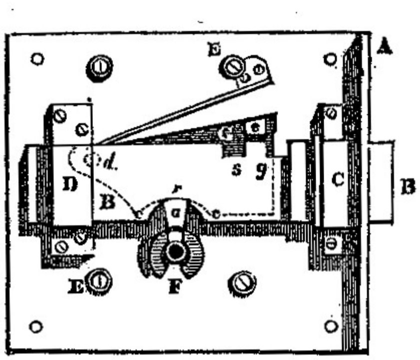


Figure 26

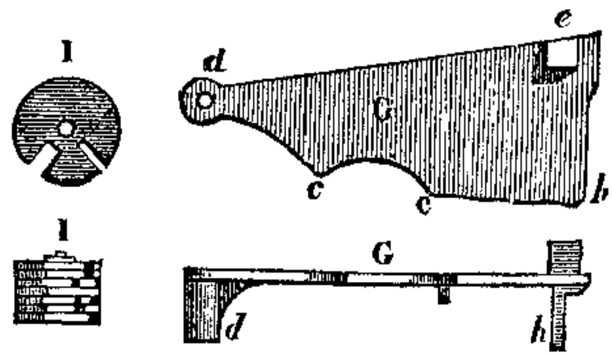


Figure 27

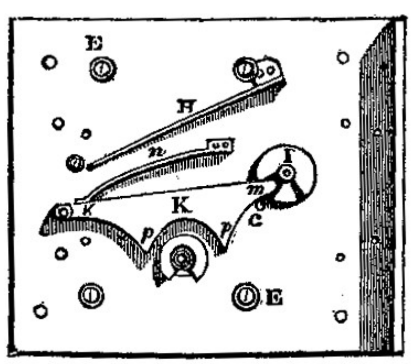


Figure 28

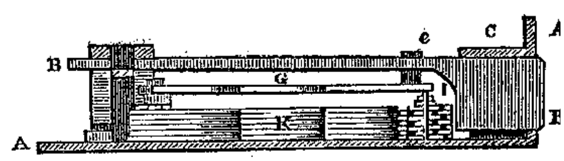


Figure 29

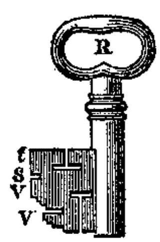


Figure 30

Details of Rowntree's tumbler-lock.

AA is the plate that encloses the whole mechanism of the lock, and fastens it to the door; **B B** is the bolt, guided in its motion

by sliding under the bridges **CD**; **EE** are pillars which support a plate covering the works; **F** are the circular wards surrounding the center or key-pin; and **a** shows the position of the key, which, in turning round, acts in a notch **t** in the bolt, and propels it; **G**, the tumbler, is a plate situated beneath the bolt, and moving on a center-pin at **d**; it has a catch or **stump e** projecting upwards, which enters the notches **f** or **g** in the bolt, and thereby retains the latter for backward or forward motion, as the case may be; **H** is a spring which presses the tumbler forward. The key **a**, in turning round, acts first against the part **c c** of the tumbler, and raises it so as to remove the stump from the notches; it can then enter the notch **r** in the bolt, and move it.

So far there is no particular security; but Mr. Rowntree sought to obtain it by the following means. There is a piece of metal **h** fixed to the lower side of the tumbler, called the *pin;* when the tumbler is caught in either notch of the bolt, the pin applies itself to a cluster of small wheels **l**, fitted on one center-pin beneath the tumbler; the edges of these wheels stop the pin, and prevent the tumbler from being raised.

But each wheel has a notch cut in its circumference **l**; and it is only when the wheels are so placed that all their notches lie in a right line, that the pin can enter this compound notch and allow the tumbler to rise. The wheels must therefore be all adjusted to position; and this is effected by a number of levers **K** centered on one pin at **k**; at the opposite end each lever has a tooth **m** entering a notch in the wheel belonging to it; so that when any lever is pressed outward, it turns its wheel round.

Now this pressure of the levers is brought about by a spring **n** applied to each; and when so pressed, the levers rest against a pin **o** fixed in the plate. The key is so cut as to determine the extent to which the levers shall act upon the wheels. The key first operates from the curved part ***p p*** of the levers **K**, and raising them, turns all the wheels **l** at once into the proper positions; in turning further round, it then operates on the part **c c** of the tumbler, causing the latter to rise and to release the bolt; and in turning still further round, it (the key) seizes the notch **r** of the bolt, and shoots it.

The key is cut into steps of different lengths, as shown at **vv**; each step operates on its respective lever **K** in a different degree from the others; the notch at **s** acts upon the tumbler, and the plain part **t** moves the bolt.

We now proceed to notice the modern tumbler-lock. This was arranged by Bird, whose patent, bearing date 29th October, 1790, was for a series of four double-acting tumblers, differing in no respect from those patented by Barron, and closely resembling those in use at the present time in the best tumbler-locks. We will describe the modern tumbler-lock more particularly when we have gone through a few historical details on the subject.

Messrs. Mitchell and Lawton obtained a patent bearing date 7th March, 1815, for a lock in which were combined with the bolt and double-acting tumblers, a series of moveable wards and a revolving curtain for closing the key-hole. The action of the wards was peculiar.

On introducing any key or instrument, and passing it round, a number of moveable wards or pieces were thrown out so as to prevent the key from being turned back or withdrawn. It was necessary therefore to pass round the key so as to unlock the lock, and if that were not possible, as in the case of a false key being used, it was held permanently, and could only be released by destroying the lock. When the bolt was once shot, the wards were carried up so as to leave a clear passage for the key. This lock does not appear ever to have come into use, on account of the violence required in case a wrong key should be used either by accident or design.

The detention of a wrong key in this lock appears to have suggested the contrivance of a *detector.* This was first made by Ruxton, whose patent is dated 14th May, 1816. His detectors were of various kinds, the object of each kind being to give information to the owner in case any one of the tumblers should be over-lifted in an attempt to pick the lock, which fact would be discovered on the next application of the true key.

This is precisely the object of the detector in tumbler-locks at the present day, and Buxton accomplished it by somewhat similar means. He also had a contrivance for holding a false key, as in Mitchell and Lawton's lock; and he recommended this form of detector in the following words:

"It is true that in this case the lock will have to be destroyed in order to open the door: the result is frightful; but we think the more terrible the result, the less likely would anyone be to tamper with it."

We now come to Chubb's lock, patented February 3, 1818, which consisted of double-acting tumblers and a peculiar kind of detector. This lock has been made the subject of various patents obtained in the years 1824, 1833, 1846, and 1847. This lock consists of six separate and distinct double-acting tumblers, all of which must be raised to a particular height, neither more nor less, in order that the bolt may pass. It also comprises a *detector,* by which, should any one of the tumblers be lifted too high in an attempt to pick or open the lock by a false key, it would be immediately detected on the next application of the proper key. The tumblers are flat pieces of iron or steel, with the plane of the surface vertical, and pivoted at one end; and the following is the mode in which the key, the tumblers, and the bolt are brought into mutual action.

The bolt shoots in and out of the lock in the usual way. It has a square stud or stump riveted on one surface; and it is to furnish obstructions to the passage of this stud that the tumblers are provided. All the six tumblers are pivoted to one pin at the end, giving to each of them a small leverage, each independent of the others.

There are six springs that press these tumblers downwards, one to each tumbler. There is a longitudinal slot or gating in each tumbler, large enough to receive the stud of the bolt; and unless all the six slots (supposing there to be six tumblers) coincide in height or position, the stud will not have a clear passage for moving laterally.

The slots are purposely made nearer the upper edge in some of the tumblers than in others, all the six being different in this respect; so that if they are all lifted ***equally,*** the slots do not coincide, and the bolt and its stud will not pass. The tumblers must then be raised ***unequally,*** those to be most raised which have the slot nearest to the lower edge. To effect this, the bit of the key is cut into six steps or inequalities, each to act upon one particular tumbler, and each cut or stepped to the exact depth which will suffice for the proper raising of the tumbler.

The key is inserted in the keyhole, and is turned; the six steps raise the six tumblers all to the proper height, to leave a clear passage along the slots; and the extreme end of the key then acts upon the bolt itself, and shoots it. To unlock it again, the same or a duplicate key must be used; for if another key be employed, differing by ever so little from the proper one, some one or more of the tumblers will be lifted either a little too much or not

quite enough.

In either case, the stud of the bolt will catch above or below the slot, instead of having a clear line of movement along the slot itself. After both locking and unlocking, the springs force the tumblers down as far as they can go, burying the stud in the recesses above the slot; so that the tumblers must be raised by the key both for locking and unlocking.

The doctrine of chances has wide play in determining the relative position of the six tumblers. In Mr. Chubb's essay, this part of the subject is treated in the following way: "The number of changes which may be effected on the keys of a three-inch drawer-lock is 1 x 2 x 3 x 4 x 5 x 6 = 720, the number of different combinations which may be made on the six steps of unequal lengths (on a six-tumbler lock), without altering the length of either step. The height of the shortest step is, however, capable of being reduced 20 times; and each time of being reduced, the 720 combinations may be repeated; therefore 720 x 20 = 14,400 changes.

The same process, after reducing the shortest step as much as possible, may be gone through with each of the other five steps; therefore 14,400 x 6 = 86,400, which is the number of changes that can be produced on the six steps. If, however, the seventh step, which throws the bolt, be taken into account, the reduction of it only ten times would give 86,400 x 10 = 864,000, as the number of changes on locks with the keys all of one size (that is, with one key of definite size in all save the lengths of the steps).

Moreover, the drill pins of the locks and the pipes of the keys may be easily made of three different sizes; and the number of changes will then be 864,000 x 3 = 2,592,000, as the whole series of changes which may be gone through with this key. In smaller keys, the steps of which are capable of being reduced only ten times, and the bolt-step only five times, the number of combinations will be 720 x 10) x 6 x 5 x 3 = 648,000. On the other hand, in larger keys, the steps of which can be reduced thirty times, and the bolt-step twenty times, the total number of combinations will be 720 x 30 x 6 X 20 x 3 = 7,776,000.

These enormous numbers have been the cause of much of the wonderment which the six-tumbler locks have excited; and, as we shall see further on, the Bramah lock presents still more of the marvelous in respect to this ringing of the changes.

The construction and action of the Chubb lock may be further illustrated by means of an engraving, **Figure 31**, in which **b** is the bolt of the lock, with a stump riveted to it marked **a**. The six tumblers are shown perspectively, the front or anterior one being marked **t**; they all move on the center-pin **a**, but are nevertheless perfectly distinct and separate to allow being elevated to different heights.

At **d** is shown one end of a divided spring, the divisions being equal to the number of tumblers, one to each, and so bent that each spring may press upon its particular tumbler.

At ***e*** *is* the detector-spring, so placed that a projecting piece in the hindmost tumbler shall be near it; this tumbler having also fixed into it a stud or pin **p**. This being the arrangement, especially in relation to the stump **s** and the tumblers, it follows that all the tumblers must be lifted to exact and regulated heights in order that the stump may pass through the longitudinal slits of the tumblers. Unless it can do so, the bolt cannot be withdrawn. As there are gaps or notches in each tumbler both above and below the proper line of passage.

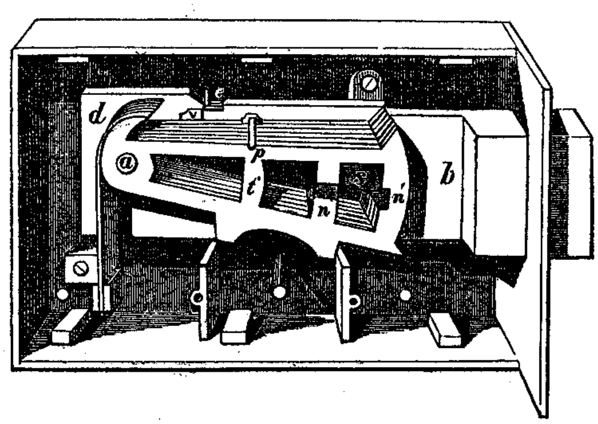


Figure 31 Chubb lock with detector and six tumblers.

As there are no ordinary means of ascertaining when any one tumbler is lifted too high or not high enough, the safety of the lock is greatly increased by this uncertainty; especially when it is considered that this uncertainty is multiplied six-fold by the different modes in which the six tumblers are slotted.

If, through the insertion of a false key, or by any other cause, any one of the tumblers be raised above its proper position, the detector spring **e** will catch the hindmost tumbler, and retain it

so as to prevent the bolt from passing; and thus, upon the next application of the true key, it will be instantly felt that some one of the tumblers has been over-lifted, because the true key will not unlock it.

To relieve the bolt from this temporary imprisonment, the key must be turned the reverse way, as for locking; all the tumblers will thus be brought to their proper position, and allow the stump to enter the notches **n n**, the beveled part of the bolt will then lift up the detector spring, and allow the hindmost tumbler to fall down into its proper place; and all this being effected, the lock may be opened and shut in the ordinary way. The pin **p** is so adjusted that if any one of the tumblers, front, back, or intermediate, be lilted too high, the pin will be lifted with it, and will catch into the detector-spring, thus producing the result just described.

The key is represented in **Figure 32**. It has six steps, besides a terminal step to act upon the bolt. The height of each step, or the distance to which it extends from the pipe of the key, depends of course on the height to which its corresponding tumbler is to be lifted; and it matters not whether the steps of the key are adjusted to the slots of the tumblers, or the slots to the steps, provided the agreement be brought about.

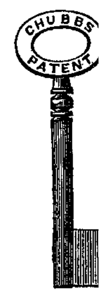


Figure 32 :
Chubb's 1

It is simply a matter of manufacturing convenience that the key steps are cut first and the tumbler-slots afterwards. We may here remark that bit, or bitt, is the name given, somewhat indefinitely, either to the whole flat part of a key, or to the small stepped portions of it. The flat part was formerly termed the ***web*** of the key, probably from the *webbed* appearance of the keys to complex warded locks.

After the reading of Mr. Chubb's paper before the Institution of Civil Engineers, Mr. Owen narrated one or two circumstances connected with the early history of Chubb's lock. A convict on board one of the prison-ships at Portsmouth dockyard, who was by profession a lock-maker, and who had been employed in London in making and repairing locks for several years, and subsequently had been notorious for picking locks, asserted that he had picked with ease one of the best of Bramah's locks, and that he could pick Chubb's locks with equal facility.

One of the latter was secured by the seals of the late Sir George Grey, the Commissioner, and some of the principal officers of the dockyard, and given to the convict, together with files and all the tools which he stated were necessary for preparing false instruments for the purpose, as also blank keys to fit the pin of the lock. A lock exactly the same in principle was placed in his hands, that he might examine it and make himself master of its construction. If he succeeded in opening the lock, he was to receive a free pardon from the Government, and a reward of £100 from Messrs. Chubb.

After trying for two or three months to pick the sealed lock, during which time, by his repeated efforts, he frequently over-lifted the detector, which was as often readjusted for his subsequent trials, he gave up the attempt. He stated that Chubb's were the most secure locks he had ever met with, and that it was impossible for any man to pick or to open them with false instruments.

Mr. Owen further stated, that in order to compare the merits of Bramah's and Chubb's locks, he had suggested a mechanical contrivance, which was applied to one of Bramah's six-spring padlocks belonging to the Excise. It was hung upon a nail, in a vertical position, secure from lateral oscillation. A self-acting apparatus was then applied, consisting of a pipe with hexagonal grooves, and a stud or bit corresponding with the division of the lock, and secured to it by a spring.

In the grooves of this pipe small slides were inserted, which pressed against the spring keys of the lock; to these slides were attached levers, acted upon by eccentrics, moved by a combination of wheels, whose teeth differed in number so as to perform the permutation required for the different depths of the spring keys, corresponding with those of the proper key to the lock. The automaton machine was set in motion by a line working over a barrel, and acted upon by a weight; and was thus left acting upon the mechanism for a considerable time.

At right angles to the pipe or false key was attached a rod and weight; and when the notches in the spring keys were brought in a line with the plane of the plate or diaphragm of the lock, the rod and weight turned the false key, opened the lock, and stopped the further motion of the automaton. In that state the slides indicated the exact depth of the grooves in the proper key, and gave the form of a matrix by which to make a key similar to the original one.

The automaton worked during a period varying from half an hour to three hours, according to the state of permutation of the apparatus at the moment of being applied, compared with that of the slides in the lock. We confess that it is difficult to understand the action of this automaton from Mr. Owen's description. We imagine that the false notches would effectively prevent the operation of the instrument, and openings would be required on each slide to bring it back, so as to meet the motions of the machine.

Mr. Owen did not state whether his apparatus had been successful with one only of Bramah's locks or with several; nor did he describe any apparatus invented with the view to the picking of Chubb's locks. He stated, however, that in order to ascertain the effect of friction on one of these last named locks, it was subjected to the alternate rectilinear motion of a steam-engine in Portsmouth dockyard, and was locked and unlocked upwards of 460,000 times consecutively, without any appreciable wear being indicated by a gauge applied to the levers and the key, both before and after this alternate action.

Mr. Owen concluded by expressing his individual opinion that Chubb's lock had never been picked. "The detector was the main feature of its excellence; and additional precaution, therefore, was only departing from its simplicity, and adding to the expense, without any commensurate advantage."

In a subsequent chapter, the degree of security afforded by various descriptions of locks, and the obstacles which they present of being picked, will come under notice; we therefore now proceed to describe briefly a few other tumbler-locks, or application of the tumbler-principle.

In Mr. Somerford's lock, for which the Society of Arts gave a premium in 1818, an attempt was made to improve upon the ordinary action of tumblers. In most such locks, all the tumblers must ascend, although to different heights, before the stud of the bolt can pass through the slots; "which arrangement," says Mr. Somerford, "gives an opportunity of introducing a nail, or a piece of stout wire into the lock, and thus raising the tumblers without the necessity of using the key." In his new lock, however, he made one lever to ascend while the other descended, by a somewhat complicated arrangement of slotted plates above and below the bolt. The key was so perforated as to be much endangered in respect to strength.

In Davis's lock there is a double chamber with wards on the side of the keyhole. The key is inserted into the first chamber and turned a quarter round; it is then pushed forward into the inner chamber, where there is a rotating plate containing a series of small pins or studs, which are laid hold of by the key. By turning the key, the plate is moved round, the tumbler is raised, and the bolt is shot backwards and forwards. This lock, which is somewhat expensive, is used to some extent on cabinet dispatch-boxes.

The lock invented by Mr. Nettlefold is so constructed, that when the bolt is shot out by the key, two teeth or quadrants are projected from the sides of the bolt, which take a firm hold of the plate fixed on the door-post or edge. This construction is said to answer well for sliding-doors.

Mr. Alfred Ainger, in 1820, received a silver medal from the Society of Arts for a draw-back spring latch, in which the objects proposed were the two following: to render the lock more difficult of violation by a pick than those ordinarily in use; and to apply to it a key of which no ordinary person could take an impress, and which would be difficult of access even in a workman's hand.

The key is very peculiar; its pipe consists of three divisions, the section of the upper and lower divisions being circular, and that of the middle division triangular; the triangular portion is intended to give motion to some part of the interior of the lock during the rotation of the key. There are collars fixed on the extremity of the key, to act each on one tumbler; and there are modes, by varying the arrangement of these collars on an octagonal stem, to give something like a permutation to the number of variations to which the action of the key may be subject. The notches or slots are rather in the bolt than in the tumblers; and there are many peculiarities in the general arrangement.

In a lock invented and patented by Mr. Parsons, the tumblers are of a particular form, being hinged on a pivot at their centers, and working into and out of two notches cut in the under side of the bolt. It must be obvious that many variations in the adjustment of the tumblers of locks might be made, without vitiating the principle on which the action depends.

Many inventors have tried the use of an expanding web to the key,

so planned that if the step of the web be long enough to reach the tumbler, it would be too long to pass through the keyhole; and therefore a principle of safety would operate by enabling the key to adjust itself at one moment to the size of the keyhole, and at another to the height of the tumbler.

Mr. Machin of Wolverhampton invented such a key in 1827. The web of the key is moveable on a countersunk pin, on which it can so far slide as to be drawn one-eighth of an inch from the barrel. The keyhole is of such a size as to admit the key only when the web is pressed close up to the barrel.

When the key in this state is introduced, and is begun to be turned round, one of the notches in the web works into a raised circular edge of steel, placed eccentrically with regard to the lock-pin; so that as the key is turned, the web becomes drawn out, and is at its greatest elongation when it arrives at the tumblers. In the second half of its circular movement, the key becomes contracted to its original dimensions, and can then be removed from the lock.

Another mode of modifying the key has been introduced by Mr. Mackinnon, the object being to enable any person to change at will the pattern or arrangement of the moveable parts of a lock and key; or to keep the key, when not actually in use, in such a state as to render it unavailing to any one but himself. It was a complex arrangement, which does not seem to have come much into use.

The lock invented by Mr. Williams, in 1839, may be designated a pin-lock, involving a principle analogous in many points to that of the Egyptian lock. This lock has a series of pins that reach through the cap, and are pressed to their places with a key like a comb or a rake-head. On the inner end of each pin is a flat piece of steel, in which is cut a notch for the passage of the bolt; but this passage is not clear until the notches in all the pieces of steel are in a right line.

The pins are moveable, and can be pushed either too far or not far enough to bring about the coincidence of position in the notches; and on this ground they are "double-acting." Now the teeth of the key are of irregular lengths, each having a length just suited for pushing the pin to the proper depth: any other lengths of teeth would fail to open the lock. There is a mechanism of springs and levers to shoot the bolt when the pins in the plate are rightly adjusted.

The arrangements in respect to the key are singular and somewhat awkward. The teeth that lock the bolt are not the same as those which unlock it, the user having to change ends and adjust the bit to a socket-handle. This is one among many examples in which a lock embodies several principles, the inventor having set himself the task of combining the excellence of many diverse locks.

In respect to the tumbler-locks generally, the simplicity of action, the strength of construction, and the non-liability of disarrangement, have given them a high place among safety-locks. The only danger seemed to be, that any person once obtaining possession of the key could take an impression from it, and thence form a key which would command the lock.

Attempts have been occasionally made to obviate this danger, by supplying the key with moveable bits that could be changed at pleasure, so as to constitute any number of effectively different bits in succession. But the locks being so constructed that the bolt could only be moved when the tumblers were in a certain position, the owner was placed in this predicament: that it was useless to alter the arrangement of the bits in the key, unless the tumblers were altered in a corresponding manner; and this would entail the removal of the lock from the door, and the rearrangement of the interior mechanism.

One of the great defects of tumbler-locks made previously to the last ten years was, that the tumblers, when lying at rest in the lock, presented at their ***bellies*** or lower edges precisely the same arrangement as the steps of the key. Indeed, in many locks of the present day, a good idea of the form of the key may be gained by feeling the bellies of the tumblers. The bellies are in fact cut out so as to compensate for the circular motion of the key, to allow them to remain at rest while the stump is passing through the gating. Even in tumbler-locks of the best construction, the tumblers will vibrate more or less during the motion of the key; a defect which must be provided against in adjusting the lock, or the stump will be caught in its passage through the gating.

Mr. Hobbs provides a simple remedy by enlarging the back part of the gating, the effect of which is as follows: when, in shooting back the bolt, as in unlocking, the key has got to its highest point, the stump enters the narrow end of the gating: but in shooting the bolt forward, as in locking, the stump enters the

gating before the key has got to its highest point, and to allow for the slight vibratory motion of the tumblers during the passage of the stump, the gating is widened.

The usual method of adjustment is to alter the forms of the bellies of the tumblers, thus greatly risking the security of the lock, a defect which was clearly perceived by Bramah, and was one of the reasons which induced him to construct locks with slides instead of tumblers.

American locks on the tumbler-principle, and the relation which all such locks bear to the Bramah lock, will be better understood after the details of the following chapter.

CHAPTER SIX: The Bramah Lock

MASTER EXHIBIT LIST

THE lock which was invented by the late Mr. Bramah deservedly occupies a high place among this class of contrivances. It differs very materially from all which has gone before it; its mechanical construction is accurate and beautiful; its key is remarkable for smallness of size; and the invention was introduced by the publication of an essay containing much sensible observation on locks generally. The full title of this essay runs thus:

"A dissertation on the Construction of Locks. Containing, first, reasons and observations, demonstrating all locks which depend upon fixed wards to be erroneous in principle, and defective in point of security. Secondly, a specification of a lock, constructed on a new and infallible principle, which, possessing all the properties essential to security, will prevent the most ruinous consequences of house-robberies, and be a certain protection against thieves of all descriptions." A second

edition of this *Dissertation was* published in 1815; but the work is now extremely scarce, and hardly attainable."

It is remarkable to observe the boldness and self-relying confidence with which Mr. Bramah, some sixty years ago, declared that *all* locks were, up to that time, violable; he felt that this was strictly true, and he hesitated not to give expression to his conviction. The following is from his *Dissertation:*

"It is observable that those who are taken in the desperate occupation of house-breaking are always furnished with a number and variety of keys or other instruments adapted to the purpose of picking or opening locks; and it needs no argument to prove that these implements must be essential to the execution of their intentions. For unless they can secure access to the portable and most valuable part of the effects, which in most families are deposited under the imaginary security of locks, the plunder would seldom recompense the difficulty and hazard of the enterprise; and till some method of security be adopted by which such keys and instruments may be rendered useless, no effectual check or opposition can be given to the excessive and alarming practice of house-breaking."

"Being confident that I have contrived a security which no instrument but its proper key can reach; and which may be so applied as not only to defy the art and ingenuity of the most skilful workman, but to render the utmost force ineffectual, and thereby to secure what is most valued as well from dishonest servants as from the midnight ruffian, I think myself at liberty to declare (what nothing but the discovery of an infallible remedy would justify my disclosing), that all dependence on the inviolable security of locks, even of those which are constructed on the best principle of any in general use, is fallacious."

"To demonstrate this bold and alarming proposition, I shall first state the common principles which are applied in the art of lock-making; and by describing their operation in instruments differently constructed, prove to my intelligent readers that the best-constructed locks are liable to be secretly opened with great facility; and that the locks in common use are calculated only to induce a false confidence in their effect, and to throw temptation to dishonesty in the way of those who are acquainted with their imperfections, and know their inefficacy to the purpose of security"

Tumblers had been so little thought of and used at the time

Bramah wrote, that his attention was almost exclusively directed to *warded* locks. The mysterious clefts in a key, connected with some kind of secret mechanism in the lock, had given the warded locks a great hold on the public mind, as models of puzzlement and security; and it was to show that this confidence rested on a false basis, that he to a great extent labored. The following is his exposition of the principle and the defects of the warded lock.

"Locks have been constructed, and are at present much used and held in great esteem, from which the pick-lock is effectively excluded; but the admission of false keys is an imperfection for which no locksmith has ever found a corrective; nor can this imperfection be remedied whilst the protection of the bolt is wholly confided to fixed wards."

"For if a lock of any given size be furnished with wards in as curious and complete a manner as it can be, those wards being necessarily expressed on what is termed by locksmiths the bit or web of the key, do not admit of a greater number of variations than can be expressed on that bit or web; when, therefore, as many locks have been completed of the given size as will include all the variations which the surface of the bit will contain, every future lock must be the counterpart of some former one, and the same key which opens the one will of course unlock the other."

"It hence follows that every lock which shall be fabricated on this given scale, beyond the number at which the capability of variation ends, must be as subject to the key of some other lock as to its own; and both become less secure as their counterparts become more numerous. This objection is confirmed by a reference to the locks commonly fixed on drawers and bureaus, in which the variations are few, and these so frequently repeated, from the infinite demand for such locks, that, even if it were formed to resist the pick-lock, they would be liable to be opened by ten thousand correspondent keys. And the same observation applies in a greater or less degree to every lock in which the variations are not endless."

"But if the variation of locks in which the bolt is guarded only by fixed wards could be multiplied to infinity, they would afford no security against the efforts of an ingenious locksmith; for though an artful and judicious arrangement of the wards, or other impediments, may render the passage to the bolt so intricate and perplexed as to exclude every instrument but its

proper key, a skilful workman having access to the entrance will be at no loss to fabricate a key which shall tally as perfectly with the wards as if the lock had been open to his inspection."

"And this operation may not only be performed to the highest degree of certainty and exactness, but is conducted likewise with the utmost ease. For the block or bit, which is intended to receive the impression of the wards, being fitted to the keyhole, and the shank of the key bored to a sufficient depth to receive the pipe, nothing remains but to cover the bit with a preparation which, by a gentle pressure against the introductory ward, may receive its impression, and thus furnish a certain direction for the application of the file."

"The block or bit being thus prepared with a tally to the first ward, gains admission to the second; and a repetition of the means by which the first impression was obtained, enables the workman to proceed, till by the dexterous use of his file he has effected a free passage to the bolt. And in this operation he is directed by an infallible guide; for, the pipe being a fixed center on which the key revolves without any variation, and the wards being fixed likewise, their position must be accurately described on the surface of the bit which is prepared to receive their impression."

"The key therefore may be formed and perfectly fitted to the lock without any extraordinary degree of genius or mechanical skill. It is from hence evident that endless variations in the disposition of fixed wards are not alone sufficient to the purpose of perfect security. I do not mean to subtract from the merit of such inventions, nor to dispute their utility or importance. Every approach towards perfection in the art of lock-making may be productive of much good, and is at least deserving of commendation; for if no higher benefit were to result from it, than the rendering difficult or impossible to many that which is still practicable and easy to a few, it furnishes a material security against those from whom the greatest mischief and dangers are to be apprehended."

There can be little doubt, in the present day, that Bramah did not over-rate the fallacies embodied in the system of wards for locks. He was sufficiently a machinist to detect the weak points in the ordinary locks; and, whatever may have been his over-estimate of his own lock (presently to be described), he was certainly guilty of no injustice to those who had preceded him; for their locks were substantially as he has described them.

To understand the true bearings of his Dissertation too, we must remember that housebreaking had risen to a most daring height in London at the time he wrote (about the middle of the reign of George III.); and men's minds were more than usually absorbed by considerations relating to their doors and locks.

"Mr. Bramah, after doing due justice to the ingenuity of Barron's lock, in which, if the tumbler be either *over*-lifted or *under*-lifted, the lock cannot be opened, pointed out very clearly the defective principle which still governed the lock. "Greatly as the art is indebted to the ingenuity of Mr. Barron, he has not yet attained that point of excellence in the construction of his lock which is essential to perfect security. His improvement has greatly increased the difficulty but not precluded the possibility of opening his lock by a key made and obtained as above described (by a wax impression on a blank key); for an impression of the tumblers may be taken by the same method, and the key be made to act upon them as accurately as it may be made to tally with the wards.”

“Nor will the practicability of obtaining such a key be prevented, however complicated the principle or construction of the lock may be, whilst the disposition of its parts may be ascertained and their impression correctly taken from without. I apprehend the use of additional tumblers to have been applied by Mr. Barron as a remedy for this imperfection."

Mr. Bramah thought that Barron had a perception of a higher degree of security, but had failed to realize it; because, by giving a uniform motion to the tumblers, and presenting them with a face which tallies exactly with the key, they still partake in a very great degree of the nature of fixed wards, and the security of the lock is thereby rendered in a proportionate degree defective and liable to doubt.

To show how this insecurity arises, Mr. Bramah illustrates the matter in the following way: "Suppose the key with which the workman is making his way to the bolt to have passed the wards, and to be in contact with the most prominent of the tumblers: The impression, which the slightest touch will leave on the key, will direct the application of the file till sufficient space is prepared to give it a free passage. This being accomplished, the key will of course bear upon the tumbler which is most remote; and being formed by this process to tally with the face which the tumblers present, will acquire as perfect a command of the lock

as if it had been originally made for the purpose. And the key, being thus brought to a bearing on all the tumblers at once, the benefit arising from the increase of their number, if multiplied by fifty, must inevitably be lost; for, having but one motion, they act only with the effect of one instrument."

It is worthy of notice, that even while thus showing the weak points of the Barron lock, Mr. Bramah seems to have had in his mind some conception of infallibility or inviolability attainable by the lock in question. After speaking of the defect arising from the bad arrangement of the tumblers, he says: "But nothing is more easy than to remove this objection, and to obtain perfect security from the application of Mr. Barron's principle."

"If the tumblers, which project unequally and form a fixed tally to the key, were made to present a plane surface, it would require a separate and unequal motion to disengage them from the bolt; and consequently no impression could be obtained from without that would give any idea of their positions with respect to each other, or be of any use even to the most skilful and experienced workman in the formation of a false key. The correction of this defect would rescue the principle of Mr. Barron's lock, as far as I am capable of judging, from every imputation of error or imperfection; and, as long as it could be kept unimpaired, would be a perfect security."

"But the tumblers, on which its security depends, being of slight substance, exposed to perpetual friction, as well from the application of the key as from their own proper motion, and their office being such as to render the most trifling loss of metal fatal to their operation, they would need a further exertion of Mr. Barron's ingenuity to make them durable."

It may perhaps be doubted whether the principle of Bramah's lock is not more clearly shown in the original constructed by him than in that of later date. In appearance it is totally different, but the same pervading principle is observable in both; and the cylinder lock can certainly be better understood when this original flat lock has been studied. The annexed woodcut is taken from the first and very scarce edition of Mr. Bramah's *Dissertation;* the description is somewhat more condensed, but perhaps sufficient for the purpose.

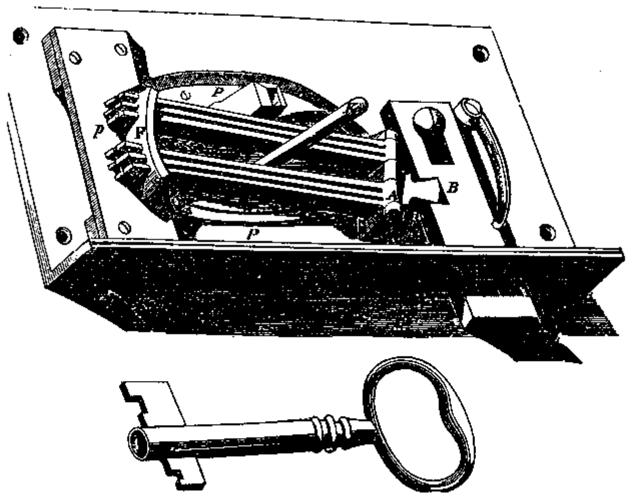


Figure 33 Bramah's first model.

The lock is supposed to be lying flat, with the bolt **B** half-shot. Ranged somewhat diagonally are six levers, turning on a horizontal joint or pivot at **A**, each lever having a slight extent of vertical motion independent of the others. Each lever rests on a separate spring of sufficient strength to sustain its weight, or, if depressed by a superior force, to restore it to its proper position when the force is withdrawn.

F *is* a curved piece of metal, pierced with six grooves or passages; these grooves are exactly equal in width to the thickness of the levers, but are of sufficient depth to allow the levers a free motion in a perpendicular direction. The ends of the levers are inserted in these grooves, and have this freedom of motion, whether lifted by the elastic power of the springs or depressed by a weight from above. In the bolt *B is* a notch to receive a peculiarly-shaped lever, which shoots or withdraws the bolt according as it traverses to the right or the left.

This lever, the six long levers, the springs beneath them, the bent piece **F**, and the pivot, all alike are fixed to a circular platform **P**, which turns on a center; so that if any force can make this platform turn partially round, the bolt must be shot or unshot by the lever which works in the notch.

The six long levers are the contrivances whereby the platform shall *not* be allowed to turn until the proper moving agent (the key) shall have been applied, the plate **p** being one of the assistants in this obstruction. This plate, which is hollow underneath, has six notches in one of its edges; the points of

the levers catch into these notches; and while so caught, the levers cannot move horizontally, and all the machinery is at a stand-still.

To enable the key to set the mechanism in action, other contrivances are necessary. Each lever has a notch at its extreme end, and the six are notched very irregularly in respect one to another. These notches must be brought all into one plane, to enable the levers to pass horizontally out of the notches in the plate, in the same way as the two prongs of a fork might traverse, one above and the other below the blade of a knife; and when the lever-notches are in this position, all in one plane and in the plane of the plate, the levers can be moved, and with it the stump which shoots the bolt.

To ensure this due pressing down of the levers, a key is used such as is shown in the cut, having six steps or bits to correspond with the six levers; this key, put upon the pin **K**, presses down all the levers to the exact distance necessary for bringing the notches into one plane, viz. the plane of the plate; the key then being turned round, turns the moveable platform **P**, and shoots the bolt.

It is evident at a glance, that unless the various steps of the key are so cut, that each shall press down its own lever to the proper extent, the ends of the levers cannot pass the notches in the plate, and the bolt can neither be locked nor unlocked.

It may be well to give Bramah's own words in relation to this lock: "I may safely assert that it is not in art to produce a key or other instrument by which a lock constructed on this principle can be opened. It will be a task, indeed, of great difficulty, even to a skilful workman, to fit a key to this species of lock, though its interior face were open to his inspection; for the levers being raised by the subjacent springs to an equal height present a *plane* surface, and consequently convey no direction that can be of any use in forming a tally to the *irregular* surface which they present when acting in subjection to the proper key."

"Unless, therefore, a method be contrived to bring the notches on the ends of the levers in a direct line with each other, and *to retain them in that position till an exact impression of the irregular surface which the levers will then exhibit can be taken,* the workman will in vain attempt to fit a key to the lock, or by any effort of art to move the bolt."

"And when it is considered that this process will be greatly impeded, and may perhaps be entirely frustrated by the action of the springs, it must appear that great patience and perseverance, as well as great ingenuity, will be required to give any chance of succeeding in the attempt."

"I do not state this circumstance as a point essential or of any importance to the purpose of the lock, but to prove more clearly what I have before observed upon its principle and properties; for if such difficulties occur to a skilled workman, as to render it almost, if not altogether impracticable to form a key when the lock is open to his inspection and its parts accessible to his hand, it pretty clearly demonstrates the impossibility of accomplishing it when no part of the movement can be touched or seen."

It is evident that Mr. Bramah had his thoughts directed to that mode of picking locks which depends on taking impressions of the moving parts, rather than to the *mechanical* or *pressure* method which has been developed in later times. There can be little doubt that a lock was, to his mind, a beautiful and admirable machine, far elevated above the level of mere blacksmith's work; and his name will ever be associated with what may be termed the philosophy of lock-making.

After the model-lock, which has just been described, was constructed, and found to corroborate the idea which was working in Mr. Bramah's mind, he proceeded to the construction of his barrel or cylinder-lock, embracing similar elements placed in more convenient juxtaposition. In his Essay he gives an engraving to illustrate the principle on which his lock acts, rather in the manner of a diagram than as depicting any lock actually made; his main object being to impart a clear notion of the action of the slides which form such a distinguishing feature in his lock.

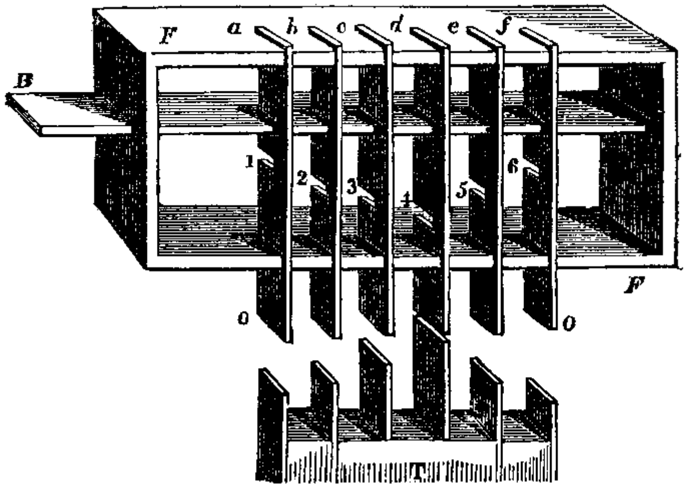


Figure 34 Diagram to illustrate the Bramah lock.

Viewed in this sense, therefore, simply as an illustrative diagram, the annexed cut may represent the action of the safety slides. **B** is a sliding bar or bolt, having a power of longitudinal motion in the frame **F**. This frame has six notches cut on each of its long sides, the two series being exactly opposite each other; and there are six similar notches cut in the bolt **B**.

The concurrent effect of all these eighteen notches is, that the six slides ***abcdef*** can move freely up and down across the bolt. When the slides are thus placed, the bolt cannot move, and may in this case be considered to be locked. There are six clefts or notches in the six slides, one to each (1, 2, 3, 4, 5, 6); and until all these are brought in a right line, the bolt cannot move through them. If a tally or key be prepared, as shown at **T** in the lower part of the cut, with six projections, and if these projections thrust up the six slides until their clefts rise to the plane of the bolt, then can the bolt be withdrawn or the lock opened. This serves to illustrate the relation between the slides and the key, as carried out in the way now to be described.

One peculiar peculiarity of the Bramah lock is, that from the essential part of the apparatus being a barrel or cylinder, much of the working can be conducted in the lathe; and this has given a beauty to the details generally and deservedly admired.

Mr. Bramah, when he worked out the theory of his lock, resolved to discard altogether the use of fixed wards, and also the use of tumblers working on a pivot at one end; substituting in their

stead a system of slides, working in a very novel way.

The body of a Bramah lock may be considered as formed of two concentric brass barrels, the outer one fixed, and the inner rotating within it. The inner barrel has a projecting stud, which, while the barrel is rotating, comes in contact with the bolt in such a way as to shoot or lock it; and thus the stud serves the same purpose as the bit of an ordinary key, rendering the construction of a bit to the Bramah key unnecessary.

If the barrel can be made to rotate to the right or left, the bolt can be locked or unlocked; and the problem is, therefore, how to ensure the rotation of the barrel. The key, which has a pipe or hollow shaft, is inserted in the keyhole upon the pin, and is then turned round; but there must be a very nice adjustment of the mechanism of the barrel before this turning round of the key and the barrel can be ensured.

The barrel has an external circular groove at right angles to the axis, penetrating to a certain depth; and it has also several *internal* longitudinal grooves, from end to end. In these internal grooves thin pieces of steel are able to slide, in a direction parallel with the axis of the barrel.

A thin plate of steel, called the locking-plate, is screwed in two portions to the outer barrel, concentric with the inner barrel; and at the same time occupying the external circular groove of the inner barrel. This plate has notches, fitted in number and size to receive the edges of the slides which work in the internal longitudinal grooves of the barrel.

If this were all, the barrel could not revolve, because the slides are catching in the grooves of the locking-plate; but each slide also has a groove, corresponding in depth to the extent of this entanglement; and if this groove be brought to the plane of the locking-plate, the barrel can be turned, so far as respects that individual slide.

All the slides must, however, be so adjusted that their grooves shall come to the same plane; but as the notch is cut at different points in the lengths of the several slides, the slides have to be pushed in to different distances in the barrel, in order that this juxtaposition of notches may be ensured.

This is effected by the key, which has notches or clefts at the end of the pipe equal in number to the slides, and made to fit

the ends of the slides when the key is inserted.

The key presses each slide, and pushes it so far as the depth of its cleft will permit; and all these depths are such that all the slides are pushed to the exact position where their notches all lie in the same plane; this is the plane of the locking-plate, and the barrel can be then turned.

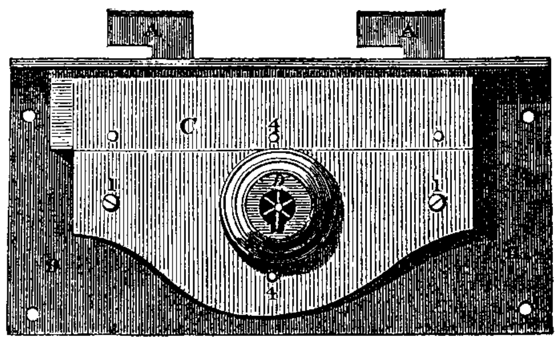
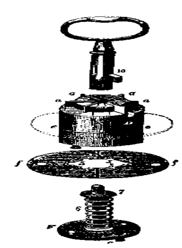


Figure 35 Exterior of a Bramah lock.

This is the principle which Mr. Bramah adopted; and we have now to trace it, step by step, by means of illustrative details. **Figure 35** represents the exterior of a box or desk lock, one among many varieties which the Bramah lock presents. **A A** shows the bolt, formed something like two hooks rising out of a bar of metal, which bar has a backward and forward motion upon the plate **B B.**

The upper edge of this plate is turned over at right angles, forming a small horizontal surface through which two openings are cut to receive the two hooked portions of the bolt. The movements of the bolt are otherwise guided by the edges of square holes through which it works; the holes being made in the edge-pieces of the lock, riveted to the main plate.

The bolt is further prevented from rising out of its place by means of a plate of metal **c**, which is secured to the edge pieces by two screws **1,l**, and by two steadying pieces. This plate has on its surface a cylindrical projection **D**, which contains in effect all the working mechanism of the lock.



The pins **4 4** are employed for securing a plate, which we shall have to describe presently. When such a lock is fixed upon a desk or box, the portion **D** projects to a small distance through a hole in the wood-work, forming in itself a very neat escutcheon, with a keyhole in the center

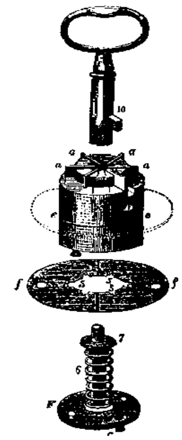


Figure 36. De

So much for the exterior. We must now proceed to examine the interior of the lock, especially the part contained within the cylinder. In **figure 36**, for convenience of arrangement, the several parts are exhibited separately, and as if the plane of the lock were horizontal, with the key acting vertically.

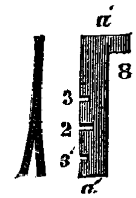


Figure 37

The essential part of the mechanism is a barrel or cylinder **E**, pierced or bored with a cylindrical hole down its center. The inside of the bore has six narrow grooves, cut parallel with the axis, and in the direction of radii; the grooves are not cut through the thickness of the cylinder, but leave sufficient substance of metal for strength.

In every groove is fitted a steel slide of peculiar form, such as is shown at ***a a*** in **figure 37**. Each slide is split in its thickness (seen in section), so that it may move up and down in its groove with a slight friction; the slides, thereby not falling simply by its own weight.

Each slide has three small notches (3, 2, 3), the use of which will presently appear. Reverting to **figure 86**, the lower part of the opening through the cylinder **E** is closed by a circular plate of metal, fixed to it by two screws; this plate is represented at **ii**, in the lower part of the figure.

This plate has a vertical pin rising from its center (also seen at **b**, **figure 39**), and serving as a key-pin on which the pipe of the key may work or slide; and it has also a short circular stud **e** projecting from its underside, and fitted to enter into a curved opening in the bolt presently to be described.

The point to be now borne in mind is this, that if the cylinder **E** turns round, the plate **F** will also turn round, and with it the stud **c**; and as this stud works into the peculiarly formed cavity **d** in. *a* portion of the bolt (**figure 38**), it causes the bolt to be shot backwards or forwards.

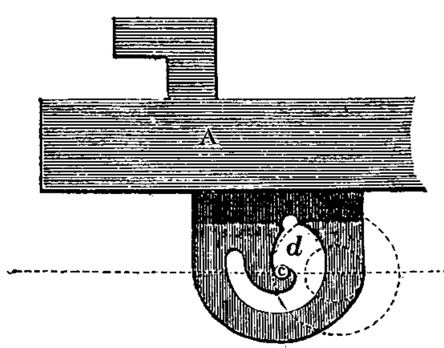


Figure 38 The bolt.

Now, in order to prevent this rotating of the cylinder unless the

proper key be employed, the following mechanism is introduced: the cylinder has a groove cut round its circumference at ***e e,*** extending sufficiently near to the internal bore to produce the desired effect without too much weakening the metal.

Into this notch is introduced the thin circular plate of metal **ff**, it being divided into two halves for this purpose; and when so placed, it occupies the position shown by the dotted portion ***e e.***

When this plate is screwed to the case of the lock by the screws **4, 4,** it cannot of course turn round; but the cylinder itself will or will not turn round according to the position of the slides. The plate ***ff*** has six notches, **5, 5, 5,** etc. in the inner edge or circle; so adjusted that, when the plate is in its place, the slides **a a** can move up and down.

The cylinder cannot move round in a circle without carrying the slides with it; and these cannot so move unless they are all depressed to such exact distances in their respective grooves, that the deep notch of each slider (shown at **2** in **figure 37**) shall come into the plane of the circular plate; when all are so brought, the cylinder can be turned.

If any one of the slides be pressed down either too low or not low enough, this turning of the cylinder cannot be effected, because the slides will be intersected by the edges of the notches **5, 5**; and it is the office of the key, therefore, to press all the six slides down to the exact distances required.

When the slides are not pressed upon by the key, they are forced upwards to the top of the cylinder by a spiral spring **6,** coiled loosely round the pin **b**; this pressure forces up a small collet, **7,** on which the upper part of the slides rest by a sort of step.

The first locks were made with a separate and independent spring to each slide; but it is a very great improvement, the introduction of one common spring to raise up the whole number; because if a person attempts to pick the lock by depressing the slides separately by means of any small pointed instruments, and by chance brings two or more of them to the proper depth for turning round, should he press any one too low, it is difficult to raise it again without relieving the spring **6,** which immediately throws the whole number of slides up to the top, and destroys all that had been done towards picking the lock.

Another improvement of this lock, and one which very much increased the difficulty of picking, and its consequent security, was the introduction of false and deceptive notches cut in the sliders, as seen at **3, 3**. It was found that in the attempt to pick this lock, an instrument was introduced by the keyhole to force the cylinder round.

At the same time that the slides were depressed by separate instruments, those slides which were not at the proper level for moving round were held fast by the notches **5, 5** in the plate **ff** against their sides; but when pressed down to the proper level, or until the notch **2** came opposite **ff** they were not held fast, but were relieved.

This furnished the depredator with the means of ascertaining which slides were pressed low enough, or to the point for unlocking. The notches **3, 3** in the slides are sometimes cut above the true notch **2**, sometimes below, and at other times one on each side (one above and one below).

They are not of sufficient depth to allow the cylinder to turn round, but are intended to mislead anyone who attempts to pick, by his not knowing whether it is the true notch or otherwise, or even whether the slider be higher or lower than the true notch.

We have not yet sufficiently described the key of the Bramah lock. One merit of the lock is the remarkable smallness of the key, which renders it so conveniently portable. The key, as shown in the upper part of the figure, has six notches or clefts at the end of its pipe or barrel; these clefts are cut to different depths, to accord with the proper extent of movement in the slides.

There is a small projection, **10**, near the end of the pipe, fitted to enter the notch **D** in the cylinder; this forces the cylinder round when the parts are all properly adjusted. The bolt of the lock, when properly shot or locked, is prevented from being forced back by the stud **c** on the bottom, **F**. of the cylinder coming into a direct line with its center of motion, as shown in **figure 39**; in this position no force, applied to drive the bolt back, would have any tendency to turn the cylinder round.

To facilitate the comprehension of this very curious and beautiful mechanism, the cylinder is shown in section in the annexed **figure 39**, the same letters and figures of reference being used as before. In the whole of this description, we have

spoken of six slides, and six only; but Bramah locks may be, and have been, constructed with a much larger number.

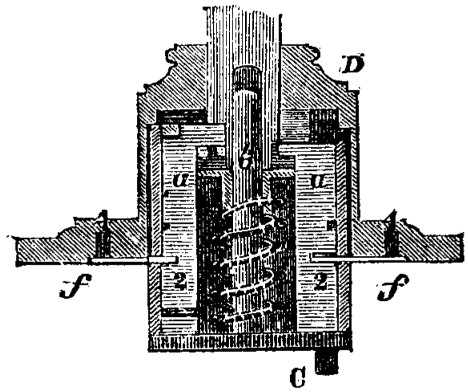


Figure 39 Section of the Bramah cylinder.

There have been several attempts made to modify the action of Bramah's lock, or to combine this action with that of some other inventor. It will suffice to describe one of these. The lock invented by Mr. Kemp of Cork, and for which a patent was obtained in 1816, is called by him the **Union lock**, as combining the principles of Barron's and Bramah's locks.

It contains two, three, or more sliders or tumblers, operated upon by two, three, or more concentric tubes. These concentric tubes are of different lengths, and are placed inside the barrel of the key; so that the barrel may, in fact, be conceived to consist of a series of concentric tubes. These tubes are made of such respective lengths as to push back the tumblers, sliders, or pins which detain the bolt; and this to the precise extent that will bring certain notches in all the sliders to the position which will allow the bolt to pass.

The inventor gives this lock its distinctive appellation because it combines something of the pushing motion which, Bramah gives to his key, with something of the tumbler-motion observable in Barron's locks. The principle of security is considered here to rest chiefly on the extreme difficulty of imitating the key.

Mr. Bramah calculates the number of changes of position of which the slides of his lock are capable of assuming before the right one would be attained. "Let us suppose the number of levers, slides, or other movables by which the lock is kept shut, to consist of twelve, all of which must receive a different and distinct change in their position or situation by the application of the key, and each of them likewise capable of receiving more

or less than its due, either of which would be sufficient to prevent the intended effect.

It remains, therefore, to estimate the number producible, which may be thus attempted. Let the denomination of these slides be represented by twelve arithmetic progressions; we find that the ultimate number of changes that may be made in their place or situation is 479,001,600.

By adding one more to that number of slides, they would then be capable of receiving a number of changes equal to 6,227,020,800; and so on progressively, by the addition of others in like manner to infinity.

From this it appears that one lock consisting of thirteen of the above-mentioned sliders, may (by changing their places only, without any difference in motion or size), be made to require the said immense number of keys, by which the lock could only be opened under all its variations."

CHAPTER SEVEN: American Locks

MASTER EXHIBIT LIST

Hobbs closed keyhole lock

THE lock-manufacture in America has undergone some such changes as in England. The insufficiency of wards to the attainment of security has been for many years known; and the unfitness of even tumblers to attain this end, without auxiliary contrivances, has been fully recognized for a dozen years back.

In this, and in other mechanical arts, the American machinists depended primarily on the invention of the artisans in the mother country, rather than on those of any continental European state. But the development of the art in the United States has not been wanting in originality; the varieties of locks have been very numerous, and many of them exceedingly ingenious. It is not necessary, however, to describe or depict any of those of simple form.

The warded locks of different countries very much resemble each other; the intricate warded locks made in France in the last century have long fallen into disuse, in consequence of the general conviction that no arrangement of wards, however intricate, can afford the degree of security required in a good lock. It will be more to the purpose, therefore, to proceed at once to a notice of those American locks that, during the last few years, have acquired some celebrity; first, however, noticing one of older date.

Stansbury's lock, invented in the United States about forty years ago, may be regarded as a modification of the Egyptian lock. It had a bolt, case, and keyhole somewhat similar to those of modern locks; but there were peculiarities of construction in other respects. There was a revolving plate, pierced with a series of holes, and having a bit or pin that moved the bolt. On the lock-case were a series of springs, each having a pin at one end; and the arrangement was such that, when the bolt was locked or unlocked, each pin would be pressed into some one of the holes.

Like as in the Egyptian lock (**figures 1 to 4**), each pin had to be pushed out, and all of them simultaneously, to allow the plate to turn and move the bolt. The key was made with a barrel and bit; and on the front end of the bit was a series of pins corresponding in position with the holes in the plate. The mode of locking or unlocking was as follows: the key was inserted in the keyhole, and turned to a certain position; it was then pressed in with some force, until the pins on the key met those in the plate; when the latter, yielding to the pressure, left the

plate free to turn and move the bolt.

Modifications of the Egyptian lock, more or less resembling this, have been brought out in some variety on both sides of the Atlantic; but scarcely any have equaled in simplicity the curious wooden relic of by-gone ingenuity in the art of lock-making.

A lock made a few years ago by Mr. Yale, in the United States, somewhat resembles the Bramah lock in having a cylinder or barrel, or rather two concentric cylinders, one working within the other. These cylinders are held together by pins that pass through them both into the keyhole. On the back of the inner cylinder is a pin that fits into a slot in the bolt, and moves it whenever the cylinder is turned.

The pins that hold the cylinders together are each cut in two; the pieces of the various pins differing in lengths as irregularly as possible. The key is so peculiarly formed, that, on inserting it in the keyhole, it thrusts the pins radially outwards; each pin being pushed just so far that the joint of the pin shall coincide with the joint between the two cylinders. The inner cylinder can then be turned, by which the bolt is locked or unlocked. If, by the use of a false key, any pin be pushed in too far, it will be as ineffectual in opening the lock as if it were not thrust in far enough; and some of these locks having been made with as many as forty pins, the chances are very numerous against the right combination being hit upon. There is a combination of something like the Egyptian with something like the Bramah lock, here attempted.

One of the principal constructions adopted in America a few years back for bank-locks is that of Dr. Andrews of Perth Amboy, in New Jersey. It was up to that time (1841) believed that the best locks, both of England and America, were proof against any attempts at picking derived from knowledge obtained by inspection through the keyhole; but there still remained the danger that the sight of the true key, or the possession thereof, for only a few minutes, would enable a dishonest person to produce a duplicate.

It was to contend against this difficulty that Dr. Andrews directed his attention; and he sought to obtain the desired object by constructing a lock, the interior mechanism of which could be changed at pleasure. The lock of his invention is furnished with a series of tumblers and a detector. The tumblers are susceptible of being arranged in any desired order; and the key has moveable bits that can be arranged so as to correspond

with the tumblers. When the lock is fixed in its place, no change can be made in the tumblers, and consequently only one arrangement of the bits of the **key** will suit for the shooting and withdrawing of **the bolt**.

The owner can, however, before the fixing of the bolt, adopt any arrangement of tumblers and bits which he may choose. But though the tumblers cannot be actually rearranged in any new order within the lock while the latter is fixed, yet by an ingenious contrivance the tumblers can be so acted upon as to render the lock practically different from its former self.

The purchaser receives with his lock a series of small steel rings, each ring corresponds in thickness with the thickness of some one of the bits of the key; so that, by suitable adjustment, any one of the bits may be removed from the key, and a ring be substituted in its place. The effect of this substitution is, that the particular tumbler that corresponds with the ring is not raised by it; it is drawn out with the bolt, as if it were part of the bolt itself.

Supposing the lock to be locked by this means, the original key would not now unlock it; for one of the tumblers has now been displaced, and can only be readjusted by the same ring which displaced it. If an attempt is made to open the lock by the original key, or by the key in its original adjustment, a detector is set in action, which indicates that a false key or other instrument has been put into the lock.

One, or more than one of the bits may be removed from the key, and rings be substituted, and consequently one or more of the tumblers may be disturbed in this peculiar way; so that the lock may change its character in all those permutating varieties which are so observable in most "safety-locks."

The shape of the tumblers is, of course, such as to facilitate this action; they have each an elongated slot, and also two notches; when a tumbler is raised by one of the bits of the key, one of the notches closes around a stump fitted into the case of the lock, and prevents the tumbler from being moved onward with the bolt; but when a ring has been substituted for a bit on the key, the tumbler cannot be raised at all; it is carried onward by a stump on the bolt.

Dr. Andrews is also the inventor of a lock that he terms the ***snail-wheel*** *lock.* In this lock a series of revolving discs, or

wheels, taking the place of the tumblers, are mounted on a central pin, on which the pipe of the key is inserted. Each disc has a piece cut out of it, into which the bit of the key enters, and in turning round moves the discs according to the various lengths of the steps on the key. On the outer edge of each disc is a notch, and by the turning of the key all these notches are brought into a line, so that a moveable tongue, or *toggle,* attached to the bolt, falls into the notches; the key is then turned the reverse way, by which means the bolt is projected.

About the time when Dr. Andrews invented his first lock, Mr. Newell, of the firm of Day and Newell of New York, constructed a lock which possessed the same distinctive peculiarity as that of Andrews, viz. that the key might be altered any number of times without rendering it necessary to remove the lock or change its internal mechanism. This was brought about, however, in a different manner. Instead of having, as in the Andrews lock, a two-fold movement to every tumbler, Mr. Newell employed two sets of tumblers, the one set to receive motion from the other, and having different offices to fill, to be acted upon by the key in respect to the first series, and to act upon the bolt in respect to the second.

Calling these two sets *primary* and *secondary,* the action of the lock may he briefly described as follows: A primary tumbler being raised to the proper height by the proper bit in the key, raises the corresponding secondary tumbler; the secondary tumbler is held up in a given position during the locking, while the primary becomes pressed by a spring into its original position. It results from this arrangement that the bolt cannot be unlocked until the primary tumbler has been raised to the same height as before, so as to receive the tongue of the secondary tumbler. And as this is the case in respect to any one primary and its accompanying secondary tumblers, so is it the case whether each set comprises four, five, or any other number. The key may be altered at pleasure, and will in any form equally well shoot the bolt; but the lock can only be unfastened by that arrangement of key that fastened it.

It is, however, desirable to trace the course of improvements more in detail, because every successive change illustrates one or other of the several properties required in a good lock. Messrs. Day and Newell's lock was not finally brought to an efficient form without many attempts more or less abortive.

Mr. Newell conceived the idea of applying a second series of

tumblers, so placed as to be acted upon by the first series. Each of these secondary tumblers had an elongated slot, such that a screw could pass through all of them; the screw having a clamp to overlap the tumblers on the inside of the lock. The head of the screw rested in a small round hole on the back of the lock, so placed as to form a secondary keyhole, to which a small key was fitted.

There was thus a double system of locking, effected in the following way: when the large key had been applied, and had begun to act on the primary tumblers, the small key was used to operate on the clamp-screw, and thus bind all of the secondary tumblers together, ensuring their position at the exact heights or distances to which the primary key had caused them to be lifted. The bolt was then free to be shot, and the first series of tumblers reverted to their original position.

But such an arrangement has obvious inconveniences. Few persons would incur the trouble of using two keys; and besides this, there were not wanting certain defects in the action and reaction of the several parts; for if the clamp-screw were to be left unreleased, the first series of tumblers would be upheld by the second series in such a way that the exact impression of the lengths of the several bits of the key could be obtained through the keyhole while the lock was unlocked or the bolt upshot.

To remedy one or both of these evils was the next object of Mr. Newell's attention. He made a series of notches or teeth in each of the secondary tumblers, corresponding in mutual distance with the steps or bits of the key; and opposite these notched edges he placed a dog or lever, with a projecting tooth suitable to fall into the notches when adjusted properly in relation to each other. When the key was used, the primary tumblers were raised in the usual way, and acted on the secondary tumblers; these latter were so thrown that the dog-tooth caught in the notches and held them fast, thereby rendering the same service as the clamp-screw and the small key in the former arrangement. No other relative position of the bits of the key could now unlock the lock.

Still, improvement as it was, this change was not enough; Mr. Newell found that his lock, like all the locks that had preceded it, was capable of being picked by a clever practitioner; and candidly admitting the fact, he sought to obtain some new means of security. He tried what a series of complicated wards would do, in aid of the former mechanism; but the result proved unsatisfactory.

His next principle was to provide a number of false notches on the abutting parts of the primary and secondary tumblers, with alterations in other parts of the apparatus. The theory now depended upon was this, that if the bolt were subjected to pressure, the tumblers would be held fast by false notches, and could not be raised by any lock-picking instrument. To increase the security, a steel-curtain was so adjusted as to cover, or at least protect, the keyhole. Great anticipations were entertained of this lock, but they were destined to be negatived. A clever American machinist, Mr: Pettit, accepted Messrs. Day and Newell's challenge (500 dollars to any one who could pick this lock); he succeeded in picking the lock, and thus won the prize.

Once again disappointed, Mr. Newell reexamined the whole affair, and sought for some new principle of security that had not before occurred to him. He had found that, modify his lock how he might, the sharp-eyed and neat-fingered mechanician could still explore the interior of the lock in such a way as to find out the relative positions of the tumblers, and thus adapt their means to the desired end. How, therefore, to shut out this exploration altogether became the problem; how to make a lock, the works of which should be ***parautoptic***, *to* coin a word from the Greek, which should signify *concealed from view.* The result of his labors was the production of the American bank-lock now known by that name. The details of this lock may now conveniently be given.

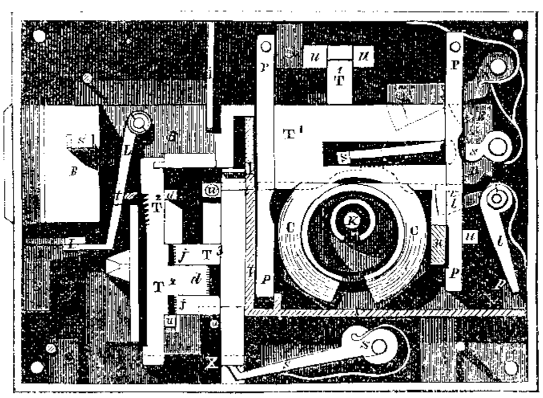


Figure 40 The American Parautoptic lock; bolt upshot.

In **figure 40** the lock is represented in its unlocked state, with the cover or top-plate removed; the auxiliary tumbler and the detector-plate are also removed. In **figure 41** it is represented as locked, with the cover and the detector-plate also removed, and the auxiliary tumbler in its place.

In these two figures, the same letters of reference apply to the same parts, unless otherwise stated. **BB** is the bolt; **T**^{1} are the first series of moveable slides or tumblers; **s** shows the tumbler-springs; **T**^{2} the secondary series of tumblers; and T the third or intermediate series—these latter coming between the first and secondary series; **PP** are the separating plates between the several members of the first series of tumblers; **s**^{1} are the springs for lifting the intermediate tumblers.

On each of the secondary tumblers **T**^{2} is a series of notches, corresponding in mutual distance with the difference in the lengths of the moveable bits of the key. It thence happens that, when the key is turned in the lock to lock it, each bit raises its proper tumbler, so that some one of these notches shall present itself in front of the tooth **t** in the dog or lever **LL**.

When the bolt **B** is projected by the actions of the key, it carries with it the secondary tumblers **T**^{2} and presses the tooth **t** into the notches; in so doing, it withdraws the tongues **d** from between the jaws ***jj*** of the intermediate tumblers ***T***^{3}*,* and allows the first and intermediate tumblers to fall to their original position. By the same movement, the secondary tumblers **T**^{2} become held in the position given to them by the key, by means of the tooth **t** being pressed into the **several** notches, as shown in the closed state of the lock (**figure 41**).

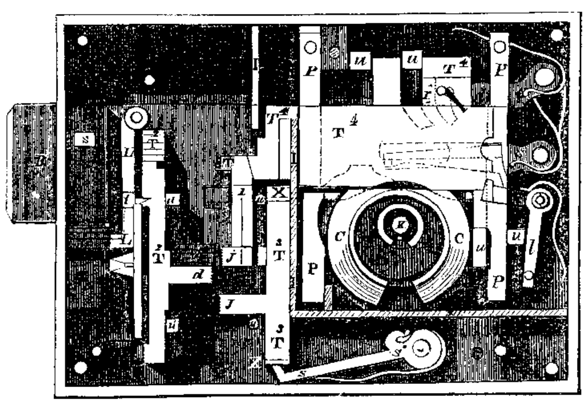


Figure 41 The same with the bolt shot.

Now let us see what results if any attempt be made to open the lock with any arrangement of key but that by which it has been locked. In such case, the tongues **d** will abut against the jaws ***jj*,** preventing the bolt from being withdrawn; and should an

attempt be made to ascertain which tumbler binds and requires to be moved, the intermediate tumbler **T^3** (which receives the pressure), being behind the iron wall **II**, which is fixed completely across the lock, prevents the possibility of its being reached through the keyhole; and the first tumblers **T** are quite detached at the time, thereby making it impossible to ascertain the position of the parts in the inner chamber behind the wall **II**. **K** is the drill-pin, on which the key fits; and **c** is a revolving ring or curtain, which turns round with the key, and prevents the possibility of inspecting the interior of the lock through the keyhole.

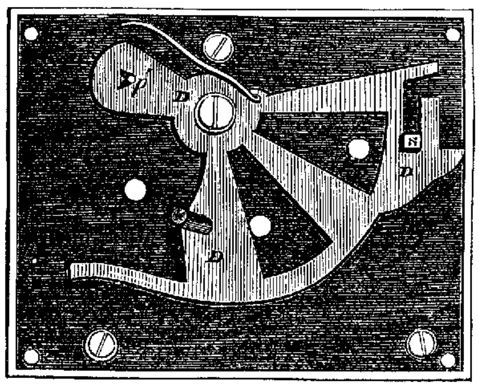


Figure 42 The detector plate of the Parautoptic lock.

Should, however, this ring be turned to bring the opening upwards, a detector-plate **D**, **figure 42**, is immediately carried over the keyhole by the motion of a pin **p^1** upon the auxiliary tumbler **T^4**, which is lifted by the revolution of the ring **c**, thereby effectually closing the keyhole.

As an additional protection, the bolt is held from being unlocked by the stud or stump **s** bearing against the detector plate; and, moreover, the lever **ll** holds the bolt, when locked, until it is released by the tail of the detector-plate pressing the pin **p^1**; **l^1** is a lever which holds the bolt on the upper side, when locked, until it is lifted by the tumblers acting on the pin **p^1**; **x** are separating-plates between the intermediate tumblers **T^3**; **uu**

x are separating-plates between the intermediate tumblers **T**^{3}; **uu** are the studs for preserving the parallel motion of the different tumblers.



Figure 43 Key of the Parautoptic lock.



Figure 44 End view of t

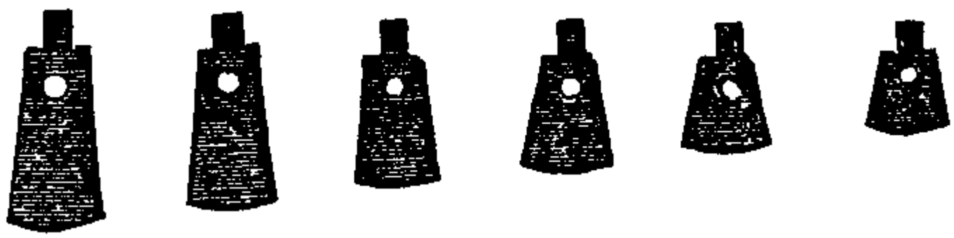


Figure 45 Separate bits of the key.

Figure 43 represents the key in two different forms, or with the bits differently arranged. Either form will lock the lock, but the other will not then unlock it. The end of the key is represented in **figure 44**, showing the screw which fixes the bits in their places. The bits for a six-bitted key are shown separately in **figure 45.**

In 1847 the parautoptic lock was exhibited at Vienna before the National Mechanics' Institute of Lower Austria; and towards the close of the year Mr. Belmont, Consul-General of Austria at New York, placed in the hands of Messrs. Day and Newell a letter, a diploma, and a gold medal, forwarded by the Institute. The letter was from the president of the Institute to Mr. Newell, and was couched in the following terms:

"The Institute of Lower Austria, at its last monthly session, has passed the unanimous resolution to award to you its gold medal, as an acknowledgment of the uncommon superiority of the combination lock of your invention; and this resolution was ratified in its general convention held on the 10th instant."

"Whilst I, as president of this Institute, rejoice in seeing the services which by this invention you have rendered to the locksmith's art thus appreciated and recognized, I transmit to you, enclosed, the said medal, together with the documents relating to it; at the same time availing myself of this opportunity to assure you of my esteem."

"COLLOREDO MANNSFELD

"Vienna, May 31st, 1847."

The diploma and the medal were similar to other honorary distinctions of the same class, and need not be described here; but the report of the special committee may be given, as it expresses the opinions of the Viennese machinists on the relative principles by which safety is sought to be obtained in different kinds of locks.

REPORT

Of a Special Committee on the new Parautoptic Permutation Lock of the American Newell, made known to the Lower Austrian Institute by the Councillor, Professor Reuter, and on the motions relating to it made by the same and accepted by the Institute. Presented at the monthly meeting, April 6th, 1847, by Mr. Paul Sprenger, Aulic Councillor on Public Works, &cc.

GENTLEMEN: --At our last monthly meeting, Mr. Reuter, Aulic Councillor and Secretary of the Institute, directed your attention to a newly invented lock of Mr. Newell, of North America, which was represented as excelling all other changeable combination locks hitherto known, and as being without a rival.

The Special Committee which was entrusted with the examination of this lock, and of the motions made by the said Secretary, and accepted by the Institute, has conferred on me the honor of making you acquainted with the results of its investigations.

The attention of your committee was chiefly occupied with the three questions proposed by the said Aulic Councillor in relation to the lock in question:

First: Whether the idea of Mr. Newell was of any practical value for already existing and still-to-be-imvented combination locks;

Secondly: Whether the idea was of sufficient importance to be published and minutely described in the transactions of the said Institute, and;

Thirdly: Whether the merits of the inventor were of sufficient importance to entitle him to a distinction from the said Institute.

The deliberations on the first question, viz. the newness of the idea, and of its practical value, would of necessity enlist the particular attention of your committee, especially since by far the greater number of its members are by their avocation called upon to be interested in the execution of all kinds of locks.

It is therefore the unanimous opinion of your committee) that the idea Of the American Parautoptic Combination Lock is entirely new and without example.

The combination locks with keys have, with few exceptions, such an arrangement that a determinate number of moveable parts (the so-called combination-parts) must by the turning of the key be raised or lifted into a certain position, if it is desired to project the bolt, or, what is the same thing, to lock it out; consequently these parts, or, as they are technically termed, tumblers, could not be transposed or changed, from the circumstances that the key-bit was one solid piece, with various steps or notches adapted to the several tumblers, and one impression from it destroyed the security of the lock.

In order, however, to add more security to such a combination lock and to make the key, in case it should be lost, or any counterfeit made from a wax impression, useless for an unlawful opening of the lock, another step was taken: the key-bit was made to consist of several bits or moveable parts, in such a manner that the owner of the lock was enabled to change the bits, and to forms as it were, new keys different from the former.

But since the bolt of the lock can only be projected whilst the combination parts or tumblers are in a certain position, which position depends upon the **order** of the bits in the key, it is evident that the owner, when changing the key, must at the same time make a corresponding change in the position of the tumblers in the lock itself, before the lock can be of any use for the newly changed shape of the key, which rendered it troublesome, and impracticable for the purpose designed, from the fact that no positive change could be made in the lock, without taking it from the door and then taking the tumblers out of the case, to change them in a suitable form for the key.

This principle of changing the lock is rarely adhered to, as few men understand the machinery of a lock sufficiently to undertake the task, and this circumstance rendered the lock quite as insecure as the former one described.

Another step toward the perfection of combination locks consisted in this, that the key remains unaltered whilst the combination parts of the lock can, before it is locked, be brought into different positions by means of moveable plates on the frame of the lock. These plates were arranged by hand to certain figures, and depended on the memory for adjustment at each time the bolt was to be locked out or in, the key operating only on the bolt, to move it back and forth when the plates were set in proper positions for the purpose; and should the owner forget the arrangement of the plates, after projecting the bolt, his key is of no use to him, and he must resort to the skill of the locksmith to gain access.

The same case may occur in the far less perfect ring-lock of **Reynier**, which is operated without keys, and is opened by means of the rings being turned in a particular position; on these rings are usually stamped letters which, by introducing some word readily suggested to the memory, thus point out the relative position of the rings.

But although in case of these ring-locks the owner is enabled to produce a change in the rings in such a manner that the opening of the lock can, as it were, only become possible by rightly arranging the altered position of the letters, still this lock of Reynier's does not possess that safety and perfection which could have insured it universal application.

M. Crivelli, formerly professor at Milan, has given a minute description of the imperfection of ring-locks generally, in the annals of the Imperial Royal Polytechnic Institute.

It is the unanimous conviction of your committee that the American Lock of Newell surpasses, in the ingenuity displayed in its construction, all other locks heretofore known, and more especially in this, that the owner can, with the greatest facility, change at pleasure the interior arrangement of his lock to a new and more complex one, at every moment of his life, simply by altering the arrangement of the bits in the key, and this is accomplished without removing the lock or any part of it from its position on the door.

Its operation is as follows: At the closing or locking of the lock, whilst the bolt is projecting, the moveable combination parts assume precisely the position prescribed to them by the key, according to the particular arrangement of its bits at the

time the key is turned.

The combination parts do not consist in one set of tumblers only, such as are found in all other locks, but there are three distinct sets or component parts fitting into each other. When the bolt is projected, it dissolves the mutual connection of the constituent pieces, and carries along with it such as are designedly attached to it, and which assume the particular positions given them by the key in its revolution. These parts are rendered permanent in their given form by means of a lever adapted for the purpose, while the parts not united with the bolt are pressed down by their springs to their original places.

If now the bolt is to be returned again, i.e. if the lock is to be unlocked, then the constituent pieces or tumblers which are in the original state must, by means of the key, be again raised into that position in which they were when the lock was closed, as otherwise the constituent parts attached to the bolt would not lock in with the former, and the bolt could not be returned. Nothing, therefore, but the precise key which had locked the lock can effect the object.

This idea in itself, considered by your committee, is as ingenious as it is new, and is accompanied by a perfection in its execution which reflects the highest honor on Mr. Newell, the inventor and manufacturer of the lock.

The lock is built strong and solid, and the several parts are admirably adapted to the functions which they are designed to perform. The walls of steel or iron which separate the security parts from the tumblers, and the cylinder which revolves with the key, present formidable barriers to all descriptions of pick-locks, and render the lock a most positive and reliable security, The tumblers consist of rolled very smooth steel plates, in which the fire-crust has not been filed away, partly in order that the lock might not need oiling, as all these parts are very smooth, and partly that the combination pieces might not easily rust, a thing the adhering fire-crust is not favorable.

The springs, which by the turning of the key must be raised together with the tumblers, are attached to levers, and press upon the latter at their center of gravity, in consequence of which all crowding towards either side is prevented, and the key can be turned with facility, in spite of the many combination parts which it has to raise; and the springs themselves are by their positions so little galled into action, that their strength

can never be impaired by use.

The lock has also another very complete arrangement in the detector tumbler, which is attached to the cap or covering of the lock. This tumbler, on turning the key either way, closes the keyhole, and not only prevents the use of false instruments in the lock, but detects all attempts at mutilating its interior parts.

This lock is especially useful for locking bank-vaults, magazines, country-houses and iron-safes, in which valuable effects, money, or goods are to be deposited for safe keeping. When it is considered that the bib of the key belonging to this lock can be transferred into every possible form within its limits, and since the construction of the lock admits of every combination of the slides resulting from the changes of the key, therefore the lock in question is, in every respect, deserving of the appellation given to it by the Secretary of the Institute, namely, the Universal Combination Lock; and justly so, when we consider that the ten bits attached to the key admit of three millions of permutations, and upward; consequently forming that number of different kinds of keys and locks.

If we consider further, that we need not be limited to the given bit, but that others can be applied, differing in their dimensions from the former; and again, if we consider that from every system arising from a difference in their relative dimensions, a large number of new keys differing from each other will result, and that this can be effected in a space scarcely occupying a square inch, then we cannot refrain from confessing that the human mind, within this small space, has shown itself to be infinitely great.

After this preliminary and general exposition, your committee can answer the three questions propounded to them the more briefly, as the locks heretofore known have all been noticed.

To question first. On the practical value of the invention of Mr. Newell, your committee were unanimous and positive that the principle on which it is based should be preserved.

To question second. For this reason the committee deemed it desirable that a drawing and description of the American lock in question should be published in the Transactions of the Institute of Lower Austria.

To question third. With regard to the claims of the inventor, Mr. Newell, to an honorary distinction from the Institute of Lower Austria, the committee recommends that he be presented with a Diploma of honorable mention and a Gold Medal.

The members of your committee, consisting mostly of fellow-tradesmen of Mr. Newell, experience great satisfaction in the fact that it has fallen to their lot to vote to their colleague on the other side of the ocean an acknowledgment of his successful ingenuity, and they close the Report with the request that the Institute will transmit to Mr. Newell of New York, in North America, the Diploma and Gold Medal, together with a copy of this Report, according to the motion of the Aulic Councillor and Professor Reuter.

[An exact copy of the original Report as preserved in the archives of the National Mechanics' Institute of Lower Austria.]

DR. SCHWARTZ,

Assistant Secretary of the Institute.

There are other circumstances connected with the American bank lock, in relation to events both in the United States and in England, to which attention will be directed in a subsequent chapter.

The English patent for Messrs. Day and Newell's lock, dated April 15, 1851 runs as follows:

"The object of the present improvements is the constructing of locks in such manner that the interior arrangements, or the combination of the internal moveable parts, may be changed at pleasure according to the form given to, or change made in, the key, without the necessity of arranging the moveable parts of the lock by hand, or removing the lock or any part thereof from the door. In locks constructed on this plan the key may be altered at pleasure; and the act of locking, or throwing out the bolt of the lock, produces the particular arrangement of the internal parts which corresponds to that of the key for the time being."

While the same is locked, this form is retained until the lock is unlocked or the bolt withdrawn, upon which the internal moveable parts return to their original position with reference to each other; but these parts cannot be made to assume or be brought back to their original position, except by a key of the precise form and dimensions as the key by which they were made to assume

such arrangement in the act of locking. The key is changeable at pleasure, and the lock receives a special form in the act of locking according to the key employed, and retains that form until in the act of unlocking by the same key it resumes its original or unlocked state. The lock is again changeable at pleasure, simply by altering the arrangement of the moveable bits of the key; and the key may be changed to any one of the forms within the number of permutations of which the pares are susceptible."

The "claims" put forth under this patent are the following:

1. The constructing, by means of a first and secondary series of slides or tumblers, of a changeable lock, in which the particular form or arrangement of parts of the lock, imparted by the key to the first and secondary series of slides or tumblers, is retained by a cramp-plate.

2. The constructing, by means of a first and secondary series of slides or tumblers, of a changeable lock, in which the peculiar form or arrangement of parts of the lock, imparted by the key, is retained by means of a tooth or teeth, and notches on the secondary series of slides or tumblers.

3. The application to locks of a third or intermediate series of slides or tumblers.

4. The application of a dog with a pin overlapping the slide or tumblers, for the purpose of holding-in the bolt when the lock is locked or unlocked.

5. The application of a dog operated on by the cap or detector-tumbler for holding the bolt.

6. The application of a dog for the purpose of holding the internal slide or tumbler.

7. The application to locks of curtains or rings, turning and working eccentrically to the motion of the key, for preventing access to the internal parts of the lock.

8. The application to locks of a safety-plug or yielding plate, at the back of the chamber formed by such eccentric revolving curtain or ring.

9. The application to locks of a strong metallic wall or plate, for the purpose of separating the safety and other parts of the lock from each other, and preventing access to such parts by means of the keyhole.

10. The application to locks of a cap or detective tumbler, for the purpose of closing the keyhole as the key is turned.

11. The constructing a key by a combination of bits or moveable pieces, with tongues fitted into a groove and held by a screw.

12. The constructing a key having a groove in its shank to receive the detector tumbler.

When the American locks became known in England, Mr. Hobbs undertook the superintendence of their manufacture, and their introduction into the commercial world. Such a lock as that just described must necessarily be a complex piece of mechanism; it is intended for use in the doors of receptacles containing property of great value; and the aim has been to baffle all the methods at present known of picking locks, by a combination of mechanism necessarily elaborate.

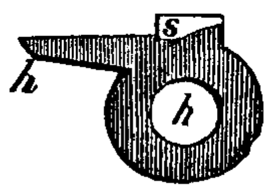


Figure 46 Moveable Stump.

Such a lock must of necessity be costly; but in order to supply the demand for a small lock at moderate price, Mr. Hobbs has introduced what he calls a ***protector lock.*** This is a modification of the ordinary six-tumbler lock. It bears an affinity to the lock of Messrs. Day and Newell, inasmuch as it is an attempt to introduce the same principle of security against picking, while avoiding the complexity of the changeable lock."

The distinction that Mr. Hobbs has made between secure and insecure locks will be understood from the following proposition, viz.

"that whenever the parts of a lock which come in contact with the key are so affected by any pressure applied to the bolt,

or to that portion of the lock by which the bolt is withdrawn, as to indicate the points of resistance to the withdrawal of the bolt, such a lock can be picked."

Figure 47 exhibits the internal mechanism of this new patent lock. It contains the usual contrivances of tumblers and springs, with a key cut into steps to suit the different heights to which the tumblers must be raised. The key is shown separately in **figure 48.**

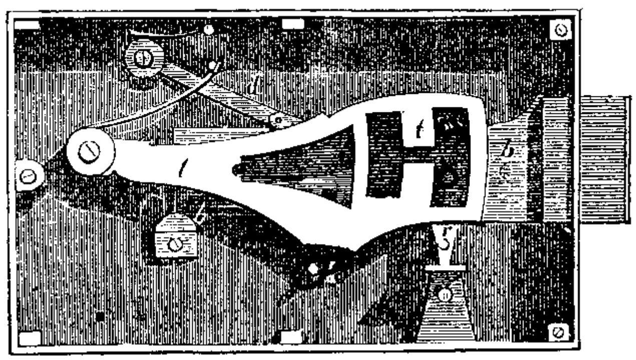


Figure 47 Hobbs's Protector Lock.

But there is a small additional piece of mechanism, in which the ***tumbler*** **stump** shown at **s** in **figures 46** and **47** is attached; which piece is intended to work under or behind the bolt of the lock. In **figure 47, b** is the bolt; **tt** is the front or foremost of the range of six tumblers, each of which has the usual slot and notches.. In other tumbler-locks the stump or stud which moves along these slots is riveted to the bolt, in such manner that, if any pressure be applied in an attempt to withdraw the bolt, the stump becomes pressed against the edges of the tumblers, and bites or binds against them.

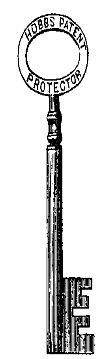


Figure 48

How far their bitting facilitates the picking of a lock will be shown further on; but it will suffice here to say, that the moveable action given to the stump in the Hobbs lock transfers the pressure to another quarter. The stump **s** is riveted to a peculiarly-shaped piece of metal ***h p*** (**figure 46**), the hole in the center of which fits upon a center or pin in a recess formed at the back of the bolt; the piece moves easily on its center, but is prevented from so doing spontaneously by a small binding spring.

The mode in which this small moveable piece takes part in the

action of the lock is as follows: when the proper key is applied in the usual way, the tumblers are all raised to the proper heights for allowing the stump to pass horizontally through the gating; but should there be an attempt made, either by a false key or by any other instrument, to withdraw the bolt before the tumblers are properly raised, the stump becomes an obstacle.

Meeting with an obstruction to its passage, the stump turns the piece to which it is attached on its center and moves the arm of the piece **p** so that it shall come into contact with a stud riveted into the case of the lock; and in this position there is a firm resistance against the withdrawal of the bolt.

The tumblers are at the same moment released from the pressure of the stump. There is a dog or lever **d**, which catches into the top of the bolt, and thereby serves as an additional security against its being forced back. At **k** is the drill-pin on which the pipe of the key works; and **r** is a metal piece on which the tumblers rest when the key is not operating upon them.

Another lock, patented by Mr. Hobbs in 1852, has for its object the absolute closing of the keyhole during the process of locking. The key does not work or turn on its own center but occupies a small cell or chamber in a revolving cylinder, which is turned by a fixed handle. The bit of the moveable key is entirely separable from the shaft or stem, into which it is screwed, and may be detached by turning round a small milled headed thumb-screw. The key is placed in the keyhole in the usual way, but it cannot turn; its circular movement round the stem as an axis is prevented by the internal mechanism of the lock; it is left in the keyhole, and the stem is detached from it by unscrewing.

By turning the handle, the key-bit, which is left in the chamber of the cylinder, is brought into contact with the works of the lock, so as to shoot and withdraw the bolt. This revolution may take place whether the bit of the moveable key occupy its little cell in the plate or not; only with this difference: that if the bit be not in the lock, the plate revolves without acting upon any of the tumblers; but if the bit be in its place, it raises the tumblers in the proper way for shooting or withdrawing the bolt.

It will be understood that there is only one keyhole, namely, that through which the divisible key is inserted; the other handle or fixed key working through a hole in the cover of the

lock only just large enough to receive it, and not being removable from the lock. As soon as the plate turns round so far as to enable the key-bit to act upon the tumblers, the keyhole becomes entirely closed by the plate itself, so that the actual locking is affected at the very time when all access to the interior through the keyhole is cut off.

When the bolt has been shot, the plate comes round to the original position; it uncovers the keyhole and exhibits the key-bit, occupying the little cell into which it had been dropped; the stem is then to be screwed into the bit, and the latter withdrawn.

It is one consequence of this arrangement, that the key has to be screwed and unscrewed when used; but through this arrangement the keyhole becomes a sealed book to one who has not the right key. Nothing can be moved, provided the bit and stem of the key be both left in; but by leaving in the lock the former without the latter, the plate can rotate, the tumblers can be lifted, and the bolt can be shot.

CHAPTER EIGHT: The Lock Controversy: Previous to the date of the Great Exhibition

IT must be evident, even on a cursory glance at the past history of the lock-manufacture, that the prime motive for the introduction of novelties and improvements in construction is the desirability of producing a lock which no one can open without the proper key. From the earliest and simplest lock, down to the latest and most complex, this object has been constantly held in view; and every clear proof or evidence that this object has not been attained has led to the invention of some new contrivance. It has been a succession of struggles to attain security, to show that this security has not been attained, to make a further and more ingenious attempt to detect the weak point in this renewed attempt, and so on.

We need not repeat here, what was stated in an early chapter, that benefit must ultimately result from a candid discussion of this question. When M. Reaumur proposed to explain how the locks

of his day could be picked or opened without the true key, his object was to show to persons who were not locksmiths how far they could depend upon the principle of security offered by locks. But before proceeding on his inquiry, the illustrious naturalist asks, "Ne craindra-t-on pas que nous ne donnions en mime tems des lecons aux voleurs?" And he replies, "Il n'y a pas grande apparence qu'ils viennent les chercher ici, et qutils en aient besoin; ils vent plus grands maltres que nous dans l'art d'ouvrir les Fortes. Apprenons donc l'art d'ouvrir les portes fermees, afin d'apprendre celui de les fermer d'une maniere qui ne laisse rien ou qui laisse peu a craindre."

Before treating of lock controversies and lock violability in England, it will be desirable first to refer to America, where this subject attracted much attention some years earlier than the Great Exhibition; an Exhibition which will always be associated in a remarkable manner with the history of locks.

Soon after the inventions by Dr. Andrews and Mr. Newell, in 1841 (described in a former chapter), the rivalry between the two locks ran high; each lock being "unpickable," according to the estimate of its inventor. Mr. Newell thought the best mode of showing the superiority of his own lock would be by picking that of his competitor; and after several trials, he succeeded in bringing into practical application that system of picking which we may designate the *mechanical,* as contradistinguished from the *arithmetical.*

Mr. Newell not only picked Dr. Andrews' lock, but he wound up the enterprise by picking his own. He was probably the first person who honestly confessed to having picked his own unpickable lock. This discovery led Mr. Newell, as has been noticed in a former page, to the invention of the triple-action or parautoptic lock.

The mechanical principle, as applied to the picking of a tumbler lock, is nearly the same whatever form of construction be made the medium of experiment. When a pressure is applied to the bolt sufficient to unlock it if the tumbler obstructions were removed, the edges of the tumbler bite or bind against the stump of the bolt, so as not to move up and down with such facility as under ordinary circumstances. By carefully trying with a small instrument each tumbler, and moving it until the bite ceases, the gating of that particular tumbler may be brought to the exact position for allowing the stump of the bolt to pass through it.

This violability is observable in the tumbler-locks under very

varied forms of construction. Mr. Newell, after he had picked his own lock, devised a series of complicated wards, to add to the difficulty of reaching the tumblers; but he could not thereby get rid of the importance of this fact, that wherever a key can go, instruments of a suitable size and form could follow: his wards did not render his lock inviolable.

His next contrivance was to notch the abutting parts of the primary and secondary tumblers, or the face of the stump and the ends of the tumblers; but this failed also. Mr. H. C. Jones, of Newark, N. J., added to all this a revolving pipe and curtain, to close as much of the keyhole as possible. But so far were all these precautions from being successful, that a lock provided with all these appendages, and affixed to the door of the United States Treasury at Washington, was picked.

The makers of locks have, each one for himself, contended against such difficulties as were known to them at the time of inventing their locks; and, mortifying as failure may be, it would be cowardly to yield up the enterprise whenever any new difficulty presented itself. Difficulties, in locks as in other matters, are made to be conquered.

To show how numerous are the sources of insecurity which have to be guarded against, to meet the skill often brought to bear upon this lock, we may adduce the reasons which led Mr. Newell to apply a curtain to the keyhole of his lock. Supposing the interior arrangement of the triple set of tumblers, and the metallic shielding wall, to be perfect, still, *if the first set of tumblers can be seen through the keyhole,* the following plan may be put in operation.

The underside of the tumblers may be *smoked,* by inserting a flame through the keyhole; and the key will then leave a distinct mark upon each tumbler the next time it is used, showing where it began to touch each tumbler in lifting it. This may be seen by inserting a small mirror hinged into the lock through the keyhole. There may even be an electric light used from a small portable battery, to illumine the interior of the lock.

By these and other means the exact length of each bit of the key may be determined; and from these data a false key may be made. It is to prevent this inspection of the works, or any other examination of an analogous kind, that the revolving curtain was applied; but, as stated in the last paragraph, even this did not suffice: ingenuity devised a mode of baffling the contrivance of

curtains as well as that of the wards and false notches in the tumblers.

When the parautoptic lock was completed, it was keenly criticized in America, owing to the long discussions respecting the merits of previous locks. In a matter of this kind, where a commercial motive would lead bankers and companies to apply a very severe test to the security of locks and similar fastenings to strong rooms and receptacles, any experiments made with their sanction became important.

Mere letters or certificates emanating from individuals, expressive of opinions concerning a particular lock, would be out of place in a volume relating to locks generally; but it is quite within the limits of the subject, and has indeed become part of the history of locks, to notice experiments and attempts of a more public character. We may therefore introduce a few paragraphs of this description, relating to the career of the American lock in America itself.

The principal bankers at Boston (U. S.) held a meeting to take into consideration measures for testing the security of bank locks. Consequent on this meeting, Messrs. Day and Newell deposited five hundred dollars with the cashier of the State Bank at Boston, to be by him paid to anyone who could pick the parautoptic lock: the trial was to be conducted under the auspices of the bank.

One of the locks was brought to the bank, and was minutely examined by two machinists on two afternoons, after which it was secured to an iron chest, and locked by a committee appointed by the bank. The key was to remain in the hands of the committee during the trial; and it was to be used at their discretion, in unlocking and locking the door, without the knowledge of either of the other parties, provided that in so doing no alteration was made in the combination-parts of the key.

Ten days were allowed to the operators for the examination and the trial; if they succeeded they were to have five hundred dollars; but if they injured the lock they agreed to forfeit two hundred, as a purchase price. At the end of the period the lock remained unopened and uninjured; and the two deposited sums were accordingly returned to the respective parties.

Messrs. Page and Bacon, of St. Louis, had a strong room lock made by one of the chief locksmiths of that city. To test its

security, the proprietors requested Mr. Hobbs to attempt to pick it; he did so, and succeeded. Whereupon the proprietors, having purchased one of the parautoptic locks deemed it no more than fair play to subject this lock to a similar ordeal, an additional zest being given by a reward of five hundred dollars offered by Day and Newell to the successful picker.

The maker of the former lock accepted the challenge; he was allowed to examine the new lock piecemeal, and was then allowed thirty days for his operations in picking. He failed in the enterprise. Of course, in this, as in all similar cases, the operator had no access to the true key.

It follows from the nature of this lock, as noticed in a former chapter, that when the bolt has been shot, if the bits of the key be rearranged in any other form, the look becomes to all intents and purposes a new lock, so far as that key is concerned, and cannot be unlocked unless the key reverts to its original arrangement.

To test this principle, a box with a parautoptic lock was placed in the room of the American Institute in 1845; it was locked; the bits of the key (12 in number) were then rearranged, and the key was placed in the hands of anyone who chose to try to open the lock, with the offer of a reward of five hundred dollars in the event of the lock being opened.

Here, instead of the operator being called upon to devise new pick-lock implements, he had the actual key placed in his hands, modified however in such a way that, though the modifier could restore the original arrangement (provided he had kept some kind of record), the operator had numerous chances against his success. The lock remained unopened notwithstanding this challenge.

We shall have occasion to show presently, that if the number of tumblers (and consequently the number of bits in the key) be small, not exceeding six, for instance, the possession of the *true* key gives any one the power of opening the lock, provided he has time and patience to go through a few hundred changes of the bits of the key; for, as some one arrangement must have been that by which the lock was locked, it must again occur if the user takes care to make *all* the arrangements in turn, and tries the lock after each.

Whether this constitutes picking a lock, each lock-owner will

decide for himself. All that it is at present meant to state is, that *without* access to the true key, the parautoptic lock has not hitherto been opened; and that *with* the true but altered key, the process of opening is possible, but is slow and tedious.

In 1846 the American Institute appointed a committee to examine into the merits of the parautoptic lock. On the 18th of September in that year the Committee made their report, signed by Professor Renwick and Mr. T. W. Harvey, as follows:

"The Committee of the American Institute, to whom was referred the examination of NEWELL'S PARAUTOPTIC BANK Lock, report that they have given the subject referred to them a careful and attentive examination, and have received full and complete explanations from the inventor. They have remarked in the lock a number of important advantages, and, in particular, very great improvements upon the permutation lock formerly submitted by him to the American Institute."

"Thus, while it retains the advantages of the permutation principle, combined with the property that the act of locking sets the slides to the particular arrangement of the bits in the skeleton key, the parts thus set are completely screened from observation, from being reached by false instruments, or from being injured by any violence not sufficient to break the lock to pieces."

"Having in the course of their inquiries examined the different existing modes in which locks may be picked, forced, or opened by false keys, the Committee have come to the conclusion that the parautoptic lock cannot be opened by any of the methods now practiced, unless by a person in possession of the key by which it was locked, in the exact form of combination in which it was used for the purpose, or in the almost impossible case of the bits being adjusted to the skeleton key by accident in that very form. As the chances of such accidental combination range according to the number of moveable bits, from several thousands to several millions to one, the Committee do not conceive that so small a chance of success would ever lead to an attempt to profit by it."

"In conclusion, the Committee feel warranted in expressing the opinion, that unless methods hitherto unknown or imagined should be contrived for the specific object, the lock in question may be considered as affording entire and absolute security."

The latest form that Messrs. Day and Newell have given to their challenge, after the experience of the last few years, is the following:

"First, a Committee of five gentlemen shall be appointed in the following manner: viz. two by the parties proposing to operate, and two by ourselves; and by the four thus appointed a fifth shall be selected."

"In the hands of this Committee shall be placed Two Thousand Dollars, as a reward to the operator if successful in picking the lock by fair means."

"We will place upon the inside of an iron door one of our best bank locks. The operator shall then have the privilege of taking the lock from the door, and have it in his possession for examination; it shall then be returned to the Committee for our inspection, so that we may be assured that it has not been mutilated or injured. The operator shall then, in the presence of ourselves and the Committee, place the lock upon the door in its original position; after which the Committee shall place upon it their seals, so that it cannot be removed or altered without their knowledge. The lock being thus secured to the door, we shall then be allowed to lock it up ourselves, upon any change of which it is susceptible."

"The time for operation to continue thirty days; and if at the end of that time he shall consider that he has made any progress towards picking the said lock, he shall have thirty days more in which to continue operations."

The Austrian report concerning the American lock was given in a former page, to which we may here refer; and then direct attention to England, and to the discussions which have lately been carried on respecting the safety of locks.

It is of course natural that each inventor of a new lock should, while describing the product of his ingenuity, point out what he conceives to be the imperfections of locks which have preceded: use has sanctioned the custom not only with regard to locks, but also in other important matters. Hence there have been many "lock controversies" in England during the last seventy years. We have seen how freely and justly the late Mr. Bramah criticized all the locks that preceded his own; and he was certainly not the man to shrink from criticism in his own case. Twenty years ago the Bramah lock was itself made the subject of criticism.

Mr. Ainger, in his lecture on the subject delivered at the Royal Institution, London, and afterwards in his article "Lock" in the *Encyclopedia Britannica,* thus narrates the circumstances which led to the adoption of the false notches in the Bramah lock as a means of security: "At length (after the original lock had acquired much celebrity,) an advertisement; appeared in the public papers, requesting those who had lost keys of Bramah's locks, not, as had hitherto been done, to break open their doors or drawers, but to apply to the advertiser, who would undertake to save this destructive process by picking. And it appeared that an individual of great dexterity could perform this operation almost with certainty.

The effect of this discovery on the demand for the locks may easily be imagined; but the effect it had in stimulating ingenuity to provide a remedy is one of the best illustrations of the proverb, that necessity is the mother of invention. Within a few days or weeks, Mr. Russell, who was at that time employed in Mr. Bramah's establishment, devised an alteration which at once, and without any expense, entirely overcame the difficulty, and converted the lock into one of perfect security. This contrivance is the most simple and extraordinary that ever effected so important an object; but before we describe it, we will endeavor to explain what has been called the *tentative* process of lock-picking, and which had been so successfully applied to Bramah's locks."

Mr. Ainger illustrates the subject by an engraving, not of an actual lock, but of a hypothetical arrangement of bolts and notches; and he then makes his reasoning apply to the actual process adopted by the picker of the real lock. "A tendency to revolve was given with some force to the barrel; then, by means of a pair of small forceps, the tumblers (sliders) were tried, and it was ascertained which one was most detained by the pressure against the locking-plate. That which offered most resistance was gradually depressed until its notch was felt to hang itself upon the locking-plate; and so on until the whole were depressed in succession, exactly as they would have been depressed simultaneously by the key."

Mr. Ainger then describes the contrivance which, in his judgment, seemed to render any further attempts to pick the Bramah lock hopeless. This consisted in cutting false notches in the sliders; so as to render it impossible for the picker to tell when he has brought a notch to the plane of the locking-plate, whether it is

a true notch, or one of shallower depth, unfitted to admit the movement of the plate."

This is a very interesting statement, for it shows that the mechanical or tentative method of opening was known in England long ago, although very little attention has been since paid to it. In a complex Bramah lock, and in locks on the combination principle, the difficulty of picking is almost insuperable, so long as what may be termed the arithmetical method is adopted. It is perfectly true, as has been so often stated, that the varied combinations in the arrangement of the slides amount to millions and even billions, when the slides are in any degree numerous; and if a person attempt to pick the lock by ringing the changes on all these combinations, it would very likely require the lives of a dozen Methuselahs to bring the enterprise to an end.

But by the mechanical method, sketched so clearly by Mr. Ainger, the exploit puts on a different aspect. The experimenter passes through the keyhole an instrument so arranged as to give a *tendency* in the bolt to withdraw in the wished-for direction; and a pressure produced in the slides by this tendency gives information concerning the state of the slides; and then comes the tentative process on the slides themselves.

Mr. Ainger was quite right in describing the false notches as an admirable addition to the safety of the Bramah lock; but he was not correct in stating that these notches rendered any further attempts on the lock hopeless. The false notches are not so deep as the true; they will permit the barrel to turn partially but not wholly round. But even supposing that the false notch had been hit upon in nearly every slide instead of the true, and that the barrel had been partially turned to the extent which these notches permitted, there would then be a binding action at the false notches different from that in the true, and this would guide the operator in his search for the true notches. It would not add a new principle different from the one before in action, but it would add to the time during which the search would have to be carried on.

We make these remarks in connection with Mr. Ainger's article, which was probably written twenty years ago. We now come to the year 1850.

At the meeting of the Institution of Civil Engineers, when Mr. Chubb's paper was read, many challenges and counter challenges were made, as to the possibility of picking certain locks. Mr.

Chubb described, among others, a lock on the patent of Mr. Davies, which, ingenious though it be, he considers not safe. Captain D. O'Brien differed from Mr. Chubb in this matter; he had had occasion to open from ten to twenty of Davies' cabinet-locks daily, during a period of two years, and he never once observed the locks to be out of order; in fact, they always appeared to afford great security. Mr. Chubb thereupon rejoined, that he was prepared to produce a workman who would pick any number of Davies' cabinet-locks, of different combinations, which he had never seen before, taking only half an hour for each lock.

As another instance, Captain O'Brien stated that, in his capacity as Inspector of Government Prisons, his attention had been much directed to the subject of secure locks; and he produced, among others, specimens of those in use at the Pentonville Prison; though not of first-rate workmanship, he characterized them as being safe, strong, and cheap. They were on Thomas's principle. The locks had been in use eight years, during which period not one had required to be replaced; and any trifling derangements had been made good whilst the prisoners were at exercise. Mr. Chubb, after making his offer concerning Davies's lock, stated that "he was willing to make the same offer with respect to the locks from the Pentonville Prison; and he might state that, in point of security, he considered them absolutely worthless; in proof of which he exhibited one of them, and a common burglar's tool, by which the lock could be opened with the greatest ease.

In respect to Bramah's lock, there was no particular challenge associated with the proceedings of the evening; but incidental observations were made as to the degree of security pertaining to it. Mr. Farey, after passing a high eulogium on the ingenuity of the principle and the beauty of the workmanship, considered it nevertheless objectionable that the sliders should be so completely exposed to view. He then proceeded to make the following observations: "It had been suggested, that a universal false key for Bramah's locks might be made, with the bottoms of its several notches formed by as many small steel sliders, extending beyond the handle of the key, so as to receive pressure from the fingers, for moving each one of the sliders within the lock, with a sliding motion in its own groove, independently of the other. During such sliding motion, a gentle force could be exerted, tending to turn the barrel round.

Under such circumstances, supposing that the motion of the barrel was prevented by any one slider only; that one, having to resist all the turning force, would be felt to slide more stiffly

endways in its groove, and therefore it could be felt when its unlocking notch arrived opposite the steel plate, and left some other slider to begin to resist the turning force.

“Such a circumstance (continues Mr. Farey) presumes a palpable inaccuracy in the radiating correspondence between the notches in the steel plate and the grooves for the sliders in the barrel, which could not happen with Bramah's workmanship.” He further remarked: "Unfortunately, if a Bramah's key fell into dishonest hands, even for a short time, an impression could be easily taken, and a false key as easily made. A turkey-quill, notched into the form of a key, had sufficed to open a Bramah's lock; and an efficient false key could be formed out of a pocket pencil-case. Such facility of fabrication was an invitation to dishonesty; and as an abortive attempt left no trace, the impunity was an encouragement to repeat the attempt until success is attained."

With respect to Chubb's locks, a discussion arose out of a statement made by Mr. Hodge. Mr. Chubb had himself stated it to be a general opinion that a skilful workman, furnished with impressions taken from the true key, in wax or soap, could make a false key to open any lock; and he considered that, in common locks, with the most elaborate wards, but with only one tumbler, as also in Bramah's locks, there was much truth in the notion.

In respect to his own lock, however, with six double acting tumblers, "a false key made ever so carefully from impressions would not be likely to open the lock, for want of exactitude in the lengths of the several steps; and if the key could not be made exact from the impressions, there would be no chance of rectifying it by trial in the lock, on account of the total uncertainty as to which part required alteration."

Mr. Hodge stated that, in America, he had repeatedly seen impressions taken of locks having twelve or fourteen tumblers, in consequence of the bellies of the tumblers, when at rest, coinciding with the form of the key. He also suggested a method of taking an impression of the bellies of the tumblers; but Mr. Chubb, Mr. Farey, Mr. Stephenson, and Mr. Whitworth, all expressed a disbelief that a Chubb's lock could be opened by the means indicated by Mr. Hodge.

Mr. Hodge admitted that he was not aware of any lock actually made by Messrs. Chubb having been picked in America; but that the locks to which he had adverted were such exact imitations, that

he had no doubt of the Chubb lock yielding to similar treatment. He further stated that there were persons in New York who would undertake to pick a real Chubb lock.

CHAPTER NINE: The Lock Controversy: During and since the time of the Great Exhibition

MASTER EXHIBIT LIST

Figure 49 Pipe key
Figure 50 Square eye

WE next come to the remarkable year 1851, which produced so many unexpected results in connection with the industrial display in Hyde Park, and conferred a lasting benefit on the useful arts and manufactures of the United Kingdom, by bringing their products into contrast and competition with those of other nations. It was to be expected that such a trial as this would afford evidences of national failure as well as of success; but probably no one suspected before the trial, that English locks, so celebrated over the greater part of the world for skilful mechanical design, beauty of workmanship, and perfect inviolability, would readily yield to a well-arranged system of lock-picking. Such, however, was the case; and we are bound to admit that Mr. Hobbs, the author of this system, is an engineer of great skill, and with a profound knowledge of the art of the locksmith.

The first step in the celebrated *lock controversy* of 1851 was taken by Mr. Hobbs himself, who declared to a party of scientific men in the Crystal Palace, that all the locks made in this country up to that date admitted of being very easily picked; and in order to explain to these gentlemen the principle upon which this was to be done, Mr. Hobbs picked one of Chubb's patent detector-locks in their presence in a few minutes.

The fairness of this experiment having been called in question by certain persons who were not present at the time when it was made, Mr. Hobbs, on July 21st, 1851, wrote a letter from the American department of the Great Exhibition, to Messrs. Chubb,

simply announcing that an attempt would be made, on the next following day, to pick a lock manufactured by them, and which was at that time on the door of a strong room in a house named by Mr. Hobbs. Messrs. Chubb were invited to be present at the operation; but no member of the firm attended.

What occurred on the day specified may best be given in the words of a letter written by those who witnessed the operation.

London, July 22 1851.

"We the undersigned hereby certify, that we attended, with the permission of Mr. Bell, of No. 34 Great George street, Westminster, an invitation sent to us by A. C. Hobbs, of the City of New York, to witness an attempt to open a lock throwing three bolts and having six tumblers, affixed to the iron door of a strong room or vault, built for the depository of valuable papers, and formerly occupied by the agents of the South-Eastern Railway; that we severally witnessed the operation, which Mr. Hobbs commenced at 35 minutes past 11 O'clock A.M. and opened the lock within 25 minutes. Mr. Hobbs having been requested to lock it again with his instruments, accomplished it in the short space of 7 minutes, without the slightest injury to the lock or door. We minutely examined the lock and door (having previously had the assurance of Mr. Bell that the keys had never been accessible to Mr. Hobbs, he having had permission to examine the keyhole only). We found a plate at the back of the door with the following inscription: 'Chubb's New Patent (No. 261,461), St. Paul's Churchyard, London, Maker to Her Majesty."

This letter was signed with the names and addresses of the following gentlemen—

Mr. Handley
Mr. T. Shanks
Mr. William Marshall
Colonel W. Clifton
Mr. W. Armstead
Mr. Elijah Galloway
Mr. G. R. Porter
Mr. Paul R. Hodge
Mr. F. W. Wenham
Mr. Charles H. Peabody
Mr. A. Shanks

Several of these names are well and publicly known in England and the United States.

This event gave rise to much newspaper controversy; and attempts were made to show that, as this was not a *test* lock, prepared expressly for challenge, the picking proved nothing as regards the finest of the manufacturers' locks. Two circumstances, however, have to be noticed: that the lock was of sufficient commercial importance to be placed on a door enclosing valuable papers, and that the makers had an opportunity to attend and witness, and comment on the trial, if they so chose.

We may here remark, that one of the ingenious contrivances of the Chubb lock, the *detector,* excited some doubt no less than fifteen years ago, as will be seen from the following. The writer of the article "Lock" in Hebert's *Engineers' and Mechanics Encyclopedia,* while speaking with much commendation of Chubb's locks, points out a curious feature, which seems to him to render somewhat doubtful the surety of the *detector* apparatus. "In Barron's and Bramah's locks," he observes, "the picker has no means of knowing whether the tumblers are lifted too high or not; but in Chubb's he has only to put the detector *hors de combat* in the first instance, by a correct thrust from the outside of the door (which might be accurately measured), so as to fix it fast in its place; the detector then becomes a stopper to the undue ascent of the tumblers, and the extent of their range is thereby correctly ascertained. Thus, it appears to us, the *detector* might be converted into a *director* of the means for opening the lock."

Much will depend on the view which is taken of the circumstance just noted. The object of the detector is not to prevent the lock from being picked, but to show that an attempt has been made to pick it; or, at least, to attain a given purpose by an indirect instead of a direct method. But if there be really any truth in the surmise that the detector actually guides a skilful hand in determining how high the tumblers should be raised, the supposed advantage will be purchased at rather a dear rate. As we are here, however, speaking of facts and not of mere opinions, it is proper to say, that the lock opened by Mr. Hobbs had the detector apparatus, but that it was not disturbed by him in picking the lock.

But instead of reiterating opinions, we will state the method by which most of the tumbler-locks made in England up to the date of the Great Exhibition can be opened or picked.

Bearing in mind the principle on which the picking of locks is said to depend, namely, that "**whenever the parts of a lock which**

come in contact with the key are affected by any pressure applied to the bolt, or to that portion of the lock by which the bolt is withdrawn, in such a manner as to indicate the points of resistance to the withdrawal of the bolt, such a lock can be picked," the first step is to produce the requisite pressure.

If the end of the bolt were exposed, this pressure might be applied by some force tending to shoot back the bolt; but as the bolt, whenever it is shot, is buried in the jamb of the door, or otherwise concealed from view, the pressure can in general only be applied through the keyhole. In order, therefore, to apply this pressure, the operator provides himself with an instrument capable of reaching the talon of the bolt, which in the case of the Chubb lock was a pipe-key of the form shown at *a b*, **figure 49**, furnished at the pipe-end with that portion of the bit of the key ***b c*** which moves the bolt (see **figure 32**, where the step which acts on the bolt is called the terminal step). The other end of the pipe-key is made square, as at ***a***, for the purpose of receiving the square eye **e** of the lever ***ef***, **figure 50**, to the further end of which **f** a weight **w** is attached by means of a string **s**.

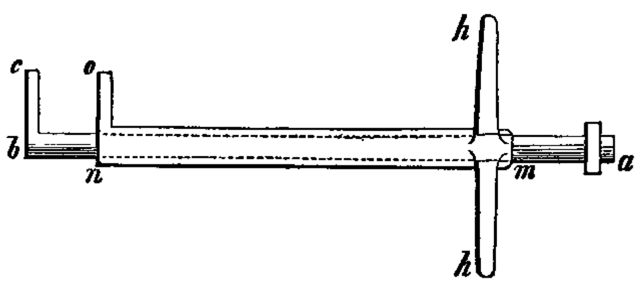


Figure 49

Now it is evident that if this pipe be introduced into the lock as far as it will go, and be turned round as in the act of unlocking, and the lever and weight be attached to the end ***a***, the bit ***b c*** of the pipe-key will maintain a permanent pressure on the bolt, which, if the weight be sufficient, will throw back the bolt as soon as the tumblers are raised to the proper height to allow the stump to pass.

The next step in the operation is to raise the tumblers to the pr
For this purpose a second pipe *mn* is made to slide upon the first

For this purpose a second pipe *mn is* made to slide upon the first
motion, and by means of the cross handle ***h h*** can be turned round or
backwards and forwards on the tube ***a b.*** This tube *m n is* also furnis
single projecting bit or step n o, corresponding with one of the
the Key, **figure 32**, and made of the proper length for entering the k

Now for the operation of opening a tumbler-lock with this simple apparatus. Referring to **figure 31**, it will be evident that if the pipe ***ab,*** **figure 49**, be passed over the pin of the lock and turned round towards the left, and the weight be attached, there will be a tendency in the bolt to shoot back, which tendency will bring the stump **s**, **figure 31**, up against the inner angle or shoulder of one or other of the tumblers, whichever happens to project, however slightly; or, as Mr. Hobbs expresses it, "one or more of the tumblers will bind."

By moving forward the pipe ***m n*** and turning round the bit **n o** in the lock, it is easy to ascertain, by delicate touch, which of the tumblers it is that binds. It may be found that all are free to move except one or two against which the stump is pressing with the force of the weight **w**, **figure 50.** The bit **n o** is therefore brought gently under the bellies of the tumblers which bind, and they are moved slightly upwards until they cease to bind.

As soon as they are set free another tumbler will bind; that is, the bolt will move through a small space, so as to bring the stump into contact with that particular tumbler which now projects; this in its turn is relieved, another tumbler binds and is relieved, and so on until the tumblers are, one by one, raised to the proper height for the stump to pass. When the last binding tumbler is raised to the proper height, the weight **w** being no longer resisted, shoots the bolt back and the work is done.

Now it must be evident that in this operation the detector apparatus need not come into operation. But if, as has been proposed, a detector-spring be added to each tumbler, it may be converted into a friend or a foe according to the use that is made of it. If the tumblers are lifted too *high,* they will be detained or detected in that position, and the operator will have to release them by turning the bit round in the opposite direction before he can begin his work again. The same force,

however, which detains the tumblers when they are lifted too high will obviously detain them when they are lifted only just high enough, and thus the detector-springs would really be of great assistance to the operator in picking such a tumbler-lock.

The apparatus which we have described for picking the tumbler-lock must be varied to suit the form of key employed in opening the lock; but it is not difficult, in the case of most locks, to ascertain this form through the keyhole, without examining the key itself

It is but fair to state in this place, that since the above method of picking tumbler-locks was made known, Mr. Chubb has added a series of teeth and notches to the stump and tumblers; the effect of which would evidently prevent the application of the above method of picking, because any permanent pressure applied to the bolt would send a tooth of the stump into a notch of the tumbler, and prevent all further motion. But recurring to the principle, that whenever the parts of a lock which come in contact with the key indicate the points of resistance when any pressure (whether *permanent or temporary)* is applied in attempting to withdraw the bolt, that lock can be picked, it follows, if this principle be admitted, that although the notches prevent the application of the form of instrument described, yet there is sufficient indication afforded by the pressure to enable a skilful operator, with proper instruments, to form a false key, as was done in the case of the lock referred to earlier.

We now proceed to the second stage in the lock controversy of 1851.

Soon after the picking of the Chubb lock in Great George street, and consequent on the excitement and discussion to which that operation led, a committee, consisting of Mr. G. Rennie, Professor Cowper, and Dr. Black, agreed to superintend the arrangements for a more severe testing of Mr. Hobbs's power to open locks. There had been for many years exhibited in the window of Messrs. Bramah's shop, in Piccadilly, a padlock of great complexity and beauty; to which an announcement was affixed, that a reward of two hundred guineas would be given to any person who should succeed in picking that lock.

This challenge was accepted by Mr. Hobbs; and the committee managed all the arrangements, as arbitrators between Mr. Hobbs on the one side and Messrs. Bramah on the other. The lock was removed to an upper room in Messrs. Bramah's establishment; where

it was placed between two boards, and so fixed and sealed, that no access could be obtained to any part of it except through the keyhole. The room was to be given up to Mr. Hobbs; he was not to be interrupted by the presence or entrance of any other persons; and he was allowed a period of thirty days for opening the lock. If the lock was not picked at the expiration of that period, Mr. Hobbs was to be considered as having failed in his attempt.

There was much negotiation and correspondence before and during Mr. Hobbs's operation on this lock. On July 2, he, with a view to this enterprise, applied for permission to take wax impressions of the keyhole. This permission being given, and the parties having met to discuss the necessary arrangements, an agreement was signed on the 19th, reciting the terms of the challenge and providing that thirty days should be allowed to Mr. Hobbs to effect his enterprise; that the lock should be secured in a certain specified way; and that the key should remain in the possession of Messrs. Bramah, who were to retain the right of using it in the lock when Mr. Hobbs was not at work. Messrs. Bramah subsequently relinquished this last mentioned privilege, in order that the trial might be perfectly fair; and it was agreed that the key should be sealed up during the whole period, beyond the reach either of Mr. Hobbs or Messrs. Bramah; and that the keyhole should be secured by an iron band, sealed, when Mr. Hobbs was not at work. These and other conditions were embodied in the agreement noticed in the last paragraph.

Mr. Hobbs commenced his labors on July 24th. After a few visits to the lock, Messrs. Bramah wished to have the privilege of inspecting it, or else that such an inspection should be made by the arbitrators; and, during a correspondence which arose out of this request, the operations were suspended. Mr. Hobbs resumed his work on August 16. On the 23d, Messrs. Bramah drew the attention of the arbitrators to the challenge, that the reward of two hundred guineas was offered to the artist who should make an instrument that would pick or open the lock; that he was to be paid the money on the production of the instrument; and that, unless some person were present, it was impossible that any one could know that the lock had been opened by the instrument which might be produced. This letter was not allowed by the arbitrators to affect the arrangements made. We may now consistently give the "Report of the Arbitrators."

"Whereas for many years past a padlock has been exhibited in the window of Messrs. Bramah's shop, in Piccadilly, to which was appended a label with these words: 'The artist who can make an

instrument that will pick or open this lock shall receive two hundred guineas the moment it is produced'; and Mr. Hobbs, of America, having obtained permission of Messrs. Bramah to make trial of his skill in opening the said lock, Messrs. Bramah and Mr. Hobbs severally agreed that George Rennie, Esq., F.R.S., of London; and Professor Cowper, of King's College, London; and Dr. Black, of Kentucky; should act as arbitrators between the said parties."

"That the trial should be conducted according to the rules laid down by the arbitrators, and the reward of two hundred guineas be decided by them; in fine, that they should see fair play between the parties."

"On July 23 it was agreed that the lock should be enclosed in a block of wood, and screwed to a door, and the screws sealed, the keyhole and the hasp only being accessible to Mr. Hobbs, and, when he was not operating, the keyhole was to be covered with a band of iron and sealed by Mr. Hobbs, that no other person should have access to the keyhole. The key was also sealed up, and was not to be used until Mr. Hobbs had finished his operations. If Mr. Hobbs succeeded in picking or opening the lock, the key was to be tried; and if it locked and unlocked the padlock, it should be considered as a proof that Mr. Hobbs had not injured the lock, but had fairly picked or opened it, and was entitled to the two hundred guineas."

"On the same day, July 23, Messrs. Bramah gave notice to Mr. Hobbs that the lock was ready for his operations."

"On July 24, Mr. Hobbs commenced his operations; and On August 23, Mr. Hobbs exhibited the *lock opened* to Dr. Black and Professor Cowper (Mr. Rennie being out of town). Dr. Black and Mr. Cowper then called in Mr. Edward Bramah and Mr. Bazalgette, and before them the lock was opened; they [the last-named two gentlemen are of course meant] then withdrew, and Mr. Hobbs locked and unlocked the padlock in presence of Dr. Black and Mr. Cowper."

"Between July 24, and August 23, Mr. Hobbs's operations were for a time suspended; so that the number of days occupied by Mr. Hobbs was sixteen, and the number of hours he was actually in the room with the lock was fifty-one."

"On Friday, August 29, Mr. Hobbs again locked and unlocked the padlock in presence of Mr. G. Rennie, Professor Cowper Dr.

Black, Mr. Edward Bramah, Mr. Bazalgette, and Mr. Abrahart."

"On Saturday, August 30, the key was tried, and the padlock was locked and unlocked with the key, by Professor Cowper, Mr Rennie, and Mr. Gilbertson; thus proving that Mr. Hobbs had fairly picked the lock without injuring it. Mr. Hobbs then formally produced the instruments with which he had opened the lock."

"We are, therefore, unanimously of opinion, that Messrs. Bramah have given Mr. Hobbs a fair opportunity of trying his skill, and that Mr. Hobbs has fairly picked or opened the lock; and we award that Messrs. Bramah and Co. do now pay to Mr. Hobbs the two hundred guineas."

GEORGE RENNIE, *Chairman*. EDWARD COPPER. J. R. BLACK.
Holland Street, Blackfriars, Sept. 2, 1851."

"It may be here stated, in reference to the space of time during which the operations were being conducted, that the actual opening of the lock occurred much earlier, so far as concerned the principle involved, though not in a way to meet the terms of the challenge. On his fifth visit, Mr. Hobbs succeeded in adjusting the slides and moving the barrel, preparatory to withdrawing the bolt; but the instrument with which the barrel was to he turned round, being too slight, slipped, and defeated the operation. Mr. Hobbs had then to readjust the barrel, and to make a new instrument to aid him; this new instrument, when completed, enabled him to open the lock in the space of an hour or two."

"On the same day Messrs. Bramah addressed a letter to the arbitrators, stating the reasons which induced them to think that, though Mr. Hobbs had succeeded in opening the lock, the manner of doing so did not come within the meaning of the challenge originally made by them. The arbitrators, however, were unanimous in their award, and Messrs. Bramah bowed to it."

"In an article written in one of the daily newspapers immediately after the opening of the lock, the following notice was given of the lock and its production: "We were surprised to find that the lock which has made so much noise in the world is a padlock of but 4 inches in width, the body of it 1 ¼″ thick, and its thickness over the boss, 2 ¾″."

"Upon opening the outer case of the lock, the actual barrel enclosing the mechanism was found to be 2 ¼″ in length and 1 ½″

in diameter. The small space in which the works were confined, and its snug, compact appearance was matter of astonishment to all present. The lock and key were made forty years since by the present head of the eminent firm of Messrs. Maudslay and Co., Mr. Maudslay being at that time a workman in the employ of Mr. Bramah."

We may here remark, as indeed has been remarked in former pages, that the Bramah lock is, and will probably continue to be, deservedly celebrated for the amount of mechanism contained in a small space, as adverted to in the last paragraph. The cylindrical form is well calculated for this concentration of power within narrow limits; and the smallness of the key is a great merit.

The objections made by Messrs. Bramah to the award of the committee were embodied in the following letter to Mr. Rennie, dated 9th September:

"DEAR SIR, WE beg to acknowledge your letter of yesterday's date, and will not trouble you to attend here tomorrow, but beg to hand you the 210£ awarded by the arbitrators to Mr. Hobbs. We need scarcely repeat that the decision at which the arbitrators have arrived has surprised us much; and we owe it to ourselves and the public to protest against it. We do so for the following reasons:

1. Because the arbitrators, having been appointed to see fair-play, and that the lock was fairly operated upon, did not, although repeatedly requested in writing to do so, once inspect or allow anyone to witness Mr. Hobbs's operations during the sixteen days he had the sole custody of the lock and was engaged in the work.

2. Because the arbitrators did not once exercise their right of using the key, although repeatedly requested in writing to do so, until after Mr. Hobbs had completed his operations; and then, instead of applying at once to prove that no damage had been done to the lock, allowed him twenty-four hours to repair any that might have occurred.

3. Because the lock being opened by means of a fixed apparatus screwed to the woodwork in which the lock was enclosed for the purpose of experiment (which it is obvious could not have been applied to an iron door without discovery), and the addition of three or four other instruments, the spirit of the challenge has

evidently not been complied with.

4. Because from the course adopted an opportunity of some good scientific results has been taken from us; as neither arbitrators nor anyone else saw the whole or even the most important instruments, by which it is said the lock was picked, actually applied in operation, either before or after the lock was presented open to the arbitrators.

5. Because during the progress of Mr. Hobbs's operations, and several days before their completion, we called the attention of the arbitrators to what we considered the interpretation of the challenge, begging at the same time that they would apply the key and appoint someone to be present during the residue of the experiment; feeling that whatever might be the result in a scientific point of view, the reward could not be awarded.

"We would add, that we think that several points which appear in your minutes should not have been mentioned in your award; more especially that Mr. Hobbs on the 2nd of June took a wax-impression of the lock, and had made, as far as he could, instruments therefrom between that date and the commencement of his operations.

"We are, dear sir, Your obedient servants,
BRAHAM AND CO."

In order that the opinions of Messrs. Bramah and others may be given with as much fairness as possible, on a matter which they could not feel but otherwise than important to them, we may state, that among the letters to which the picking of the Bramah lock gave rise in the public journals, was the following addressed to the *Observer* newspaper on 10th October:

"SIR, This controversy having excited an unusual degree of public attention for some time past, perhaps you will be good enough to allow us to state in your journal, that the lock on which Mr. Hobbs operated had not been taken to pieces for many years, and it was only on examining it (after the award of the committee) that we discovered the startling fact, that in no less than three particulars it is inferior to those we have made for years past. The lock had remained so long in its resting-place in our window that the proposal of Mr. Hobbs somewhat surprised us. After his appearance, however, no alteration could of course be made without our incurring the risk of being charged with preparing a test-lock for the occasion. We were therefore bound

in honor to let the lock remain as Mr. Hobbs found it when he accepted the challenge.

No one inspected his operations during the sixteen days he had the sole custody of the lock and was engaged at the work. We are therefore compelled to advertise another 200 guineas, in order that we may see the lock operated upon and opened, if it be possible; and thus gain such information as would enable us to use means that would defy even the acknowledged skill of our American friends.

We believe the Bramah lock to be impregnable; and we cannot open it ourselves, with the knowledge Mr. Hobbs has given us. We have fitted up the same lock with such improvements as we now use, and some trifling change suggested by the recent trial, and restored it with its challenge to our window. We have not done this in a vain, boasting spirit; on the contrary, we feel it rather hard that, from the way in which the former trial was conducted, we are driven to adopt this course. Had anyone inspected Mr. Hobbs's operations during that trial it would not have been necessary.

"We are, sir, &c.,
BRAMAH AND CO."

Messrs. BRAMAH are well entitled to offer any explanation concerning the relative perfection of the lock in question, and of one that they could now produce with certain improvements in some parts of the working mechanism; but if these improvements do not involve any new invention, patented or otherwise, that is, if the lock be really a carrying out of the contrivances already made public, it is difficult to see why it should not yield to the same treatment as the other. It is true that, shortly after the decision of the arbitrators, Messrs. Bramah exhibited a new lock in their window, and repeated their challenge in the same terms as before, with the single addition, that applications were to be made in writing only. We have reason to know that an application was made, and that the consequence was the withdrawal of the challenge. In respect to the actual contest, however, the character and position of the arbitrators ought surely to hold Mr. Hobbs justified in his proceedings. They were not all Americans (supposing nationality to give a bias in the matter); two were Englishmen, both of distinguished rank in respect to mechanical knowledge; and as Mr. Hobbs was as much bound by their decision as Messrs. Bramah, he was entitled to claim any advantage resulting from a favorable decision.

The following is a description, so far as can be given in words, of the mode in which Mr. Hobbs operated on the Bramah lock. The first point to be attained was to free the sliders from the pressure of the spiral spring; the spring was very powerful, pressing with a force of between 30 and 40 lbs.; and until this was counteracted, the sliders could not be readily moved in their grooves. A thin steel rod, drilled at one end, and having two long projecting teeth, was introduced into the keyhole and pressed against the circular disc between the heads of the sliders; the disc and spring were pressed as far as they would go. In order to retain them in this position, a curved stanchion was screwed into the side of the boards surrounding the lock, and the end brought to press upon the steel rod, a thumb-screw passing through the drilled portion of the instrument and keeping it in its place. The sliders being thus freed from the action of the spring, operations commenced for ascertaining their proper relative positions.

A plain steel needle, with a moderately fine point, was used for pushing in the sliders; while another with a small hook at the end, something like a crochet-needle, was used for drawing them back when pushed too far. By gently feeling along the edge of the slider, the notch was found and adjusted, and its exact position was then accurately measured by means of a thin and narrow plate of brass, the measurements being recorded on the brass for future reference. The operator was thus enabled, by this record, to commence each morning's work at the point where he left off on the previous day. The lock having eighteen sliders, the process of finding the exact position of the notch in each was necessarily slow.

Mr. Hobbs employed a small bent instrument to perform the part of the small lever or bit of the key; with this he kept constantly pressing on the cylinder which moved the bolt. He thus knew that if ever he got the slide-notches into the right place, the cylinder would rotate and the lock open. He could feel the varying resistance to which the sliders were subjected by this tendency of the cylinder to rotate; and he adjusted them one by one until the notch came opposite the steel plate. The false notches added, of course, much to his difficulty; for when he had *partially* rotated the cylinder by means of the false notches, he had to begin again to find out the true ones.

This description accords pretty nearly with that given in a former page; but we reproduce it here to show not merely what might be the process adopted, but what really *has been* done. One

circumstance ought at least to be noted in these transactions: there is no mystery; the method adopted is the result of a process of reasoning candidly and openly explained.

In justice to Messrs. Bramah we thought it our duty to give them an opportunity of stating what improvements they had made in their locks since the date of the Great Exhibition; and accordingly, on the 28th April, 1853, our publisher addressed to Messrs. Bramah a note, stating that a *Rudimentary Treatise on the Construction of Locks* was being prepared, and inviting them to contribute thereto. The following is a copy of their reply:

"124 Piccadilly, May 2nd, 1853.

"SIR, Pressure of business has prevented our sending an earlier reply to your favor of the 28th July.

"The lock on which Mr. Hobbs operated during the Great Exhibition had been made nearly forty years, and when taken to pieces the sliders were found to be in iron, instead of steel; and the keyhole of the lock being three times larger than it ought to have been, enabled the operator to fix down the spring of the lock, and yet leave himself ample space to turn and bend the sliders (being in iron) at pleasure."

"The barrel of the lock in which the sliders act, instead of being whole length from front to back of padlock, was not quite half its proper length; a serious oversight in the workman who put the lock together, as the barrel being short, the sliders were necessarily so, which diminished the number of notches in the sliders full one-half, and to that extent diminished the security of the lock, and increased the facility of the operator."

"We send for your inspection a box of guards, which will show you the barrel and sliders of our Bramah lock. You will observe several notches in each slider, only one of which will turn on the locking-plate, the others being what are termed false, or security ones. These notches being out only the exact width of the locking-plate, require the most perfect accuracy to carry each down to its proper distance."

"In the lock on which Mr. Hobbs operated, in addition to the sliders being so short, and only half the number of security-notches in each, the notch which passed round the locking-plate was found to be cut twice the width it ought to

have been. The whole of these defects have been corrected since the Exhibition."

We are, Sir, yours respectfully,
"BRAMAH and Co." per J. Smyth.
"To John Weale, Esq., 59 High Holborn.'

In the Jury Report of the Great Exhibition, Class XXII., are the following remarks: "On the comparative security afforded by the various locks which have come before the jury, they are not prepared to offer an opinion. They would merely express a doubt whether the circumstance that a lock has been picked under conditions which ordinarily could scarcely ever, if at all be obtained, can be assumed as a test of its insecurity." The conditions here alluded to probably refer to the free access which Messrs. Bramah allowed Mr. Hobbs to have to their lock during a period of thirty days, and we are hence led to infer that the burglar is denied any such facilities. On this point we would refer to the opinion of a high authority.

In a paper "on the History and Construction of Latches and Locks," by Mr. Chubb, read before the Society of Arts, 22d. 1851, the following graphic passage occurs:

"In order to show the absolute necessity of secure locks and safe depositories for property, especially in banking establishments, it may not be out of place to trace the systematic care and great sagacity with which the large burglaries are planned. You will bear in mind that an unsuccessful attempt is seldom made where the booty is of any magnitude. The first-rate 'cracksmen' always know beforehand where to go, when to go, and what they are going for."

"When a 'plant,' as it is termed, is made upon a house or a bank, precise information is gained, if possible, as to the depository of the valuables; and if it is found that the safeguards are too strong in themselves, and that the locks are invulnerable, the affair is quietly dropped. But if otherwise, then no expenditure of time or misapplied ingenuity is spared to gain the desired end."

"The house is constantly watched, the habits of its inmates are observed, their ordinary times of going out and coming in are noted; the confidential servants are bribed or cajoled, and induced to leave the premises when their employers are absent, so that impressions may be taken from the locks, and false keys

made. When all the keys required are made, one or two men who have not been previously initiated are generally called in, and receive their instructions to be ready at a certain hour on the following day to enter the house. A plan of the premises is put into their hands, they are cautioned to step over a certain creaking stair or plank, and the keys of the different doors are given them. The day or evening is chosen when it is known that the inmates will be from home; the servant, taking advantage of their absence, fulfils a long-standing engagement with his new and liberal friends. A signal is given—the two confederates enter—the so-called safe is swept of its contents, all the doors are carefully relocked and not until the bank is opened for business next morning is the robbery discovered."

In an article in *Frazer's Magazine* for November 1852, the following observations were made on the Exhibition Jury Report on Locks: "This jury seems to have consisted of the only persons in England who did not hear of the famous 'lock controversy' of last year; for one can hardly imagine that, if they had heard of a matter of so much consequence to the subject they were appointed to investigate, they would have altogether abstained from saying anything about it."

"They may be excused for not knowing, because very few people did know, fortunately for our safes and strongboxes, that the mode of picking Bramah's and Chubb's locks, by which the transatlantic Hobbs gained so much glory, was suggested and explained in the *Encyclopedia Britannica* nearly twenty years ago. But it does seem very strange that they, or at least their reporter, should not have known, long before the Report finally left his hands, that Hobbs had picked both of those locks, and taught every lock-picker in England how to do it, if he possesses the requisite tools and fingers."

"Of course, however, the reporter did not know it, as nobody could read any newspaper last autumn without knowing it. And this jury did exercise their judgment to the extent of declaring that Hobbs's own lock (under the name of Day and Newell) 'seems to be impregnable.' Notwithstanding all which, they express their inability to 'offer any opinion on the comparative security afforded by the various locks that have come before them.'"

"The only discrimination which they venture to make is, that the keys of Bramah's and Chubb's locks are of convenient size, while Hobbs's is ponderous and bulky, and his lock complicated; and they might have added (without any very painful amount of

investigation), enormously expensive, in consequence of its complication, and probably also more likely, on the same account, to get out of order and stick fast, and so become rather inconveniently impregnable, on the money door of a bank, for instance, than the other two locks, especially Bramah's."

"In relation to the opinion just given, it may be remarked that the American lock has shown no tendencies to get out of Order; if well constructed (and good construction is a *sine qua non* in such mechanism), the parts work into and upon each other with very little friction. In respect to expense, and to the size of the key, a bank-lock is not one in which economy would be much studied, security being the great desideratum."

"No attempt is made to produce a parautoptic lock of small size or for cheap purposes. The lock, therefore, must be judged of with reference to what it undertakes to perform. And this brings us to notice the attempts made in England to pick the parautoptic or American bank-lock."

"The following were the circumstances connected with Mr. Garbutt's attempt to pick the American lock. It is of course known that a challenge was affixed to the American lock in the Great Exhibition, and it was this challenge which Mr. Garbutt accepted. Mr. Garbutt, it may be here observed, was a working locksmith and engineer; he had been entrusted by Messrs. Fox and Henderson with the care and adjustment of the metal check-tables at the pay-places of the Crystal Palace; he had at a previous period been in the employ of Messrs. Bramah."

"We mention these facts only on account of an erroneous rumor at the time that he was an agent of Messrs. Bramah in respect to the acceptance of the American challenge; whereas we believe he acted independently, by and for himself."

"On Sept. 10th, 1851, Mr. A. H. Renton, Mr. E. H. Thomson, and Mr. W. F. Shattuck, the first an engineer, and the other two American exhibitors, were appointed arbitrators to superintend the arrangements, and they met Mr. Garbutt and Mr. Hobbs at the house No. 20 Knightsbridge."

"The following conditions were agreed to: That a Newell lock should be selected, and should be screwed to a wooden box; that Mr. Garbutt should have access only to the keyhole of the lock, through which keyhole all his operations for picking the lock should be conducted; that Mr. Garbutt should have uninterrupted

and exclusive access to the box, between the hours of nine in the morning and nine in the evening for thirty days, beginning on the 11th of September, he having during that time the privilege of introducing one associate, and the arbitrators reserving to themselves the right of inspecting the seals placed by them on the box; that, in order to afford every information concerning the internal arrangement of the lock, the trial-lock should be taken to pieces in presence of all the parties; that it should be examined by Mr. Garbutt; that it should be locked and unlocked with the proper key by him and by Mr. Hobbs; that it should be fastened to a box, and the fastenings sealed by the arbitrators; that the key, when the lock was finally locked, should be sealed up by the arbitrators and delivered to Mr. Hobbs, who would retain it until required by the arbitrators to hand it over to them."

"That at the expiration of the thirty days, or earlier in case either of the success or the abandonment of the attempt, the arbitrators should examine the lock. And, finally, that if Mr. Garbutt should have succeeded in picking the lock (that is, in withdrawing the bolt without injuring the lock), the sum of 200£ should be paid to him by Mr. Hobbs."

"In accordance with the above agreement, Mr. Hobbs produced a parautoptic lock, with ten tumblers marked No. 8560. The key and the lock were examined by Mr. Garbutt. The lock was again put together, affixed to a box, and sealed. Mr. Hobbs set the bits of the key (ten in number) to an arrangement chosen by himself, and the lock was then locked by all parties in succession; the key, after the final locking, being sealed up and returned to Mr. Hobbs. Mr. Hobbs at the same time delivered to Mr. Garbutt a similar but smaller lock, which he was to be allowed to retain during the whole period of the trial, to assist in rendering him familiar with the construction of both locks."

"On the 11th of October, the day on which the prescribed period expired, the arbitrators met at the house in question, when Mr. Garbutt delivered up to them the lock uninjured, but *unopened.* The award of the arbitrators was thereupon given in the following terms: "We therefore hereby certify that Mr. Garbutt having had uninterrupted and exclusive access to the lock during the period of thirty days, and, availing himself of the conditions of the agreement, had every facility for opening the lock that could be obtained without possession of the true key, has delivered up the same into our hands unopened and uninjured; and the said lock has been delivered by us to Mr. Hobbs."

It will of course be understood that it was one condition of this enterprise, that the particular combination of bits in the key wherewith the lock was finally locked should not be seen by Mr. Garbutt. The key was in the first instance tried by Mr. Garbutt and by the members of the committee, and was found to turn readily in the lock; Mr. Hobbs then left the room; and rearranged the bits of the key so as to produce a new combination; he then returned to the room, and locked the lock with the key in its altered form; he allowed all present to feel the key turn freely, and then, without allowing anyone to see the combination, wrapped the key up in paper, in which it was sealed as above described. Whether Mr. Garbutt, or anyone, could have succeeded better by a momentary glance at the arrangement of the key, was not at that moment the question: the terms of the challenge were that he should *not* see it. What are the circumstances likely to occur if the operator really has access to the key (provided the bits are not very numerous) we may shortly explain.

It is necessary to draw a distinction between *picking of a lock* and ringing *the changes on a permutating key;* otherwise some of the late occurrences connected with locks can hardly be understood.

After the reading of a paper by Mr. Hobbs before the Society of Arts, a discussion arose, in which it was stated that the Newell lock had been picked in London. Mr. Hobbs deemed it necessary to refute this statement. The report was circulated in many of the London newspapers; and Mr. Jeremiah Smith, the operator in question, supported it by his own statement. Under these circumstances Mr. Hobbs, on April 2, 1852, addressed a letter to the editor of the *Observer;* of which the following paragraph was intended to point out the distinction above mentioned between "picking" and "ringing the changes."

"Early last autumn I lent to Mr. Potter, of South Molton Street, one of my locks, for the purpose of giving him an opportunity to make himself acquainted with its principle and construction. After he had had the lock in his possession several weeks, a report reached me that one of Mr. Potter's workmen had picked my lock. I immediately called on Mr. Potter to ascertain the fact. Mr. Potter informed me that for the purpose of testing the possibility of opening the lock by means of an impression taken, or a copy being made of the true key, Mr. Smith had made a copy of the key by means of a transfer instrument, which instrument he showed me at the time. After the key was made, it

was tried, and found to lock and unlock the lock as readily as the original key. Mr. Potter then sealed the screws of the lock, changed the combination of the key, and locked it."

"Mr. Smith then took the lock, and with the key that he had made by copying the original, hit the combination, and unlocked it. The lock was of the smallest size, having but six tumblers; the number of changes that could possibly be made were 720. The time occupied by Mr. Smith, according to his own statement, was six hours and fifty-five minutes; this, allowing one minute for each change, would give him time to have made 415 out of the 720 changes before hitting the right one. I asked Mr. Smith why he did not use the original key instead of making a copy? His answer was, that 'he could change the one he made faster, as he did not have to screw the bits in.' Any person will readily understand the difference between ringing the combination of a key and picking a lock."

In other words, the process was this: the operator had the true key, and might have used either this or one which he made from it. This would have sufficed for opening almost any lock ever constructed instantly; but in the American lock he had to find out which of 720 combinations was the right one, and he was employed almost seven hours in doing this. The exploit showed patience, but had little bearing on the practical subject of lock-picking.

In March 1852, Mr. Smith put forth an offer to accept the challenge made by Mr. Hobbs in respect to the Exhibition lock. Mr. Hobbs agreed to the offer, and chose, as arbitrators on his part, Mr. Hensman, Engineer to the Bank of England, and Mr. Appold, inventor of the centrifugal pump which attended so much attention at the Great Exhibition.

Mr. Hobbs requested Mr. Smith to appoint arbitrators on his side also; but this was not done. Mr. Smith, at a meeting held by the four persons named, expressed a wish that an ordinary commercial lock should be the one experimented on, instead of the more complicated test-lock which had been at the Great Exhibition.

This was a departure from the terms of the original challenge; but Mr. Hobbs waived his objection on this point, and offered to substitute a bank-lock with ten tumblers for the Exhibition lock with fifteen, the former being similar in construction but less complex. Another meeting was agreed upon, but Mr. Smith did not attend; and the matter was, by himself, brought to a sudden

termination.

To show the effect of difference in the number of tumblers and key-bits, we may state that, while, at a minute per change, it would take twelve hours to go through all the combinations with a six-bitted key, it would require seven years with a ten-bitted, and 2,500,000 years with a fifteen-bitted key! So much for power of combination, in the arithmetical mode of picking.

We now proceed to notice the violability of sundry minor locks. It might at first appear that the *letter-lock is* exceedingly difficult to pick; and so it unquestionably is, as long as we merely attend to the chance medley trials by turning the rings round and round until we happen to hit upon the right combination. But there is another mode of solving the riddle, mechanical rather than arithmetical. A piece of common wire, bent in the form of the shackle, is put in between the ends of the lock; the spring or elasticity of the wire tends to force the ends apart; this causes the pins or studs on the rod to press against the inner edges of the rings.

By trying all the rings in succession, some one of them will be found to bind or cling more than the others; this is turned round until the cessation of the bind shows that the notch in the ring has been brought into its right position relatively to the pin on the rod. Then another ring which binds more than the rest is treated in a similar way; until at length all the rings seem to be so far liberated as to indicate that the notches are in the right positions. In the dial-lock, similarly, when a pressure has been brought to bear upon the bolt in the right direction, a trial of the pointers will soon bring the notch in each wheel to the required position.

Some short time after the events in London connected with the lock controversy, Mr. William Brown of Liverpool described the letter-lock noticed in a former page, characterizing it as a lock which he believed no one could pick. An incident in the history of this lock was thus narrated in one of the Liverpool newspapers. "Mr. Hobbs was taken by Mr. Milner to the office of Messrs. Brown, Shipley, and Co., and shown this lock. The safe-door was closed and locked by the cashier at Mr. Brown's request; and then Mr. Hobbs began to illustrate his views of the construction of the lock by manipulation and explanation, with which the subject of them appeared to sympathize so entirely and promptly that the door opened in a few minutes."

In respect to the picking of the Egyptian lock, the main difficulty would be in obtaining any false key that would correspond with the pins of the lock; but this might be accomplished in a way analogous to that which is practiced in many other cases. If a small piece of wax be laid on a blank key, the key inserted into the lock, and the blank pressed upwards against the pin-holes, there would be left an impression of those holes on the wax; this impression would furnish a guide to the fabrication of a false key. There is also very little difficulty in picking this lock by one of the ordinary instruments.

For the Yale lock, combining something like the pin-action of the Egyptian with the cylinder-action of the Bramah locks, the picking requires the use of an instrument that will fit between two of the pins, and to the outer end of which is attached a lever and weight; by this means a pressure is exerted upon the cylinder in the right direction for it to turn, and the pins are made to bind.

Then, with another instrument, the pins are felt, and each one moved until it seems to be relieved from the bind: this indicates that the joint in the pin coincides with the joint between the two cylinders; and when all have been similarly treated, the weight acting on the inner cylinder will turn it. It is evident that this method is the same in principle as the one applicable to the Bramah lock.

CHAPTER TEN: Effects of the Great Exhibition of 1851 in Improving English Locks

MASTER EXHIBIT LIST

Parnell's Lock
Denison's Lock
Chubb Barrel and curtain lock
Chubb tumbler-bolt lock
Chubb bank-lock

Aubin's lock
Hobbs Protector lock
Saxby lock
Yale lock

WE have now to refer to the effects of the lock controversy. It was no doubt annoying to be told, on good authority, that the machines on which we so much prided ourselves were wrong in principle; and that our locks, in order to afford the degree of security which are expected of such contrivances, must be reconstructed. The grumbling with which the first part of this proposition was received would alone have sufficed to lead to a suspicion of its truth, if the large number of new locks that have actually appeared had not confirmed it. Whether the second part of the proposition has been fairly carried out, is a point that must now be considered.

One of the first locks produced during or immediately after the lock controversy was Mr. Parnell's, to which the bold term *of patent defiance lock is* attached. This lock is said to depend for its security on a mode of arrangement which may best be described in the inventor's own words:

"Viewing the lock from its exterior, it presents nothing remarkable; but, upon removing the plate, it will be seen that all possible access to the mechanism with false or surreptitious keys is effectually prevented by a solid cylinder of *hardened [?] brass,* with protecting wards extending the whole depth of the lock, and having in the center the aperture for the key, which fits to a mathematical nicety so exact as to preclude the possibility of any second instrument being used to open it."

"This protecting cylinder must revolve with the key to get to the works; and the moment it passes from the keyhole in going round to lock or unlock, the solid portion moves into its place, and so completely closes that aperture that the point of a pin, or a fine steel-pen, has failed to be inserted between it and the outer plate or cap, to say nothing of the utter hopelessness of perforating the metal."

"The cylinder or protecting cap, though it revolves by the action of the key somewhat in the same way as the cylinder of the Bramah lock, appears to be intended rather for closing or protecting the keyhole than for governing the movements of the bolt."

"The internal arrangements of the lock are as follow: Supposing the bolt to be shot, and to be about to be unlocked, the key, by the time it has made about one-third of a rotation, meets with a forcible resistance in the shape of an upright spring-bolt or detector of strong steel acting on the revolving cylinder. The key passes this detector, and arrives at the levers or tumblers. In the bolt-stud which works in the slot of these tumblers there is a small deep serrated notch on one side, corresponding to similar notches on each of the tumblers; if, therefore, the bolt be forced, these notches would lock into each other in a similar manner to the catch on a ship's windlass or a hoisting crane."

"There is also a double-action tumbler-bolt, so adjusted, that if any of the tumblers be over-lifted, this little appendage becomes thrust down at one end into the bolt of the lock, where it wedges all fast until the tumblers become properly readjusted. The double-action tumbler-bolt also falls into the lock-bolt when the latter is locked or shut, thereby imparting an additional strength to the lock."

"The key has a power of expansion or enlargement while turning in the lock; it meets with an eccentric plate which draws out the bits somewhat; so that, at the moment of acting on the tumblers, they protrude farther from the pipe of the key than when the key entered the keyhole. The key is, in fact, larger when in than when out of the lock. There is connected with the works of the lock a detention-cap so formed that, in the event of a false key being used, a powerful bolt instantly locks into the revolving cylinder, and holds fast the surreptitious instrument."

Such is, in substance, the account which Mr. Parnell has given of his own lock. It must, however, be stated, that the points of security or novelty claimed by Mr. Parnell for his lock were patented by previous inventors. The revolving cylinder or curtain was claimed by Mitchell and Lawton in the patent of 7th March, 1815, as noticed earlier in this book. The expanding key-bit was claimed by Mr. Machin of Wolverhampton in 1827, and by Mr. Mackinnon; while the serrated notches in the tumbler were used by many lock-makers long before the date of Mr. Parnell's patent. The detention-cap for catching and holding a false key when put into the lock was also patented by Mitchell and Lawton.

We come now to notice a lock lately invented by Mr. E. B. Denison (the author of the *Rudimentary Treatise on Clocks* in this series), which has the merit of combining considerable novelty in

construction with security. After the details given in the two preceding chapters, it will certainly be no small praise when we express our conviction that in the present state of the art of lock-picking, this lock may be considered as secure. Mr. Denison has furnished us with a description of his lock, which we insert almost in his own words.

Mr. Denison claims for this lock the following advantages:

1. **That a very large and strong lock on this construction only requires a very small key.**
2. **That no key is required to lock it, although it is free from the inconvenience pertaining to spring-locks, viz. that the door cannot be shut without locking itself. Moreover this lock is more secure than any spring-lock can be.**
3. **That it cannot get out of order from the usual causes of the tumblers sticking together or their springs breaking, inasmuch as the action of the tumblers does not depend on anything but the key and the handle, and there are no tumbler-springs.**
4. **That for the same reason, the parts of this lock do not require any polishing or delicacy of execution.**
5. **That the keyhole being completely closed by a curtain, except when the key is in, the lock is protected from the effects of the atmosphere and dust entering at the keyhole.**
6. **That this lock is secure against any known mode of picking; the smallness of the keyhole prevents the insertion of any instrument strong enough to open the lock by violence.**
7. **That this lock, from the simplicity of its construction, admits of being made at small cost.**

These objects are accomplished as follows:

In **the large sized** locks, such as would be used for safes and large doors, the tumblers **T. figure 51**, are made of pieces of hoop-iron, six or seven inches long and twelve inch wide: these tumblers are supported by and turn on a pin **a**, placed at about the middle of their length; so that being balanced on the pin, or nearly so, and having their separating plates **p** between them which cannot turn, the tumblers will stand in any position indifferently; and in order to secure sufficient friction to keep them steady, one or more of the separating plates **P** is bent a

little, so as to act as a spring when the cap of the lock is screwed down.

The lock is shown in **figure 51** as locked, the bolt **B** having been shot by the fantailed piece **f** on the handle, and the tumblers sent down, so that the stump s cannot enter their jaws by the other piece of the handle; and it is evident that the handle cannot draw the bolt back again until the tumblers have all been raised by the key to the proper position to allow the stump s to enter their jaws.

It will be observed that in the position shown in the figure, the stump does not touch the tumblers; and consequently, so long as the bolt is kept in the position represented, no pressure of the stump against the tumblers can be felt, although by means of a false key or pick-lock the tumblers can be raised to any height.

No implement, however, can be pushed into the keyhole without first pressing in the curtain **x**, which is held up against the cap of the lock by the two spiral springs **c c** on each side of the keyhole; and at the back of the curtain there is a square plug **p** which goes through a hole in the back of the lock, and has a notch in it through which the bolt can pass when the curtain is up, closing the keyhole, but at no other time.

In other words, the act of pushing in the key sends down the curtain plug, the effect of which is to hold the bolt fast in the position in which the stump cannot be made to touch the tumblers. If the proper key is used and turned about half round to the right, it will bring the tumblers to the proper height for the stump to pass. The key is then taken out; for so long as it is in the lock, the bolt cannot be moved; and then turning the handle to the right, the bolt is drawn and the door opened.

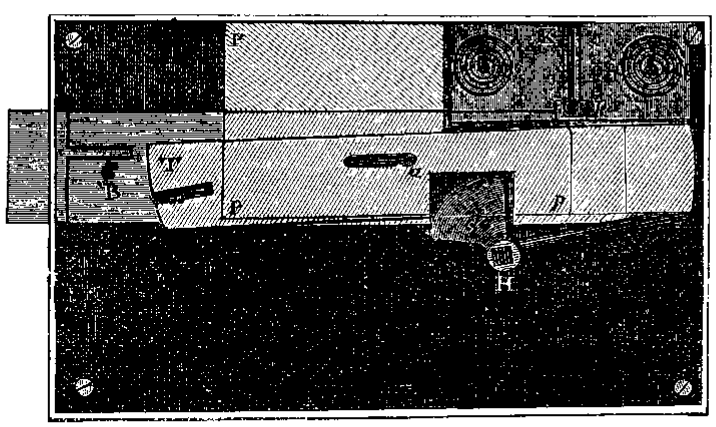


Figure 51 Mr. Denison's large lock.

The handle **H** should be so made, that as soon as the fantailed piece has sent the bolt just clear of the tumblers, the other arm to the right of **H** may begin to move the tumblers; but the fantail need not send the stump above one-sixteenth of an inch beyond the tumblers; and the curtain-plug and bolt must be so adjusted that the curtain cannot be pushed in until the bolt is so far out that the stump is this one-sixteenth of an inch beyond the tumblers.

The curtain **K** need only be a thin piece of steel, and the bolt **B** must be thick enough for the curtain to go down just to the level of the thin plate **P** between the bolt and the first tumbler **T.** The curtain-plug **p** is made as long as the keyhole and rather broader, and of the shape represented, partly for the sake of steadiness in pushing in the curtain, and also for more completely protecting the keyhole; for if an attempt be made to pick the lock by drilling into the keyhole, the drill will pass into the inside of the door and not into the inside of the lock.

It is true that iron safes have been made for some years in which any number of large bolts are shot by a handle and then locked by a very small key. But in such locks the key must be used in locking, and this leads to certain objections, viz. the key must occasionally at least be confided to some person whose duty it is to lock up the safe after the owner has left the place; there is also the temptation to leave the key in the lock, since it will be wanted in locking up; and thus there is the danger of some dishonest person taking an impression of the key. Besides this, the real strength and security of such safes is only that due to the small lock which locks into the main bolt; whereas in Mr. Denison's lock the security and strength are those due to the lock itself, with its large and strong tumblers, and other provisions peculiar to its construction; and the key for a lock of the largest size, which was lately exhibited at the Society of Arts by Messrs. S. Mordan and Co., the makers, only weighs a little more than a quarter of an ounce. It may be mentioned that for large, locks the key may be solid, although in the small ones it is more convenient to have a pipe-key, on account of the different construction of the curtain.

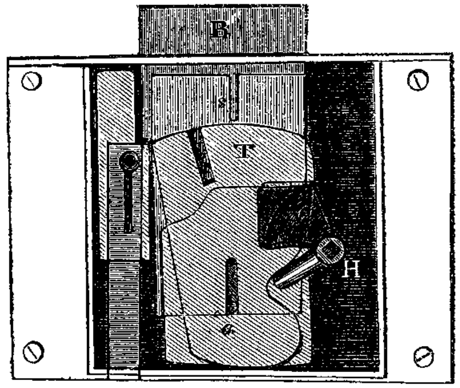


Figure 52 Mr. Denison's small lock.

The arrangement of the small lock for drawers, etc. is somewhat different from that of the large ones, and will be understood by referring to **figure 52**. The action of the handle **h** on the bolt **B** and on the tumblers **T** is sufficiently clear from the figure. The curtain in this case has no plug, but is only a flat plate held up by a thin spring behind it, and moving up and down on the drill-pin of the key, and kept from turning by having one edge against the side of the lock.

The bolt has a kind of second stump, only coming up so high as to be able just to pass under the corner of the curtain when it is up, but not able to pass when the curtain is at all pressed down by anything inserted in the keyhole. In a drawer lock the key has only to be turned a quarter round in order to raise the tumblers. In small locks, the friction of the tumbler-plates is quite enough to keep them in any position, without putting the pin in the middle so as to balance them, as in large locks with heavy tumblers.

In the making of these locks the key must be made first, with proper provisions to prevent the repetition of the same pattern; a kind of pattern or model for locks of each size should be made; the tumblers put on the pin with plates of the intended thickness between, and when raised by the key to the proper height they should be clamped down; and the jaws for the stump of the bolt may then be cut by a circular saw moving in a slit in the model corresponding to the place of the stump. The tumblers for large locks may be cut off from a strip of hoop-iron to the proper lengths by a stamping cutter, giving them the proper circular end, and a punch might at the same time make the pin-hole in the middle. The tumblers for small locks should be stamped out of sheet brass or iron.

It will thus be evident that from the general simplicity of construction, and the small amount of finish required in the working parts, this lock can be made at small cost. We may also add that this lock is as creditable to the public spirit as to the mechanical skill of the inventor; for the lock is not patented, patents being, in Mr. Denison's estimation, obstructions to the progress of science.

The next result of the "lock controversy" which we have to notice is the production of not less than three improved locks by Messrs. Chubb. We thought it our duty to invite the attention of this celebrated firm to the preparation of this *Rudimentary Treatise,* and in answer to the application of our publisher we received the following communication from Messrs. Chubb, which we insert verbatim:

"It will not be necessary to describe the lock as originally made, as a description of it will be found in Mr. Chubb's paper read before the Institution of Civil Engineers."

Lock No. 1. The first of the improvements introduced consists of a barrel, to which a circular curtain is attached, revolving round the drill-pin in the lock; so that if any instrument is introduced to attempt to pick it, the curtain immediately closes up the keyhole, and prevents the introduction of any auxiliary instruments, there being several required in action at once to produce any effect.

"If by any means these several instruments can be introduced simultaneously, the barrel keeps them all confined in a very small space, preventing their expansion, and renders it impossible to work them independently of each other; therefore they are of no avail, being incapable of acting as more than a single pick, which is perfectly useless. The barrel and curtain have each been previously used *separately* in locks, but until patented by Mr. De la Fons in 1846, they had not been used *in combination.* Neither of them, used separately, is of much use, but when combined they afford a very great security."

Locks have been, and still are shown, containing either the barrel or curtain *singly,* and as these have been picked, it has been asserted that the improvement now introduced in Chubb's lock is equally insecure; but a slight examination of the difference in their construction will prove the contrary. Mr. Chubb has purchased the patent-right of this part of Mr. De la Fons'

invention, and applies it to all his locks.

Lock No. 2. The next improvement, recently patented by Mr. Chubb, is based upon the assumption that there may be a possibility of overcoming the security of the barrel and curtain as already described (although this assumption is not in the slightest degree admitted), and consists in applying what is called a 'tumbler-bolt,' working on a hinge connected with the main bolt. The web of the key does not in any case touch the main bolt in unlocking, but acts only on the tumbler-bolt.

All the tumblers must first be lifted, each to its proper position, before the tumbler-bolt will act. Should any pressure be applied to either bolt before the tumblers are all at their exact position, the effect would be to throw the bolts out of gear, and thus effectually to stop the stump of the main bolt from passing through the racks of the tumblers. None of the many plans of picking which have been suggested, such as smoked key-blanks, thin key-bits, etc., would be of the least avail against a lock made on this principle. Different kinds of detectors may be applied to these locks.

It is submitted that this lock, retaining all the simplicity and durability which have distinguished Chubb's lock for so many years, and combining with them these important improvements, affords a complete security against all surreptitious attempts of any nature. Locks on the same principle are being made on the permutation plan, with any number of tumblers, and any number of changes in combination that may be desired.

It has been suggested that the 'detector,' instead of giving additional security to Chubb's lock, affords a partial guidance to a person attempting to pick it. This objection holds good to a certain extent in these locks as originally made, in which all the tumblers had an *equal* bearing against the detector stump; but in the locks as now constructed this objection is entirely obviated, by giving the tumblers an *unequal* bearing, whereby, if an operator feels the obstruction of the detector stump, he cannot tell whether the tumbler which he is lifting is raised too high, or not high enough.

"LOCK No. 3. For banks, Mr. Chubb has introduced what he particularly calls his 'bank lock.' It contains a barrel with a series of curtains. While the keyhole is open, all access to the tumblers from the keyhole is completely cut off by two sliding pieces of solid metal, which fit closely on either side of the

barrel. These pieces are acted upon by an eccentric motion, so that when the key is applied to the lock, and turned in it, the keyhole is shut up by the revolution of the curtains, and then only do the sliding pieces of metal move aside to allow the key to act upon the tumblers."

"These pieces return to their position when the key has passed; therefore, while the key is lifting the tumblers, all communication is cut off from the exterior of the lock by these sliding pieces and the series of curtains. The bolt is made in two pieces, the main bolt never being in contact with the key, which acts only on the talon bolt, and by it transmits the motion to the main bolt."

"After the action of locking, the talon-bolt is partly repelled, and a lever or 'dog' connected with it locks into a series of combinations arranged upon the front parts of the tumblers, and holds them securely down, so that none of them can be lifted in the least degree until the talon-bolt is thrown forward to release them. If, therefore, any pressure be applied to this talon-bolt to endeavor by its help to ascertain the combinations of the tumblers, it will only the more tightly lock them down, and render the attempt ineffectual."

"By another contrivance it is rendered impracticable to move a pick or picks round in the lock more than a small distance, unless the tumblers could previously be all lifted to their right positions, which can only be done by the right key. Should one or more of the tumblers be surreptitiously raised by any possible means, they cannot be detained in this uplifted position, for the action of turning back the pick to try to raise another tumbler sets in motion a lever which allows the tumblers already raised to drop to their former position, leaving the operator just as far from the attainment of his object as at the outset."

Such is the statement with which Messrs. Chubb have favored us respecting their three new locks. We are willing to admit the enterprising spirit which has led to their production, and the ingenuity which has been bestowed on their construction; but whether they mark a step in advance in the art of lock-making may perhaps admit of doubt.

With respect to the lock No. 1, we would remark, that locks with the barrel and curtain combined were made by Mr. Aubin of Wolverhampton in 1833, and that a specimen of such a lock was exhibited on his stand of locks in the Great Exhibition. Locks

with the combined barrel and curtain were also made and sold by Mr. Jones of Newark, N.J.

With respect to the lock No. 2, the object of the *tumbler-bolt is* evidently intended to produce the same effect as the *moveable stump* in Mr. Hobbs's protector-lock, **figure 47**; but with greater complexity in the construction, there is less efficiency in the action of this part of Mr. Chubb's lock as compared with that of Mr. Hobbs, inasmuch as a pressure of the stump against the tumblers, corresponding with the strength of the spring which holds the bolt in its place, can always be produced, thereby giving friction, and affording indication as to which tumbler it is that is in tight contact with the stump.

With respect to the barrel and curtains of lock No. 3, and all similar contrivances, the object of which is said to be to prevent the entrance into the keyhole of all instruments except the proper key, we would offer the self-evident remark, that the same aperture which admits the key will also admit some other instrument. In the case of Mr. Chubb's "bank lock," it may be questioned whether the revolving curtain, etc. give it any advantage over the other locks already referred to which are furnished with similar contrivances.

The effect of the *talon-bolt* in this lock appears to be the same as that of the false notches, namely, to hold the tumblers in the position in which they were placed when the pressure was applied. Hence, a pressure applied to the talon-bolt affects the parts which come in contact with the key in the act of locking and unlocking; and this circumstance brings the lock under the application of the principle stated earlier, and thus, if this principle be admitted, may render the security of the lock somewhat questionable.

Various other locks have been brought out since the date of the "lock controversy" in the year 1851. We would gladly notice them all, did they show novelty of design and mark an advance in the art of the locksmith. We must, however, admire the ingenuity with which Mr. Hobbs's moveable stump has been more or less adopted; but in the attempts to imitate it the objection has not been removed, that it is possible to produce on the tumblers a pressure or friction equal to the strength of the spring which holds the tumblers down.

There is, however, a lock which has lately been introduced to the public, which calls for special notice, on account of the high

honors which have been bestowed upon it. We refer to the prize lock of the Society of Arts, London, the invention of Mr. H. J. Saxby of Sheerness, who has received the Society's medal and the sum of ten guineas as the reward of his ingenuity.

The interior of this lock consists of a cylinder with four pins or slides radiating from the center and pressed into the keyhole by means of spiral springs. The pins project beyond the periphery of the wheel or cylinder, and into slots in a ring that is affixed to the case of the lock, thereby preventing the cylinder from being turned. On each pin is a notch, so placed that when the proper key is inserted into the keyhole, the notches on the several pins will be brought into a position such as will allow the cylinder to turn. The turning of the cylinder in this, as in the Bramah lock, shoots the bolt.

A lock on precisely the same principle, but more secure in its construction, was described by Mr. Hobbs in a paper read by him before the Society of Arts in January 1852, when diagrams illustrative of the same were exhibited. This paper was not reported at any length in the journal of the Society's proceedings; but the same paper was read by Mr. Hobbs, March 1, 1852, before the Liverpool Polytechnic Society, and a full report thereof, and a description of the lock in question, is given in the "Transactions" of that Society, from September 1849 to December, 1852 (8vo, Liverpool 1853). This lock is no other than the Yale lock already noticed in this text, and is thus described at page 196 of the " Transactions:"

"Another description of cylinder-lock was invented, a few years since, by a Mr. Yale of the State of New York, U.S.A."

"The Yale lock has two cylinders, one working within the other; and they are held together by a series of pins reaching through the cylinders into the keyhole, which is in the center. On the back of the inner cylinder is a pin that fits into a slot in the bolt, and moves it as the cylinder is turned. The pins that hold the cylinders together and prevent the inner one from turning are cut in two at different lengths. The key is so made, that by inserting it into the keyhole the pins are moved, so that the joint in the pins meets the joint between the cylinders, and allows the inner one to be turned. But, as with the slides of the Bramah lock, should any one of the pins be pushed too far, the cylinder is held quite as firmly as though it had not been touched. Some of these locks have been made with as many as forty pins; and to a person unacquainted with the principles on which

locks are picked, they would seem to present an insurmountable barrier."

"**Figure 1** represents the case of the lock containing the bolt **A**, having a groove **B**, to receive the pin c on the cylinder. **Figure 2** shows the cap or top-plate of the lock, and the cylinders; **D D** is the outer cylinder, that is stationary, being fastened to the plate; **EE** the inner or moving cylinder; **FF** the four rows of pins, being cut in two at different lengths, and reaching through the cylinders into the keyhole; **G G** are the springs that press the pins to their places; **c** the pin that fits into the groove and moves the bolt. **Figure 3** is an end view of the key, showing four grooves. **Figure 4** is a side view, showing the irregular surface of the grooves by which the pins are adjusted."

"For the purpose of picking the lock, an instrument is made that will fit between two of the pins; to that is attached a lever and weight, thereby getting a pressure on the cylinder and causing the pins to bind; then with another instrument the pins are felt, and as they are found to bind, they are pressed in until they are relieved (as they will be when the joint comes to the right place), thereby easily opening the lock. There is a great similarity in the operation and security of this and the lock manufactured by Mr. Cotterill of Birmingham."

In the *Society of Arts Journal* for the 24th June, 1853, is a letter from Mr. Hobbs on the subject of the prize lock, which it appears, he picked, "in the presence of parties connected with the Society, in the short space of three minutes."

CHAPTER ELEVEN: The Lock and Key Manufacture

MASTER EXHIBIT LIST

THE manufacture of locks and keys, considered as a department of working in iron, is one that requires, and indeed admits of, very little description. The hammer, the file, the drill, the fly-press, are the chief instruments employed; the iron itself being brought to something like the desired state and form by rolling or casting, or both. But the manufacture is interesting in its social features, in its relation to the persons employed and the buildings occupied.

One by one, several departments of industry have progressed from the *handicraft* to the *factory* system, from that system in which a man and a few apprentices work in a small shop in the lockmaker's garret or kitchen, to that in which organization is maintained among twenty or fifty or a hundred men. Locks have scarcely yet passed out of the first stage, but there is no good reason whatever why they should so remain; there are as many reasons for progress in this as in other arts, and indications are not wanting that some such progress will be made.

So far as England is concerned, the neighborhood of Wolverhampton is the great storehouse whence locks are obtained. Eminent lock-makers reside in London and in other principal towns; but Wolverhampton is regarded by all as the center of the trade. This is not a modern localization, for we have information respecting the locks of Wolverhampton a century and a quarter ago. Among the Harleian Manuscripts is an account of "The Voyage of Don Manuel Gonzales (late merchant), of the City of Lisbon in Portugal, to Great Britain: containing an Historical, Geographical, Topographical, Political, and Ecclesiastical Account of England and Scotland; with a Curious Collection of things particularly rare, both in Nature and Antiquity."

This work appears to have been written about 1732; it was translated from the Portuguese, and printed in Pinkerton's Collection of Voyages and Travels. With reference to Wolverhampton, Gonzales says: "The chief manufacturers of this town are locksmiths, who are reckoned the most expert of that trade in England. They are so curious in this art, that they can

contrive a lock so that if a servant be sent into the closet with the master key, or their own, it will show how many times that servant hath gone in at any distance of time, and how many times the lock has been shot for a whole year; some of them being made to discover five hundred or a thousand times. We are informed also that a very fine lock was made in this town, sold for 20£, which had a set of chimes in it that would go at any hour the owner should think fit."

If Gonzales was correct in these descriptions, they indicate an exercise of considerable ingenuity in lock-construction, especially in reference to the lock which keeps a registry of the number of times it has been opened. There is abundant evidence that the old lock-makers were very fond of these knick-knack locks, which would do all sorts of strange and unexpected things; and this may in part account for the great favor in which locks have been held by amateur machinists.

The lock-manufacture in South Staffordshire is of a remarkable character, comprised as it is within so small an area. Although Wolverhampton is known commercially as the chief depot of the English lock trade, yet it is at Willenhall, three or four miles eastward of that town that the actual manufacture is chiefly carried on. When the Commission was appointed a few years ago to inquire into the condition of children employed in trades and manufactures, Mr. R. H. Horne was deputed to examine the Wolverhampton district; and his report is too curious, and too closely connected with our present subject, to be passed unnoticed. We here give an abstract of such parts of his report as bear reference to the lock-makers of Willenhall.

Almost the entire industry of Willenhall is in the three articles of currycombs, locks and keys, and articles connected incidentally with locks, such as bolts and latches. At the time Mr. Horne wrote, in 1841, there were among the master manufacturers 268 locksmiths, 76 key-makers, 14 bolt-makers, and 13 latch-makers; besides many small masters living in such out-of-the-way corners that they escaped enumeration.

In the *Post-Office Directory* of that district, of later date, there are entries of rather a curious character. In the first place it is observable that different kinds of locks are made by different persons, each manufacturer confining his operations apparently to one kind of lock; one is a *rim-lock* maker, another a *trunk-lock* maker, a third a *cabinet-lock* maker, a fourth a *padlock* maker, a fifth a *mortise-lock* maker, and so on.

But a much more singular feature is, that lock-making is combined with retail dealing of a totally different kind; thus among the occupations put down opposite the names of individuals are, "key-stamper and beer-retailer," "door-lock maker and beer retailer," "grocer and trunk-lock maker," "Malt-Shovel tavern-keeper and rim-lock maker," "lock-maker and provision dealer," "grocer and key-maker," "cabinet-lock maker and Woolpack tavern," "key-stamper and registrar of births, etc.," "Hope and Anchor and cabinet-lock maker," "auctioneer and locksmith," "rim-lock and varnish maker," and so forth. It is probable that in some of these cases the wife attends to the retail shop, while the husband attends to the workshop.

Among all the lock-manufacturers of the town there are scarcely half a dozen in what may be termed a large way of business; there are many who employ from five to fifteen pairs of hands, but the great majority are small masters who are themselves working mechanics, and are aided by apprentices from one to four in number, perhaps two on an average.

Mr. Horne thinks that there were not fewer than a thousand boys at work in the town, chiefly upon locks and keys. The children and young persons are employed at all ages, from seven up to manhood; from the earliest age, indeed, in which they are able to hold a file. It is a characteristic fact, where so many of the male inhabitants are employed at the bench from such early years, that a certain distortion of figure is observable; the right shoulder-blade becomes displaced and projects, and the right leg crooks and bends inwards at the knee, like the letter K, it is the leg which is hindermost in standing at the vice. The right hand also has frequently a marked distortion. "Almost everything it holds takes the position of the file. If the poor man carries a limp lettuce or a limper mackarel from Wolverhampton market, they are never dangled, but always held like the file. If he carry nothing, his right hand is in just the same position."

The hours of labor among the small masters are scarcely brought within any system at all; for all the work is piecework, not paid for by the day or hour; and each man works as long as he likes, or as long as his business impels him. Some will file away from four or five in the morning till eleven or twelve at night. In the larger shops, where there are many hands employed, they come to work when they like, leave when they like, and do as much work as they like when there; this freedom of action being spread over a working-day of perhaps sixteen hours.

The masters say that the men prefer this system, or want of system, to anything more precise and regular. In the beginning of the week there is often much idleness and holiday-keeping; and the Willenhall men make up for this by a day of sixteen, eighteen or even twenty hours work towards the end of the week. In the beginning of the week, men and boys have defined hours and definite periods for meals; but towards the end of the week, when hurry and drive are the order of the day, they eat their meals while at work, and bolt their victuals standing.

"You see a locksmith and his two apprentices, with a plate before each of them, heaped up (at the best of times, when they can get such things) with potatoes and lumps of something or other, but seldom meat, and a large slice of bread in one hand; your attention is called off for two minutes, and on turning round again, you see the man and boys filing at the vice."

In the processes as carried on at Willenhall, they are applied chiefly to the manufacture of mortise, box, trunk, rim, cabinet, case, bright, dead, closet, and padlocks. Except some of the parts of the brass-work, which are *cast,* these locks are *made by forging, pressing,* and filing. The forging is a light kind of smith's work, aided by a light hammer and a small pair of bellows; children and young persons are largely employed in this process.

Pressing is a kind of work by which certain parts of the lock are pressed or stamped out. The presses are of various sizes, but all require much strength to work them; the press has a horizontal lever, crossing the top of a vertical screw, and there is generally an iron weight at the end of each arm or half of the lever to increase the power; one of the lever arms is grasped in the right hand of the presser, and whirled round with a jerk; while the fingers of the left hand place the metal in its proper position, and remove it when it has been stamped or pressed.

There is, of course, a die or cutter attached to the press, to cut the metal in the proper form. Sometimes the press has only one arm to the lever, and no weight at the end of this, so that the labor of working is much increased. Children and youths are employed at this process, so far as their strength will admit. The last process, *filing is* that by which the separate pieces are shaped and smoothed for adjustment in their proper places; here children and youths are almost exclusively employed; they stand upon blocks so as to be able to reach the vice, and then work

away with the file, unrelieved by any change in the nature of the process.

In key-making the processes may be said to comprise *forging, stamping, piercing, end fling.* The forging differs very little from that required in making the pieces for a lock. The stamping is effected by placing the end of an iron wire, taken red-hot from the forge, into one half of a key-mold made in a block or kind of anvil; a heavy weight is then raised between an upright framework, in the grooves of which it runs by means of a cord; the cord is drawn by both hands, with the assistance of one foot in a stirrup attached to the end of the cord; at the bottom of the weight thus raised is the other half of the key-mold. Such being the nature of the stamping apparatus, the process is thus conducted: the foot in the stirrup being suddenly raised, and the cord loosed, the weight falls upon the red-hot wire, and the blow stamps it into the two molds or half-molds, which are brought accurately together by means of the slides or side-grooves in the framework.

The rough key is also trimmed and cleared by the pressing apparatus; that is, the surplus metal all round is cut off by a single blow; and the metal which fills up the ring or handle of the key is cut or pressed out in the same way. This is a heavy part of the key-work, for which the labor of men rather than that of boys is required.

The process of *piercing* the key consists in making the pipe or barrel, required for most keys, except those which are intended to open a lock for both sides; the pipe is drilled by a small machine worked with the foot like a lathe; it is a process requiring more skill than strength, relatively to other parts of the manufacture.

The fling of a key is important; for not only is the whole key made bright, but the wards are cut by the file and chisel. Boys and youths are employed in filing the common keys; but those of better quality are entrusted to men.

The apprenticeship system is carried on to a remarkable extent among the lock and key makers of Willenhall. The small masters take apprentices at any age at which they can work. Some of them employ only apprentices, never paying wages for journeymen, but always taking on a new apprentice as soon as a former one is out of his time. The boys are mostly procured from other towns, and they bring with them a small apprenticeship-fee and a suit or two

of clothes. They are bound to the masters by legal indenture or contract; and the masters board and lodge and clothe them during their apprenticeship.

One consequence of this system is that when the apprentice has served his time, he is almost driven to become a small master himself from want of employment as a journeyman; and he then takes apprentices as his master did before him. This accounts for the fact that in Willenhall there are few large manufacturers and few journeymen; while there is a constantly-increasing number of small masters and of apprentices.

The Willenhall makers nearly all look to the Wolverhampton factors or dealers for a market for their wares, for at least as concerns locks and keys; there are some other articles which they sell more frequently to Birmingham houses. The master and an apprentice, or perhaps two, generally trudge off to Wolverhampton on a Saturday, bearing the stock of locks which he may have to sell; and the money receipts for the locks or keys sold are usually in part spent at the large market of Wolverhampton previous to the homeward journey.

The Willenhall men take contracts at so low a price as to prevent the competition of other places; it is stated, that whatever be prices elsewhere, nothing can come below the Willenhall prices for cheap locks. The men work hard for small returns, and yet they have a strong yearning for their own town. A Willenhall girl will seldom marry except to a townsman; and thus they intermarry to an extent which maintains their characteristics as a peculiar community.

As an example of their disinclination to leave their own town, Mr. Horne states the following circumstance: "Some years ago a factor, who had projected a manufactory in Brussels, engaged some five-and-twenty Willenhall men, whom he was at the expense of taking over. He gave them all work, and from hard-earned wages of from 9s. to 15s a-week, these 'practiced hands' found themselves able to earn 3£ per-week and upwards.

But they were not satisfied, and began to feel uncomfortable; first one left, and returned home; then another; then one or two; until, in the course of a few weeks, every man had returned to Willenhall, there to work harder and earn less.

It is just possible that the application of the factory system to lock-making may first become important by making the *best* locks

cheaper than they can be made by the handicraft method; for there seems not much probability, at least for a great length of time to come, that any new system will be able to compete with Willenhall in the common locks, those of which more thousands are sold than there are tens of the better locks. In this, however, it would not do to predict rashly. Hand-loom weaving is cheap enough, unfortunately for those who practice it; but yet the factory system comes down as low as the lowest hand-loom weaving.

The editor of Hebert's *Encyclopedia,* after noticing the facilities for opening most locks by copying the key, makes the following announcement: "It affords the editor of this work much satisfaction to state, that he has in his possession a lock, the key of which *cannot be copied,* a locksmith possessing no tools by which an exactly similar one can be made; the machine by which the original one was made is so arranged as to be deprived of the power of producing another like it. The lock is very simple, very strong, and can be very cheaply made. The cost of a complete machine to make them would be about 100£; with that they might be manufactured at one-half the expense of any patent lock. The inventor is desirous to have the subject brought before the public under a patent; but want of time to devote himself to such an object at present obliges him to lay it aside."

The invention not being patented, the editor of course gave no diagram or engraving of the lock or machine; nor does there appear to have been a patent obtained during the sixteen or eighteen years which have elapsed since the above notice was published. There are, however, mechanical principles sufficiently well known to lead to a belief that such a machine is practicable; a ticket-printing or numbering machine will, in printing 100,000 tickets, produce such variations that no two impressions shall be identical; and a key-making machine might, after fashioning a particular part of each key, modify the arrangement of certain wheels and pinions so far as to produce a slightly different result when the next key is to be operated on.

In the manufacture of locks and keys generally there is no reason why the factory system should not, to a certain extent, be applicable. By this will be understood, the production of similar parts by tools or machines, graduated in respect to each other with more care than can be done by the hand method.

If we suppose that a lock of particular construction comprises twenty screws and small pieces of metal, and that there are required, for general disposal in the market, five sizes of such

a lock; there would thus be a hundred pieces of metal required for the series, each one differing, either in shape or size, from every one of the others. Now, on the factory or manufacturing system, as compared with the handicraft system, forging, drawing, casting, stamping, and punching, would supersede much of the filing; the drilling machine would supersede the drill-stock and bow, and other machines would supersede other hand-worked tools.

This would be done, not merely because the work could be accomplished more quickly or more cheaply, but because an accuracy of adjustment would be attained, such as no hand-work could equal, unless it be such special work as would command a high rate of payment. For any one size in the series, and any one piece of metal in each size of lock, a standard would be obtained which could be copied to any extent, and all the copies would be like each other.

To pursue our illustration, the manufacturer might have a hundred boxes or drawers, and might supply each with a hundred copies of the particular piece of metal to which it is appropriated, all so exactly alike that any one copy might be taken as well as any other. Ten pieces, one from each of ten of these boxes, would together form a lock; ten, one from each of another ten boxes, would form a second lock, and so on; and there would be, in the whole of the boxes, materials for a thousand locks of one construction, a hundred of each size.

Now the advantage of the machine or factory mode of producing such articles is this, that they can be made in large numbers at one time, whenever the steam-engine is at work; and that when so made, the pieces are shaped so exactly alike, the screws have threads so identical, and the holes are bored so equal in diameter, that any one of a hundred copies would act precisely like all the others, thereby giving great advantages to the men employed in putting the lock together.

These principles are being applied by Messrs. Hobbs and Co. in their London establishment. A number of machines, worked by steam-power, are employed in shaping the several pieces of metal contained in a lock; and all the several pieces are deposited in labeled compartments, one to each kind of piece. The machines are employed, in some cases to do coarse work, which they can accomplish more quickly than it can be done by men; and in other cases to do delicate work, which they can accomplish more accurately than men; but so far is this from converting the men into lowly-paid automatons (as some might suppose), that the

manufacturers are better able to pay good wages for the handicraft labor necessary in putting the locks together, than for forming the separate parts by hand; just as the "watchmaker," as he is called, who puts the separate parts of the watch together, is a better-paid mechanic than the man who is engaged in fabricating any particular parts of the watch.

It may be observed that the system of manufacturing on a large scale, by many men engaged in one large building, is more nearly universal in the United States than in England. The workshop system, as pursued at Willenhall by the lock makers, is very little practiced in America. Being comparatively a new community, and being at liberty to select for imitation or for improvement whichever of the usages or systems in the old country they may prefer, the Americans have preferred to adopt the factory system rather than the workshop system, and to carry out the former to an extent not yet equaled in England; not yet equaled, we mean, in the number of trades to which it is applied.

CHAPTER TWELVE: English Patents for Locks-Aubin's Lock Trophy

WE propose to conclude this small work with a few details respecting the various patented inventions in locks, and concerning Mr. Aubin's remarkable lock trophy. These two subjects relate to locks in general, rather than to any specified constructions in particular, and can on that account more conveniently be given here than in connection with any of the foregoing chapters.

Mr. Chubb, in the appendix to his paper on LOCKS and KEYS read before the Institution of Civil Engineers, gave a useful list of all the patents taken out in England in relation to this subject, down to the year 1849. We here transcribe this list:

List of Patents for Locks and Latches granted since the Establishment of the Patent Laws.

AS no complete list of the patents granted for locks from the time of James I. has hitherto been published, it is believed that the following list, which has been very carefully drawn up, and which comprises all patents from the year 1774, when the first patent for a lock was granted, to the present time, will be found useful as a reference {for all who are interested in the Subject).

1774	**May**	**27**	**Black, George, Berwick-on-Tweed.**
1774	**May**	**27**	**Barron, Robert, London.**
1778	**May**	**29**	**Martin, Joshua Lover, Feet-street, London.**
1779	**May**	**28**	**Henry, Solomon, Swithin's-lane, London.**
1780	**March**	**4**	**Campion, J. Newcastle-court Strand, London.**
1782	**January**	**18**	**Hutchinson, Samuel, Marylebone, London.**
1784	**January**	**18**	**Bramah, Joseph, Piccadilly, London.**

1789	July	7	Cornthwaite, Thomas, Kendal, Westmoreland.
1790	February	23	Rowntree, Thomas, Surrey-streot, Blackfriars London.
1790	October	29	Bird, Moses, Wardour-street, London.
1791	July	19	Ferryman, Rev. Robert, Gloucester.
1791	November	3	Antis, John, Fulneck, near Leeds.
1797	November	18	Langton, Daniel.
1798	May	3	Bramah, Joseph.
1798	December	8	Turner, Thomas.
1799	April	11	Davis, George.
1801	February	10	Scott, Richard, Lt. Colonel.
1801	June	24	Holemburg, Samuel, London.
1801	June	24	Roux, Albert, Switzerland.
1805	May	18	Stansbury, Abraham Ogier, New York.
1805	December	29	Thompson, William, Birmingham.
1815	March	7	Mitchell, William, Glasgow; and Lawton, John, London.
1816	May	14	Ruxton, Thomas, Esq., Dublin.
1817	February	8	Clark, William, Esq., Bath.
1818	February	3	Chubb, Jeremiah, Portsea.
1819	October	18	Strutt, Anthony Radford, Mackeney.
1820	April	11	Jennings, Henry Constantine, Esq., Middlesex.
1820	December	14	Mallett, William, Dublin.
1823	July	10	Fairbanks, Stephen, Middlesex.
1823	November	13	Ward, John, Middlesex.
1824	June	15	Chubb, Charles, Portsea.
1825	May	14	Young, John, Wolverhampton.
1828	May	17	Chubb, Charles, London.
1829	June	1	Gottlieb, Andrew, Middlesex.
1830	January	18	Carpenter, James, and Young, John, Wolverhampton.
1830	January	26	Arnold, John, Sheffield.
1831	April	14	Rutherford, William Jedburgh N.B.
1831	May	23	Barnard, George, Bristol.
1831	July	27	Young, John, Wolverhampton.
1832	December	20	Parsons, Thomas, London.
1833	December	3	Parsons, T., Newport, Salop.
1833	December	20	Chubb, Charles, London; and Hunter, E. Wolverhampton.
1834	September	6	Longfield William, Otloy.
1834	October	11	Audley, Lord Barron Stafford.
1835	March	18	Hill, H., Birmmgham.
1835	December	16	Warwick, J., London.

1836	February	21	Fenton, Rev. S., Pembroke.
1838	June	30	Uzielli M., London.
1838	November	13	Thompson, S., London.
1839	February	21	Uzielli M., London.
1839	June	12	Sanders, J. Stafford.
1839	July	3	Cochrane, A., Strand, London.
1839	July	20	Schwieso J. C., London.
1839	August	1	Williams, W. M., London.
1839	December	2	Guest, J., jun., Birmingham.
1840	February	27	Williams, W. M., London.
1840	March	20	Gerish, F. W.
1840	May	2	Pearse, W., Hoxton, Middlesex.
1840	June	13	Wolverson, J., and Rawlott, W., Stafford.
1840	October	22	Clark, T.
1840	December	23	Baillie, B., London.
1841	March	29	Tidesley and Sanders, Willenhall and Wolverhampton.
1841	May	6	Hancock, James, Sidney-square, Mile End.
1841	July	14	Berry, Miles, Chancery-lane.
1841	September	28	Strong, Theodore Frederick Goswell-road.
1841	November	9	Smith, Jesse, Wolverhampton.
1842	January	15	Poole Moses, Lincoln's-inn.
1842	May	24	Duce, Joseph, Wolverhampton.
1842	June	13	Williams, W.M., 163 Fenchurch-street.
1842	December	29	Rook, Joseph, jun., Birmingham.
1843	November	25	Tann, E.E. and J., Hackney-road.
1843	November	25	Rock, Joseph, jun., Birmingham.
1844	July	30	Fletcher, Rev. William, Moreton House, Buckingham.
1845	April	15	Carter, George, Willenhall.
1845	July	12	Ratcliff, Edmund, Birmingham.
1845	December	4	Poole, Moses, Lincoln's-inn.
1845	December	22	Smith, Philip, High-street Lambeth.
1846	July	6	De la Fons, John Palmer, Carleton-hill, St. John's Wood.
1846	July	15	Thomas, William, Cheapside.
1846	December	14	Chubb, John, St. Paul's Churchyard.
1847	January	11	Chubb, John, and Hunter, Ehenezer, sen., St. Paul's Churchya
1847	April	15	Collett, Charles Minors, 62 Chancery-lane
1848	September	28	Newell, Robert Stirling, Gateshead.
1849	May	8	Wilkes, Samuel, Wednesbury-heath, Wolverhampton.

Mr. Chubb also gave a list of such papers in the Transactions of the Society of Arts as refer to locks and keys.

List of References to the "Transactions of the Society of Arts," on the subject of Locks.

vol	page.	
1.	317	Mr. Moore.
2.	187	Mr. Cornthwaite
3.	160	Marquis of Worcester.
3.	165	Mr. Taylor.
3.	163	Mr. MarshaU.
18.	239	Mr. T. Arkwright.
18.	243	Mr. Bullock.
19.	290	Mr. w. Bullock
36.	111	Mr. M. Somerford
38.	111	Mr. A. Ainger
38.	205	Mr. Bramah
42.	125	Mr. J. Duce.
43.	114	Mr. W. Friend.
45.	123	Mr. Machin.
48.	132	Mr. S. Mordan.
50.	86	Mr. A. Maokinnon.
51.	128	Mr. J. Meighan

Among the most curious mechanical productions in the Great Exhibition of 1851, was one that attracted very little notice, viz. that forwarded by Mr. C. Aubin of Wolverhampton. Whether it was that attention, so far as regards locks, was too much absorbed by the "lock controversy," or whether there was a deficiency of descriptive cataloging, no juror or newspaper critic, as far as we are aware, took notice of the production in question. In the *Official Illustrated Catalogue* it is entered simply as "Specimens to illustrate the rise and progress of the art of making locks, containing forty-four different movements by the most celebrated inventors in the lock trade."

This trophy of lock ingenuity (for such it may be justly considered to be) is now in the possession of Mr. Hobbs. Springing from a hexagonal base-piece is a central axis, about three feet in height, supporting four horizontal circular discs, placed at different parts of its height. Each of the vertical faces of the base-piece contains a lock, which is worked by its respective key. Each disc contains a number of locks: sixteen on the lowest, twelve on the next above, nine on the third in height, while a Bramah lock surmounts the whole.

All the locks on the discs are so arranged that their bolts shoot outwards, or radially away from the axis of the machine. Every lock has its own proper key inserted in the keyhole; and as the locks lie down horizontally, the shaft of each key is of course vertical.

There are delicate pieces of mechanism contained within the central axis and within the discs, consisting of levers, racks, and pinions; and the Bramah lock is contrived so ingeniously, that the Bramah key, by acting upon that lock, acts upon all this mechanism. The Bramah barrel, in rotating horizontally under the action of its key, gives a rotary movement to a rod passing vertically through the center of the whole apparatus; this rod, at the levels of the several discs, acts upon racks and pinions, and these in turn act upon the key-pins of the several locks.

When, therefore, the Bramah key is turned, the whole of these key-pins rotate, each exactly in the same way as if the lock were being closed or opened, and the bolts shoot in or out accordingly. The Bramah key, although it acts as a master key, is not such as usually obtains that designation; it is simply a means of putting in action certain rack-and-pinion mechanism, which does not belong to lock-work considered *per se.*

All the locks are faithful representatives of the several patents or modes of construction to which they severally refer; and each exhibits the works sufficiently open to display the principle on which it is arranged. Each lock is numbered, and is referred to in an accompanying description. The works are finished with the utmost care and polish; and the trophy being somewhat tastefully arranged, and kept under a glass shade, forms a really elegant specimen of mechanical skill.

For an account of the locks themselves that constitute this trophy, we cannot do better than avail ourselves of the description given in the article "Lock" in Tomlinson's *Cyclopedia of Useful Arts,* adding a few further details in respect to some of the locks of the series. The locks are arranged and numbered according to their similarity of construction; and it is instructive to remark the evidence here afforded, that many patentees would have caved much time and money if they had better known the productions of their predecessors. In describing these locks we shall do so briefly, sufficient to show their relative principles of construction; many of them having been described more or less fully in former chapters.

No. 1 on the list is called a *Roman lock; it* consists of a single bolt, with a binder-spring for holding the bolt in any position in which it may be placed until a sufficient force is applied to overcome it: it embodies the simple principle on which thousands of common locks are annually made.

No.2, called a *French lock* (all such designations are of rather doubtful correctness), resembling No. 1 in everything except having the addition of a friction-roller. The bolt of either of these two locks can easily be forced back by pressing on the end.

No. 3 is marked *Ancient;* it is a bolt-lock, and was found in an ancient building. It exhibits an improvement on both the former specimens, in so far as the bolt requires, before it can be shot, to be pressed down, in order to release it from a catch at the back end of the bolt; this release cannot be effected without the aid of a key or some other implement applied through the keyhole, and thus the bolt answers the purpose both of bolt and tumbler.

No. 4, also marked *Ancient, is* in principle a single-acting tumbler-lock; that is, one in which the tumbler may fail to be lifted high enough, but cannot be raised too high, to release the bolt: whereas a double-acting tumbler, being susceptible both of too much and too little ascent, must be raised to one definite and precise height to attain the required object.

No. 5, an *old English lock,* exhibits a great advance in principle, being provided with the double action just described AS being wanting in No. 4.

No. 6, *modern English* (no maker's name), is a single-acting tumbler-lock.

No. 7, by *Mace* is a double-acting tumbler, but without exhibiting any peculiarities of construction.

No. 8 is *Somerford's first patent.* It is a double-acting *draw* tumbler-lock; that is, there is a tumbler which is drawn down instead of being lifted, as in most locks.

No. 9, designated, we know not on what grounds, an *Indian* lock, has a single-acting tumbler with a pin.

No. 10, patented by Thompson in 1805. In this lock there are two tumblers, one of which is single and the other double-acting.

Next follow a considerable number of locks, which differ one from another too slightly to render any formal description necessary. No. 11, by *Daniells,* is a single-acting tumbler, differing only in form from those previously used. No. 12 is by W*alton.* No. 13 is *Barron's* first patent, taken out in 1774. No. 14 is by *Bickerton.* No. 15 is a *Dutch* lock. No. 16 is by *Duce* senior. No. 17, by *Sanders, is* a lock with four double-acting tumblers. No. 18, patented by *Cornthwaite* in 1789, is so nearly like Sanders's, brought before public notice in 1839, as to corroborate what we have said concerning the identity, or at least close resemblance, of inventions widely asunder in point of time. No. 19 is by *Richards and Peers.*

No. 20 is *Somerford's* second patent; a lock which seems to embody the principle of Hr. Tann's "reliance-wards," patented many years later. No. 21 is *Rowntree's* lock, patented in 1790. No. 22 is the first patent lock of *Duce* junior, dated 1823. No. 23 is *Parsons'* first patent, of 1832. No. 24 is *Bickerton's* second. No. 25, patented by Price in 1774; this, so far as at present appears, was the first lock ever constructed with four double-acting tumblers, bearing a closer resemblance than would generally be supposed to those patented by other persons in more recent years. No. 26 exhibits a somewhat similar coincidence. It was introduced by Aubin in 1830, and is furnished with a *revolving curtain* for the purpose of closing the keyhole during the revolution of the key. Other inventors have since then adopted the revolving curtain; and in a patent taken out so recently as 1852, this appendage is claimed as part of the patent.

No. 27 *is Barron's* second patent, dated 1778; a lock which has perhaps been the model for a larger manufacture of plain simple tumbler-locks then any other. No. 28 is by Bird, 1790. No. 29 is the second patent of *Duce* junior. No. 30 is *Ruxton's,* 1818. No. 31 is *Chubb's* simplified lock, 1834. No. 32 is by *Marr.* No.33, by *Tann, is* the "reliance-ward" lock adverted to above as having been anticipated, in respect to its leading principle, by *Somerford's* second patent. No. 34 is by *Hunter,* 1833. No. 35 is *Parsons'* second patent, of the same year. No. 36 is by *Lang,* 1830. No. 37 is *Lawton's* dated 1815. No. 38, patented by *Strutt* in 1839, has an arrangement for holding the tumblers, in the event of a pressure being applied to the bolt; an arrangement bearing a considerable resemblance to one recently adopted in Chubb's bankers' lock. No. 39 is by *Scott,* 1815. No. 40, *Chubb's* patent of 1818, is the original detector-lock of this maker. Most

of the detectors since patented by various persons are little other than variations of Chubb's original.

No. 41, *Parsons'* third patent of 1833, is a *changeable* lock of peculiar construction. The elevation of the tumblers is regulated by an adjusting-screw passing through the lock to the inside of the door; this screw changes the positive but not the relative positions of the tumblers; so that the same difference in the steps of the key must be retained, the change being made only in the length of the bit: the number of changes for each lock is very limited.

No. 42, invented by *Pierce* in 1840, seems to be a carrying out of the plan suggested by the Marquis of Worcester in his *Century of Inventions,* where he says that "a lock may be so constructed that if a stranger attempteth to open it, it catches his hand as a trap catcheth a fox; though far from maiming him for life, yet marketh him so, that if once suspected he might easily be detected."

In Pierce's lock a steel barb or sharp arrow-head is concealed below the keyhole, in such a manner that if any person in attempting to open the lock should over-lift the tumbler, the barb would be thrust by a spring into his hand. It is said that the patentee himself experienced the efficacy of this invention, by receiving the barb into his own hand.

No. 43, by *Burton,* patented in 1816, is furnished with a tell-tale, so arranged that if the tumbler be over-lifted in an attempt to pick the lock, a pin or catch is thrown out from the lock, which would be visible on opening the lock with the proper key. This invention preceded Chubb's detector by two years, and would be entitled to some of the honors of originality were not Chubb's arrangement much more simple and effective.

No. 44 is *Bramah's* patent of 1784, and the crowning lock of the trophy, by which all the others are opened. Similar locks by *Russell* and *Mordan* are applications of the Bramah principle, with little or no variation.

No attempt has been made in these pages to describe every variety of lock that has been introduced. Several forms of puzzle locks, known as *Russian* and *Chinese Locks,* have the forms of various animals, and they are locked and unlocked by pressing upon or moving some portion of the body of the animal: the security of such locks depends in many cases upon keeping the part to be

pressed or moved secret.

There are also various forms of alarm locks; but these do not greatly differ from common locks, except in having certain appendages, such as a pistol, which if loaded and properly adjusted, will be fired on any attempt being made to open the lock, either with its own key or some other instrument.

Some locks are furnished with a bell or a rattle, which is rung or sprung on attempting to open the lock, and in this way the inmates of the house are informed of the attempt to effect an entrance. It will, however, be evident to anyone who has read the preceding pages that devices of this kind do not add to the security of the lock; they rather tend to degrade the art of the locksmith to that of the toy-man. The locksmith, in common with every other artist, can only improve in his art by studying the principles upon which it rests, and illustrating them by the most approved examples which the constructive genius of his predecessors or contemporaries has furnished.

APPENDIX.

CHAPTER THIRTEEN: On an Improved Construction of Lock and Key

*By J. Beverley Fenby, Mechanical Engineer, of Birmingham. Extracted chiefly from the Proceedings of the Institution of Mechanical Engineers, 1866.

THE simple fixed-guard or *warded* lock is SO utterly worthless for security, no matter what amount of good workmanship be bestowed upon it, that it demands but short notice. It was contrived with the intention of making the passage to the bolt intricate; but it will be seen at once that this intricacy does not really offer any security. The wards of a lock are circular arcs of thin metal, so arranged as to require a key of peculiar pattern to pass amongst them, the shape of the cuts in the key being a

section of the wards. The fixed-guard or warded lock was the one in general use in the middle ages.

To make a really complicated box of wards, and to cut keys which shall accurately fit their sweep is a matter requiring considerable manual dexterity; and some warded locks are therefore expensive. But even with the best of them, all that it is necessary to do for opening the lock is to take a blank key which will properly fit the keyhole, coat it with wax, and then inserting it in the lock, press it round against the wards, which will cause them to leave an accurate impression of their section on the key.

The parts impressed are then cut out with small files, drills, and saws, and the occasional use of fine cross-cut chisels. The key will then pass those wards which impressed themselves upon it; and if these are the only wards, it will go completely round and open the lock. If there are also other wards in addition, not brought up flush with the first wards, the key is waxed again and pressed against them, and then further cut out as before. This process is evidently one of absolute certainty, and the key so made is in all respects as capable of mastering the lock as the original key.

These warded locks are however easily opened with merely a piece of bent steel wire, bent into such a sweep as will reach right round the wards instead of passing amongst them, thus escaping all chance of being obstructed by them. Such an instrument *is* called by burglars a "twirl."

The next kind of lock is the *tumbler* lock, in which the bolt is moved backwards and forwards by the key as usual, but these movements cannot take place until a small lever with a stump on one side be lifted. This lever and stump form the tumbler, which is held down by a spring; and in the tail of the bolt are two notches, into one of which the stump fits when the bolt is shot, and into the other when it is withdrawn. All that is necessary to effect the picking of this lock is to lift the tumbler high enough for clearing the stump out of the notch, and then draw back the bolt. The tumbler may be lifted with one pick, and the bolt drawn back with another; but generally one pick will suffice for both purposes.

In the Barron tumbler lock the principle of double-action was introduced. The next improvement was the *lever* lock properly so called, under which designation the majority of the modern locks

may be classed.

The Bramah lock was an admirable contrivance with remarkably beautiful mechanism contained in a small compass; and since its invention there have been several ingenious modifications of the same principle in different radial locks, such as the Yale lock, in which the slides move radially instead of axially. One advantage in these radial locks is the greater difficulty in copying the keys, in comparison with the flat keys of ordinary lever locks: this difficulty however is not an insurmountable one.

A very ingenious addition was made to the action of the lever lock in Newell's American lock, which was shown in the 1851 Exhibition, and described within this present volume.

Though locks such as those already referred to exhibit great dissimilarity of construction, yet there is one point in which they all agree, and that is in the possession of a direct passage from the outside to the works. Although various locks have been devised with the object of having no direct passage to the works from the outside, one consideration shows the inevitable existence of such a passage; namely, that without it the key could not possibly at one and the same time touch the hand of the operator and the works of the lock. It therefore follows that any instrument which can pass in the same space as the key may be brought to bear on the works, whatever may be their construction.

It can now be shown that, if picking instruments are thus brought to bear on the works through the keyhole, there is a regular tentative system whereby the picking of any lock with an open keyhole can sooner or later be effected.

From the foregoing observations it is evident that there are two important defects in the principle of the previous lever locks, which being defects in principle are fatal to their security; namely, the means of access to the works of the lock through the keyhole, allowing of a series of attempts being made to open the lock by picking instruments; and also the facility afforded for repeating the trial of a false key made from a wax impression of the true key, and thus perfecting it by successive alterations after trial.

In consequence of the possibility thus allowed of making these successive attempts either by picking instruments or by a false key, it has been shown by the cases that have occurred of locks

of the best makes which have been falsely opened, that, however numerous and complicated may be the secondary impediments introduced into these locks, there can be no real security against the ultimate success of sufficiently numerous and persevering attempts, except by the adoption of some new principle of construction specially meeting the above two defects.

In the invention of the Improved Lock and Key now to be described, and which has been termed the ***adytic*** lock, the writer's object has been to meet this requirement. In **figure 53** is shown an elevation of this lock, such as is made for an iron safe; two of the front cover plates being removed to show the construction.

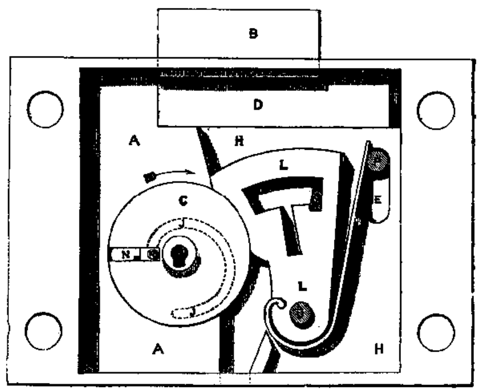


Figure 53

The head **B** of the main bolt is of such a thickness as to be flush with the face of the levers **L** and guard **A;** and the strap or tail **D** of the bolt is thin, and passes behind the levers and guard, and also behind the plate **H H.** The part of the tail **D** which would lie under the levers **L** and cylinder **c** is removed, as seen in **figure 54**, and replaced by a separate flat plate or stump-bolt, carrying the stump **S.** This stump bolt has a projection **K** upon it, let into a recess in the tail **D** of the main bolt, but with 1/10th inch vertical play in the recess. A spring in the tail of the main bolt presses the stump-bolt downwards, keeping the stump **s** in the notches of the levers **L**, as shown in **figure 54.**

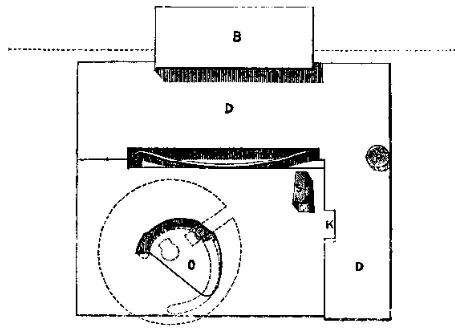


Figure 54

The stump-bolt can thus descend 1/10th inch at first without moving the main bolt, and this amount of vertical movement is sufficient to carry the stump in and out of the notches in the levers; but the stump-bolt cannot descend further without taking the main bolt with it.

Immediately in front of the bolts come the fixed plate **H H.** in which is cut the cam groove shown by the dotted line **J J**; and also the vertical slot **E** for the pin **P** to work through, together with another vertical slot in which the stump s fits and works. This plate carries the center pin **u** on which the levers **L** turn.

The levers are six in number, though any other number may be used; and they occupy collectively 3/8ths inch thickness. In front of the plat **H** is fixed the guard **A**, which is made of iron or steel, and has the brass cylinder **c** ground into it.

The guard is made a shade thicker than the levers **L** in order to prevent the back plate **H** and the corresponding front plate from being so tightened on the levers as to impede their freedom of movement. The cylinder **c** is the same thickness as the levers, excepting the center boss **F**, which projects from the back of the cylinder and works in a bearing in the back plate **H** and also projects in front through the thickness of the two front cover plates.

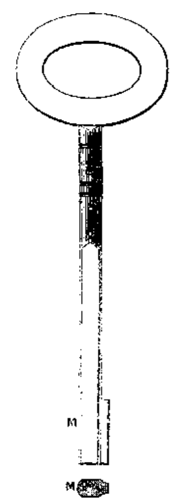


Figure 55

The small keyhole in the center of the boss goes only a short distance into the cylinder **c**, being merely for the purpose of enabling the stem of the key **M figure 55**, to turn the cylinder; the bit of the key is a separate piece, **N. figure 57**, which is inserted through a separate keyhole into the radial slot of the

revolving cylinder **c**, as shown at **N** in **figure 53**.

This radial slot is cut in the side of the cylinder **c** that is furthest from the levers when the cylinder is in the position shown in **figure 53**; and in the slot fits the slide block **R** which is a steel block having a pin projecting on each side. The back pin enters the guide groove ***J J*** in the back plate **H.** as shown by the dotted line, and the front pin enters the corresponding guide groove in the front cover plate, which is shown removed. The back pin of the slide block projects through the back plate **H.** as shown in **figure 56**, and works in the cam groove **o** in the tail of the stump-bolt **s**, **figure 54**, which is so shaped that as the slide block travels round the guide groove ***J J.*** shown by the dotted lines, it moves the stump-bolt vertically as may be required according to the position of the bolts and levers.

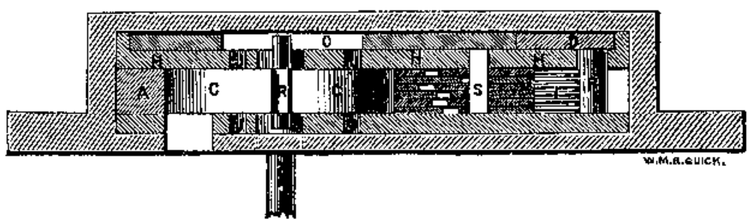


Figure 56

In the position of the lock shown in **figure 53**, the bit **N** has been inserted into the vacant space of the radial slot in the cylinder **c**, in front of the slide block **P**. The size of this vacant space is 3/8ths inch long by 1/8th inch wide and 3/8ths inch deep; and in the two front cover plates of the lock, and also in the door to which the lock is attached, a hole is made of the same shape. In the door there is no bearing for the center boss **F** but only a small keyhole corresponding in size with that in the boss **F** for
inserting the stem of the key.

In the position of the parts shown in **figure 53**, it will be seen that the levers **L** are held pressing down against the circumference of the cylinder **c** by their springs **I** bearing against the pin **P**. In this position also the bolt spring between the main bolt and the stump-bolt, **figure 54**, presses the stump **s** down into the notches of the levers, so that the levers are completely locked by the stump, as seen in **figure 53**.

In order to unlock the lock, which in **figure 53** is shown with the

bolt shot, it is necessary that all the gatings **G** in the levers should be brought precisely under the stump **s**. Through the center keyhole **F** there is no communication possible at any time with the levers **L** nor will any instrument, however slender, if passed into the radial slot through the aperture at **N** be able to reach them, whether the cylinder **c** be in the position shown in **figure 53** or turned round into any other position. For the only difference made by turning the solid cylinder **c** is that the radial slot in it is carried away from the aperture in the external plates, and the solid part of the cylinder is brought opposite to the aperture, which is thereby completely closed against the insertion of a picking instrument.

This construction accordingly not only precludes the possibility of opening this lock with an ordinary key, in which the part that acts on the levers is attached to the stem of the key, but it also renders it an absolute impossibility to introduce a pick of any form, as nothing can reach the levers except a detached piece of such a size and shape as to be capable of traveling round in the vacant space left in front of the slide block **R** in the radial slot of the cylinder **c**.

For the purpose of unlocking the lock, the bit **N**, **figure 57**, is used This bit is of such a size as to fit into the vacant space of 3/8 x 3/8 x 1/8 inch in the radial slot of the cylinder **c**; and the indent at **v** is merely for the purpose of ensuring the insertion of the bit in the right direction, the external aperture for the bit being made with a corresponding projection to fit the indent in the bit. This bit being inserted through the aperture in the door, is pushed in by means of the key stem **M**, which is flattened on two sides for that purpose, as shown in **figure 55**; and the bit is thus pushed home into its place in the radial slot of the cylinder, as shown at N, **figure 53**.

The key stem **M** is now inserted into the center keyhole **F**, and the cylinder is turned round by it in the direction shown by the arrow, carrying round the slide block **R** and the bit **N**. The slide block **B**, while moving through the concentric portion at the commencement of the guide grooves ***J J***, does not affect the bit; but by means of the cam groove **o** in the tail of the stump-bolt, **figure 54**, it moves that bolt so far as to lift the stump **s** completely out of the notches in the levers **L** which are thereby left free to be raised. On continuing to turn the cylinder **c**, the eccentric part of the guide grooves **J J** causes the slide block **R**

to move outwards along the radial slot, pushing the bit **N** before it; and the bit is thus made to project beyond the circumference of the cylinder, which it can then do, being no longer confined by the guard **A**.

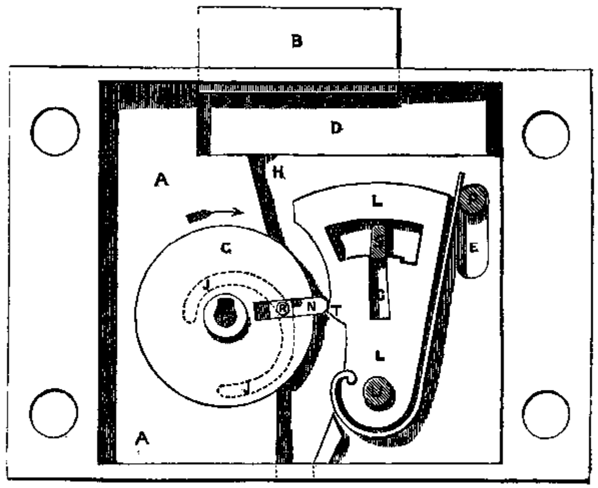


Figure 58

The further projection of the bit as the cylinder revolves causes the steps in the bit to lift their respective levers; and the steps in the bit are so arranged that, when the cylinder arrives at the position shown in **figure 58**, all the gatings **G** are brought simultaneously opposite the stump **s**, which is instantly shot down through the distance of the 1/10th inch play by the bolt spring. The bit **N** remains in contact with the extreme part ***T*** of the levers while the stump **s** is entering the gatings, the action of the bolt spring being so rapid that the bit cannot move through any appreciable distance during the time.

In other locks a spring action of this kind would greatly facilitate the picking, inasmuch as it would afford the gentle uniform pressure desired upon the levers. In other locks, therefore, the bolt is caused to move, and the stump to enter the gatings, by the direct contact of the key with the bolt, instead of by a spring; but as the key, while moving the stump into the gatings, is also altering its position under the levers, a slight tremulous motion of the levers is thereby occasioned, which no care in manufacture can obviate.

This tremulous motion is aggravated by the circumstance that, as the keyhole is open to inspection, it is necessary to make all the levers fit flush with one another when down, in order to

avoid affording any clue to the shape of the key from the positions of the levers; but as the various steps of the key, being of different lengths, describe different arcs, the curves of the levers when raised are of necessity in error to them all.

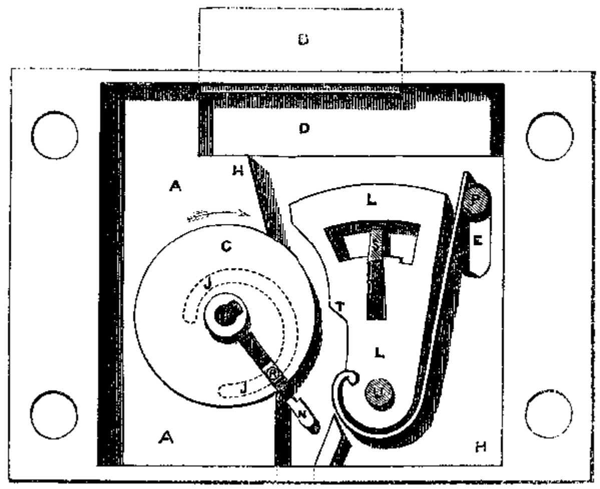


Figure 59

The result of these combined faults is that the gatings have to be made wider than the stump, to allow a sufficient amount of play, thus introducing a fatal element of insecurity in the construction of the lock, since the security is of course enhanced in proportion as the gatings fit the stump accurately.

In the new lock, on the contrary, the arc ***T*** **figure 58**, in each lever, can be shaped truly to its own proper radius, independent of all the rest of the levers; and as the action of the stump is instantaneous in catching the gatings as soon as they are all brought simultaneously under it, the stump and gatings can be made to fit one another with the most perfect accuracy, and without the slightest play.

On turning the cylinder **c** further round, the bit **N** passes from under the levers, which remain held back by the insertion of the stump in the gatings; and just before reaching the position shown in **figure 59**, the slide block **R** has pushed the bit completely out of the radial slot, and the bit falls down as shown in **figure 59**, and drops through a hole into the inside of the safe that is locked.

At this point the back pin of the slide block comes in contact with the lower side of the cam groove **o** in the stump-bolt, **figure**

54; and by turning the cylinder **c** onwards to the position shown in **figure 60**, the withdrawal of the bolt **B** is completed, bringing the parts into the position shown in **figure 60**.

In these drawings only one lever **L** is shown; but there are altogether six levers, as shown in the sectional plan, **figure 56**. The pin **P** is fixed in the tail **D** of the main bolt, so as to travel with the bolt; and by this means the springs **I** are released from strain, as shown in **figure 60**, as soon as the bolt is withdrawn.

From the nicety with which the various parts of this lock are constructed, it is evident that the levers must be very accurately lifted by the bit of the key in order to withdraw the bolt; and therefore any error in the bit, such as would occur with a false bit, will effectually prevent the lock from being opened. This may be illustrated by supposing the false bit to be so close an imitation as to have five of its steps absolutely correct, and the sixth only slightly wrong: though it is almost impossible that such a near approach to correctness could be attained in practice.

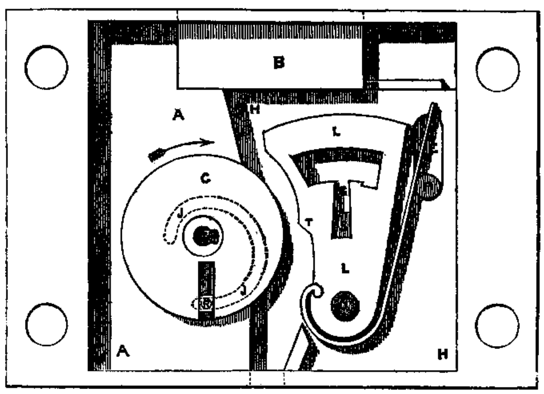


Figure 60

The counterfeit bit being inserted in the lock, and the cylinder turned round, all will go on the same as with the true bit, up to the time when the false bit reaches the point **T** of the levers, as previously shown with the true bit in **figure 58**. Here a change of action takes place; but what is the nature of the change the operator has no means as yet of ascertaining. In the case supposed, where five of the steps in the bit are right, but the sixth is wrong, the gating of the sixth lever does not precisely coincide with the others, nor with the stump **a**; and the consequence is that, at the critical moment when the stump ought

to spring into the gatings and hold back the levers from falling forwards, it will be prevented from entering the gatings, owing to the entrance being partly blocked up by the one lever, which stands more or less across it.

The fact, however, that the stump cannot enter the gatings does not become known to the operator until the cylinder c has been turned further round, so as to bring the slide-block pin in contact with the lower side of the cam groove **o** in the stump-bolt; and before this point has been reached the false bit has already passed clear of the levers, which, not being retained by the stump, are instantly thrown forwards again by their springs, and locked in their original position by the stump entering the notches. At the same time the false bit has dropped into the inside of the safe in the same manner as the true bit, as shown in **figure 61**.

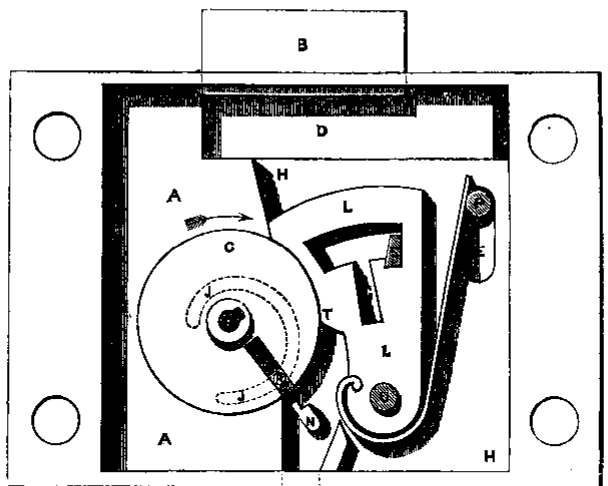


Figure 61

Hence a person putting a false bit into one of these locks will not only infallibly lose it at the very first trial, but will do so without gaining any information as to the nature of its inaccuracy; for as the gatings of the levers cannot be seen or felt, all that can be told about the action of a false bit is, that it has failed to open the lock. In fact, a counterfeit bit passes under the levers, and through the lock, just like the true bit; and it is only the stoppage afterwards met with of the bolt that indicates the failure of the false bit, which is by that time gone beyond recovery. Whatever amount of labor therefore, may have been spent on the fabrication of a counterfeit bit, this bit can only be tried once, so that no alteration can afterwards be made in it.

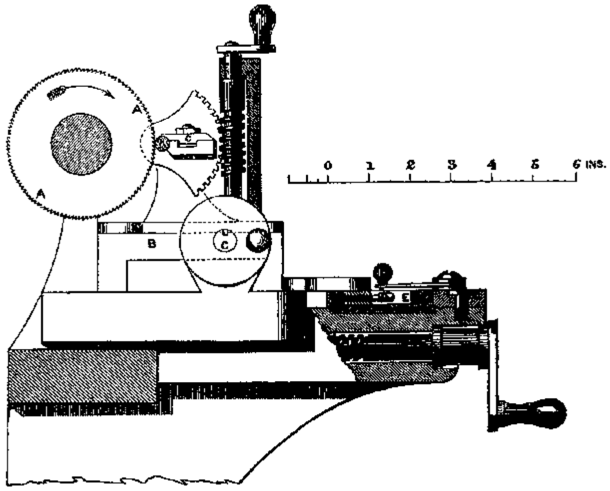
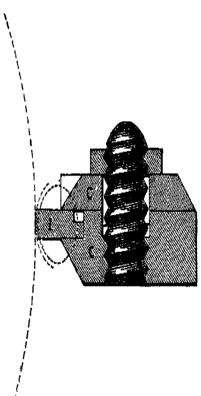


Figure 62

Nothing that can be inserted into the radial slot of the cylinder **c** through the aperture in the front plates can do any injury to the lock; and a charge of gunpowder inserted in that way would only blow out again at the orifice without damaging the lock, both the apertures for the key being merely blind holes with parallel sides.

For the manufacture of the bits for the keys of this lock a self-acting machine is employed, in which the height and width of the several steps in the bit are regulated by adjustments of very great accuracy, and admitting of an almost endless variety of figure for the bits. This key-cutting machine is shown in **figures 62 to 64**, and consists of a small circular saw **A**, running vertically, of the same thickness as each step in the bit **I**, which is brought up to the saw by the slide-rest **B**. The bit **I** is fixed in the holder **c**, which rocks upon a center so as to give the required curvature to the edge of each step in the bit when cut by the saw, as shown in the full-size section of the bit-holder, **figure 63**.



Figur

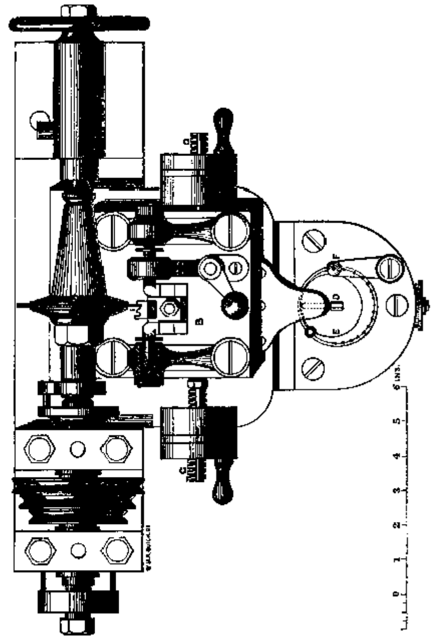


Figure 64

The adjustment of the depth of cut is effected by the setscrew **D** upon the slide-rest. Coming up against the eccentric ring **E** upon the bed of the slide-rest; this ring is turned round by hand, and set to sixteen different positions by means of the catch-pin **F** and the sixteen holes on the circumference of the ring, allowing of sixteen different depths of cut.

The lateral adjustment for the pitch between the successive steps of the bit is effected by the two bed-screws **G G** acting on the slide-rest **B**, having a dividing plate on the head, and such a pitch of thread that one turn of the screws traverses the slide-rest through the exact distance of one step in the bit.

The occurrence of any play or backlash is entirely prevented by having the screws placed one at each end of the slide-rest; so that by slacking back one screw through one or more turns, and then advancing the other through the same number of turns, the slide-rest is always held with perfect steadiness between them, filling exactly the space between the ends of the two screws.

The number of changes admissible in this key-cutting machine, if used for making keys for locks having six levers, is the number of permutations that sixteen terms are capable of when taken six together, which is upwards of sixteen millions. Some of these changes are so slight that too great accuracy of workmanship

would be required to make the locks accordingly; but of those changes that differ from one another so far that no lock could be opened by any other than its own key, more remain than could be used up by all the locks in the world.

The writer may observe that it was the study of the circumstances of the great gold robbery on the 15th of May, 1855, by Agar and his confederates (when two of the best lever locks were picked, and gold stolen weighing upwards of 200 lbs., while in transit on the South-Eastern Railway from London to Paris, packed in three sealed iron-bound boxes, enclosed in a bullion safe, secured by those locks), and of the various modes of picking locks, which led him to turn his attention to the achievement of what had been so long and perseveringly sought after, namely, an unpickable lock.

The principle of a detached bit has been previously tried, in so far as that locks have been made in which the bit of the key was deposited in the lock by unscrewing the key stem, and then withdrawn by screwing in the stem again. But inasmuch as the detached bit, even though it failed to open the lock in the case of a counterfeit key, could always be brought back again to the keyhole and removed, this admitted of a repetition of attempts with successive alterations of the one counterfeit key, without the certainty that any warning would be given by the lock of such attempts having been made.

In another still more complicated lock with a detached bit there were two keyholes, into one of which the bit of the key was put, and the stem being then unscrewed from the bit, was put into the second keyhole and turned round so as to close the first keyhole over the bit; a separate handle was then turned to work the lock, six separate operations being required for either opening or closing the lock.

Further, a kind of retainer has been attempted by so arranging the lock that, if any key was put in but the right one, it was held in the keyhole in such a manner that it could never be got out. In this case, however, if the false key would not open the lock, neither would it let even the right one do so, and it would be necessary to break open the door secured by the lock.

In the new lock here described, the special points that have been aimed at are the following:

Firstly, in no position of the lock is there any access to the

works from the outside through the keyhole. This access through the keyhole is more or less a defect in all other principles of lock, as it admits of feeling and manipulating the works for the purpose of getting information for picking the lock in the absence of the right key; whereas in the new lock there is no opening whatever at any time, except the two plain parallel recesses into which the key and the bit are fitted.

From the moment the turning of the lock commences both these recesses are effectually blocked up: the one for the bit being conveyed bodily away from the keyhole, and its place taken by the solid metal of the cylinder; while the other is completely filled by the key, which cannot be withdrawn except by turning it back to the original position.

In consequence of this construction, no injury can be done to the lock by explosion of gunpowder in the keyhole, the only openings from the outside being parallel at their sides, and not communicating with any portion of the interior of the lock; and the simplicity and solidity of construction are such that the revolving cylinder is made practically air-tight within its bearing. This effectually prevents all attempts to open the lock by picklocks, and leaves no alternative but the attempt to make a sufficiently accurate copy of the true key.

Secondly, as no clue whatever can be obtained from the outside of the lock respecting the key required, the attempts upon the lock are thus limited to the chance of obtaining a wax impression of the true key. The difficulty of making a counterfeit key sufficiently correct by this means for opening one of the best of the previous constructions of lock is very great; but in the new lock this difficulty is greatly increased by the fact of the levers remaining absolutely stationary while the stump enters the gatings in consequence of which the gatings are made so close a fit to the stump that an exceedingly minute error in the lifting of any of the levers is sufficient to prevent the lock being opened.

This extreme delicacy of construction can be carried out practically without objection in the new lock, because there is no possibility of putting a strain from the key upon the stump, so as to cause injury by forcing it at the moment of entering the gatings, for the only force acting upon the stump at that time is the uniform pressure of its own spring.

In addition to this source of increased safety, there is the

still more important circumstance that only a single trial can be made of each counterfeit bit; because, if carried forwards far enough to try its effect in opening the lock by passing the levers, the bit is inevitably lost by falling through the lock and inside the door. Thus not only is all chance prevented of a second trial with the same key, but the bit retained inside the door gives warning of the attempt having been made, and shows how near the counterfeit key has approached to the original.

The numerous cases that have occurred of attempts to open locks by counterfeit keys, such as the remarkable instance previously referred to, show that even with the most practiced hands it is next to impossible to make from a wax impression a key that will serve for opening a good lock the very first time it is tried; and the striking importance is therefore seen of this arrangement in the new lock, which prevents more than a single attempt being made with a counterfeit.

Thirdly, another advantage to be named in this lock is that the stem alone of the key is required to lock it, but it can only be unlocked by the complete key. The stem, therefore, can be left by the principal of an establishment for locking up by a subordinate; but the bit, which is the essential part of the key required for opening the lock, need never be used or seen by any one but the principal himself.

As the hole in the external door-plate for the stem of the key has a notch on one side only to admit the key stem, and the cylinder is prevented from making a complete revolution, the stem of the key cannot be withdrawn from the lock except when the bolt is shot; so that its absence from the keyhole serves as a proof that the bolt is shot.

Fourthly, one other advantage in this lock is its simplicity and solidity of construction. It contains no more parts than the simpler forms of lever lock having the same number of levers, and the total number of separate pieces in the complete lock is only sixteen. The principle of security, therefore, upon which the new lock is constructed, avoids entirely the complications and the delicate and minute class of work rendered necessary in other locks by the use of detectors and the other auxiliary contrivances employed for increasing the difficulty of picking.

Mr. Fenby exhibited, at a conversazione of the Institute of Civil Engineers, and at the meeting of Mechanical Engineers, specimens of his adytic lock, and showed its action both with the true key

and with counterfeit keys; and he showed by trial that the counterfeit failed to open the lock, notwithstanding that by means of the permutating cutting machine it had been made a much nearer approach to a perfect copy than was practicable in the best handwork from a wax impression.

He also exhibited the key-cutting machine employed for cutting the bits; and also a set of burglar's tools employed for drilling into the door of an iron safe sufficiently for breaking open or removing the lock, showing that the hold required for giving the cutting pressure upon the powerful drill employed for the purpose was obtained by a steel cross-piece inserted into the keyhole and turned at right angles, so as to hold across inside the lock; but in the new lock, as the keyhole had no opening into the lock, and only a slight shoulder on one side, no means were afforded for obtaining the required hold for the drill.

The following are the salient points of the discussion that followed the reading of his paper:

The Chairman remarked that the paper just read "gave a very excellent and clear description of the detailed working of the new lock, and he thought this construction of lock was a most valuable one, as affording real security against all fraudulent attempts. He inquired whether there would be any possibility of tampering with the lock by examining it upon the inside of a safe door, whenever the door might happen to be left unlocked.

Mr. Fenby replied that there was no means of tampering with the lock from the inside of the door, as the two keyholes for working the lock were only in the front face of the door, and the lock was all closed up on the inside of the door, excepting the hole through which the bit was allowed to drop out; but this would be useless for the purpose of tampering with the lock, as the bit dropped down a tube leading to the bottom of the door, through which no examination of the lock could be successfully made.

The Chairman inquired whether there was any provision against the bit being accidentally locked up inside the safe, in which case it appeared the lock could not be opened again.

Mr. Fenby replied that the owner of the safe must of course be careful after unlocking the safe to take the bit out before locking it again, otherwise there would be no means of opening the lock afterwards with that key. As a precaution, however, against any such accident, each lock was provided with three

bits, all duplicates, one of which would be kept in the pocket for use, while the two others would be preserved in a place of safety for the chance of any such contingency.

Moreover, in most of the safes fitted with these locks, the tube through which the bit dropped had been made of such a length as to carry out the bit on opening the door, dropping it into a smell tin tray outside the safe; and by this means the accidental locking in of the right bit was rendered impossible.

One of the advantages of the new lock was that the stem of the key was not required to be kept constantly in the possession of the owner, but it might be left in the lock, as the bit alone was the valuable part of the key; and as the bits were of such small size and convenient shape, a number of them might readily be kept in the pocket by a person having charge of a number of safes, without the inconvenience attending a large bunch of ordinary keys.

In the case of an attempt being made to open the lock with a counterfeit bit, the advantages of retaining the counterfeit inside the safe were not merely that the person attempting the lock was deprived of his instrument, while the proprietor immediately discovered the attempt upon the next occasion of opening the safe; but the retention of the counterfeit itself afforded the means of judging, by a comparison with the true bit, whether the attempt had been made altogether in the dark as to the actual construction of the lock, or whether it was likely that some clue regarding the true bit had been obtained by means of a wax impression or otherwise. In the latter case, the owner of the safe might think it desirable to have the lock taken off, and the arrangement of the levers altered, and a new bit made so as to baffle any further attempts.

Mr. W. S. Longridge observed that the inconvenience that had been alluded to with the new lock, of accidentally locking up the bit inside the safe, was no greater than occurred with an ordinary safe lock if ever the key was accidentally lost; in either case, unless the precaution was taken of keeping a duplicate in reserve, it would of course be necessary to have the safe broken open.

The Chairman inquired how the ideas had been arrived at of separating the bit from the key, and of preventing all access to the works through the keyhole, and also of retaining the bit inside the door after any attempt at unlocking.

Mr. Fenby replied that his attention had in the first instance been attracted to the subject of the picking of locks as a mechanical problem, and he had found that there had hitherto been no principle in lock making which could effectually baffle persevering attempts at picking. For although there were certain complicated constructions of locks, having many points of excellence, they had all yielded in time to the picking instrument in clever hands; and it must be remembered that any individual lock when once constructed remained stationary as regarded subsequent improvement, whereas the art of picking that lock was continually progressing towards success, with all previous constructions of locks, and it was clear therefore that the lock must ultimately be defeated.

He had been further stimulated in the investigation of this subject by the occurrence of the great gold robbery referred to earlier; and the circumstance which had struck him most forcibly in connection with that robbery had been that locks of the best make hitherto known had admitted of seven successive trials being made upon them without detection, each trial furnishing the information for further perfecting the counterfeit key, until the locks were at length opened.

These considerations had led him to the conclusion that two points were established and were required to be kept in view for the construction of any lock that should be really secure against fraudulent attempts. The first point was that wherever a man could get instruments into the lock he could ultimately solve any problem laid before him by the maker of the lock, as the lock when once made could be tried any number of times if an instrument could be got into it at all. Hence he had concluded that it was requisite for all access to the interior to be cut off, so as to preclude all possibility of getting a pick-lock in; and this was accordingly accomplished by adopting the plan of separating the bit from the stem of the key.

The second point established was that it was necessary to prevent the possibility of making a succession of trials with the same counterfeit key; and it had then struck him that, if the bit of the key were arranged to drop inside the safe in unlocking, there would be no means of going on gradually improving and touching up the counterfeit from the results of previous trials, as the false bit would be irrecoverably lost in the very first attempt, without furnishing any clue whatever as a guide for alteration in a subsequent trial.

The first lock that he had invented for meeting the requirements thus pointed out had been made with a solid block having a tunnel through it, but involving the same principle of retaining the bit of the key and keeping the levers inaccessible from the outside. Subsequently, however, he had abandoned that construction and produced the new lock shown in the drawings, having the revolving barrel with radial slot.

The Chairman proposed a vote of thanks to Mr. Fenby for his paper, which was passed.

CHAPTER FOURTEEN: Fenby's Patent Stop-Lock

MASTER EXHIBIT LIST

This lock has been designed with a view to doing away with several weak points in the construction of lever locks.

The introduction of the moveable stump by Mr. Hobbs in order to defeat picking by the tentative method of applying pressure to the bolt, so as to cause binding between the stump and the levers, was a great advance in the art of lock-making.

The moveable stump, as so constructed, was, however, open to this objection, that while sufficiently delicate and certain in its action to render picking very difficult, it was at the same time, through the smallness of its parts, resulting from the confined space available for its action, unsuited to withstand any amount of force applied to push back the bolt.

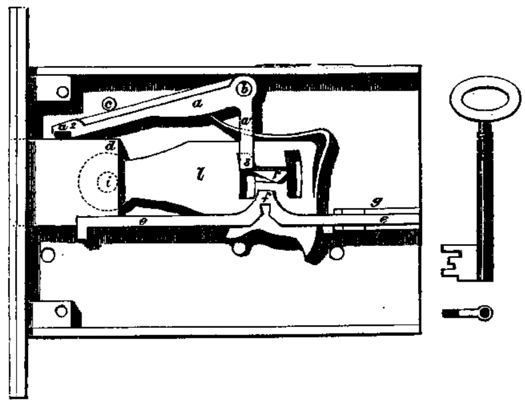


Figure 65

In the look under notice the stump **s** is formed in the solid on the shorter arm **a**^{1} of a cranked lever or oscillating stop **a**. This stop **a** works on the steel pin or center **b**, which latter has a bearing in both plates of the lock. At the end **a** of the stop a is a recess formed to fit the corner **d** of the bolt head. **C** is a stud limiting the range of **a** in an upward direction, so that when in its normal position the stop **a** may just clear the bolt-head, as shown in **figures 65**, **66**, and **67**.

The tail of the bolt, instead of being in the form usually adopted, is formed of the bar **e** set on edge so as to reach from the back to the front plate of the lock, completely dividing the lower part, in which the keyhole lies, from the upper, in which the main parts of the works are placed.

This bar **e** works between the guide pieces **g g** so that in whatever position the bolt may be, the division of the lock into two chambers is complete. At **f** is the recess in which the key acts to move the bolt. The levers **l** turn upon the pin **i** formed in the solid of the bolt-head. The part of each lever on which the key is to act passes through a slot or recess in **e**, the parts **h** and **h**^{1} of the levers being struck to the arcs of circles, having their centers coincident with that upon which the levers turn at **i**.

As it is not possible to lift the levers out of this slot in the bar **e**, and further, as the levers and bolt move together in a longitudinal direction, the movements necessary to locking and unlocking open no communication between the upper and lower chambers of the lock.

The springs of the levers are formed out of the solid metal of the levers themselves, and are thus not liable to that displacement which so often occurs with separate springs, nor to the corrosion by oxidation incidental to steel springs. They are cut round the corner, and down the front of the lever, to gain greater elasticity.

In **figure 65**, the lock is shown with the front plate removed, and the works as they stand when unlocked. **Figure 66** is the same, except that the works are shown locked, and the back plate removed instead of the front. **Figure 67** shows the *front* view of **figure 66**. **Figure 68** shows the result of any attempt to pick the lock by pressure.

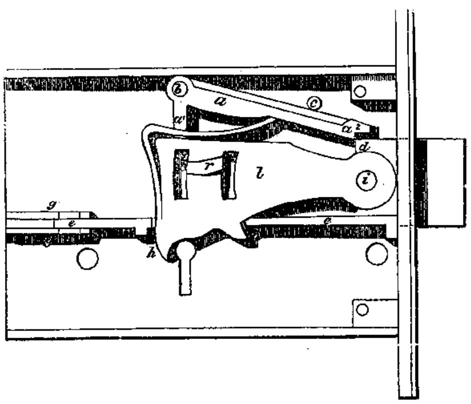


Figure 66

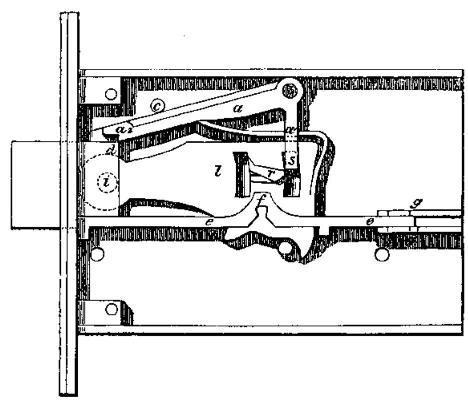


Figure 67

The lock being locked, as shown in **figures 66** and **67**, it will be seen that the stop **a** just clears the angle **d** of the bolt-head.

Further that the gatings **r** of the levers **l** cannot pass the stump **s** unless the levers be so lifted as to coincide with each other and the stump. The stop **a** being held up by a very light pressure from the lever springs, a small force applied to the stump **s** is sufficient to upset its equilibrium, and bring down its end $\mathbf{a}^2$ upon the bolt-head at **d**, as shown in **figure 68**.

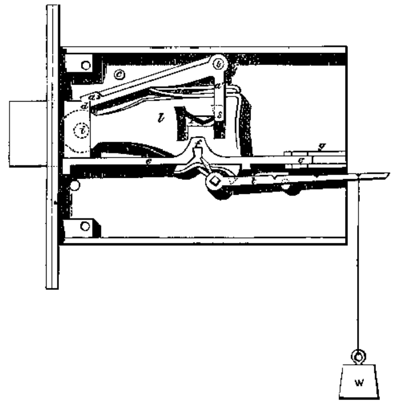


Figure 68

This occurs whenever an attempt is made *to "feel"* the stump with the levers; and not only does the stop **a** free the levers from all pressure, and so preserve them and the stump from injury, and the lock from being picked, but it also forms a strut for securing the bolt: in fact, no violence short of that necessary to shear the pin **b** can make the bolt yield.

The drawings show a mortise lock, but the improvements shown are universally applicable in the construction of locks of all kinds.

For the manufacture of these and other locks, and kindred articles, Messrs. J. B. Fenby and Co., engineers of the Liverpool Works, Birmingham, have put up, from the designs of their managing partner, Mr. J. Beverley Fenby, an experimental set of machinery, almost entirely self-acting, and calculated to turn out large quantities of the component parts of locks and other articles with extreme accuracy and rapidity.

The whole set works on the interchangeable system, as already in use for military small arms. It is not, however, to be supposed that, because the parts of the locks are interchangeable, one key will open several locks, such a source of insecurity being guarded against by the permutating key-cutting machines invented by Mr. Fenby. These machines give complete command over the making of keys, whether it be required to make a comparatively unlimited number, all differing from each other, to make a number alike, or to make sets with master keys. Atmospheric and hydraulic pressure also plays an important part in shaping many of the parts of the locks.

NOTE UPON IRON SAFES

AT the conclusion of this work upon locks it will not be out of place to make a few remarks upon the degree of real safety that attaches to what are commonly called "safes," and to point out in a common-sense way what are the chief dangers that these may incur from depredators (whether burglars or in times of public anarchy and violence), and what are the main conditions to be relied upon for safety; assuming that, by one or other of the constructions pointed out in the preceding pages, the *lock* of the safe be such as to be practically unpickable, and that carelessness shall not have placed the true key in the possession of the thief.

There can be no doubt upon the mind of any mechanic or engineer, thoroughly acquainted with practical working in metals, that a good deal of what has been brought forward and affirmed, both by safe-makers and by burglars themselves (turned approvers), as to the wonderfully-ingenious devices resorted to by the latter, by which, if we were to believe it all, nothing in the shape of steel or iron can possibly withstand ultimately the redoubtable powers of these people, is simply fiction—imaginary ingenuity utterly impracticable if tried.

Such, for example, is the notion of its being possible, by an ounce or two of gunpowder exploded in the interior, to so blow asunder and dislocate the parts of a well-made safe lock that the bolts shall then be easily got loose, or that a steel-plated safe which resists the drill can be softened "by the blowpipe." And just as absurd are some of the wonderful pieces of ingenuity by which some of the burglars' actual devices are supposed to be met and frustrated; as, for example, one for which we believe a patent has been obtained, consisting in filling-in the hollow space between the inside and outside plates of the safe with cast-iron bullets left loose. These might, no doubt, break a flat-stemmed drill after that had pierced the outer plate, but could have no effect whatever upon a round-shanked drill, such as one of the ordinary American spiral, or teredo-pointed drills.

That there are some methods of violence still untried, and yet at the command of the burglar who dares to risk a tolerably loud noise of explosive agents, is well known to skilful mechanical engineers, and for obvious reasons it would be unwise that we should give any information as to such; but the real practical and too-often effectual methods of the burglar limit themselves almost entirely to the use of the succession of steel wedges, followed by the powerful steel-pointed pinching bar, or bars, to the forcing or prizing-screw, and to making more or less way for

this by cutting out beforehand by the pin-drill.

A safe, to be safe, must be so circumstanced or so constructed, or both, that it should be able to resist the best efforts that can be made by these methods for several hours; perhaps we might say as much as thirty to thirty-six hours—viz., from Saturday night to Monday morning.

Now we hesitate not to say that the unsafeness of "safes" arises not from any structural difficulty whatever, but almost always from the parsimony and ignorance of those who purchase and employ them. Safes, like razors, are made to sell, and if the public demand is for cheap safes, such as we see every day advertised in the newspapers, it was sure to have been, and is, met by a supply of things called safes which are utterly unsafe. The great mass of the showy green and gold gewgaws that one sees in the safe-shop windows, with flaming testimonials as to their fire and burglar-proof powers, are simple shams: a genuine safe could not be made at their prices.

The very first condition to constitute a genuine safe is that it shall have an ample mass of metal--i.e. not of cast-iron, but of wrought-iron, or best of steel, all around it; and especially that the margins of metal all round the door shall be of such huge and surplus scantling that no amount of wedging, by construction possible, should be able to bend any one side sensibly.

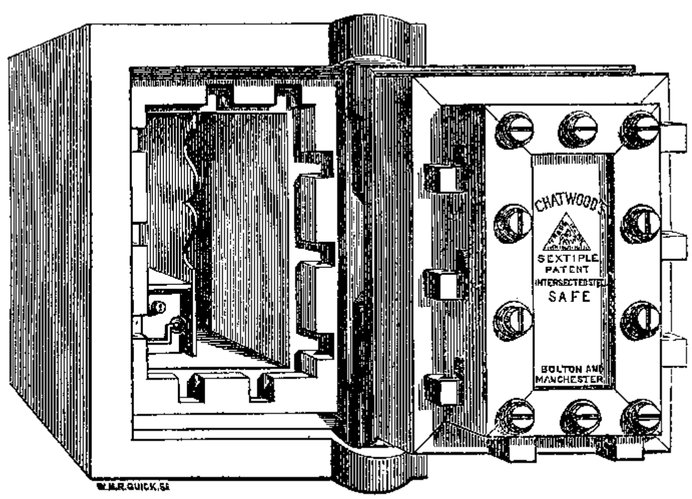


Figure 69 Chatwood's Safes.

The next is that the workmanship of every part of the safe be first-class: not that there be merely a molded door with a showy

lock and a trumpery brass-plate upon it, but that every corner and joint of plate with plate in sides and back be effectually united and jointed in the best manner, and that the fitting of the hardened edges of the door shall be like those of a valve, and not even let a watch-spring be got in between. If these obvious conditions be observed, and that the safe itself be properly posited in the premises, it will be found, even with ordinary forms of construction as to doors and bolts, but with a really unpickable lock, a very hard nut for the best burglar to crack.

But much more may be effected without any serious increase of cost. Several forms of safes are now made, the rabbets of the doors of which are so formed that it is almost a physical impossibility to get any wedge, however thin, to drive in between the door and the frame. This is effected in Chatwood's patent safes (of Bolton and Manchester), as figured above, by making the door rabbets in cross section curvilinear so that even if the fit be not so perfect but that the edges of a very thin wedge can still be inserted, it yet cannot be driven, for as it goes forward, it must become curved, and if soft, so as thus to bend, the thin steel will not bear the severe strain of driving, but if hard, it breaks off into short bits close to the entrance.

In addition to this Chatwood's (and we believe other maker’s) safes have bolts so constructed, as seen in the **figure 69**, that they *hook* or lock into the bolt recesses in the frame in such a manner as to hold the opposite sides of the frame together, so that, independent of its own proper stiffness, it cannot be bent anywhere, unless by tearing asunder the end on the iron bar constituting each cross-bolt. The bolts, in fact, not only secure the door (as in ordinary) from opening, but secure the door and frame together. With such a safe, if the owner will only provide a proper position for it in his premises, he may rest pretty easy in mind.

Safes are very commonly stood upon a wooden floor, or made to form part of a wood-framed bookcase, or press, or stand in a recess. Often they are comeatable all round, and even underneath, with nought but an inch board below them, and almost always they are left with the front door freely and fully exposed, and with ample and convenient room left all round. This for two or three workmen to manipulate the safe as they may.

Now the only real conditions of safety are that the iron safe should be bedded into brickwork set in Portland cement and sand;

or, what is much better, in hard granite or gritstone masonry, bedded in like manner. Without this be done, a fire-proof safe is simply a delusion; constructed how it may be, it is only a crucible of more or less badly-conducting power, in which, after a time longer or shorter, deeds, bank-notes, documents, etc., will be calcified, and coin or jewelry melted, and gems flawed and destroyed.

We say this in the full face of the delusive so-called "fiery ordeals" to which many of the so-called double-cased fire-proof safes are alleged to have been for hours exposed. The safe should always be embedded in masonry, and rest upon that in such a way that it cannot get undermined by either fire or burglars.

Whenever the premises admit of it, the door of the safe itself should be set back ten or twelve inches from the face of the wall in which it is embedded, and an outer door, flush with the face of the wall, should be provided of iron, with a good lock and multiple bolts. The door of the safe should open to the right; and if so, the outer door should open to the left; and neither should open more than square to their position when shut.

No one but a practical workman or engineer can have an adequate notion of the extent to which any mechanical operation upon the door of a safe thus circumstanced is hampered by its being set back into the wall, and with an outer door that even when open, cuts off all ready manual access to the inner door from one side.

When premises are constructed, as they should be for all banks and bullion merchants, jewelers, etc., having special regard to a safe as an indisputably secure depository, then the safe should be completely iron or steel cased, and embedded in hard stone masonry (we shall not here go into additional special precautions against the remoter effects of fire), covered in with a strong fire-brick arch, and with nothing but the solid ground below.

The door of the safe should only be approachable through an iron or stone-lined passage, just the size of the safe-door, and no more. This should be some feet in length, and have an outer double cased steel door, or perhaps that and an intermediate iron falling-door or portcullis, between the outer door and the safe-door. With a safe-door so circumstanced, even supposing both these outer doors forced and open, it is almost impracticable for even a single workman, however agile or adroit, to perform any mechanical operation whatever upon the door, least of all upon its surrounding rabbates. These are so close to the solid granite

walls, starting out at right angles from the rabbate all round, that he has no room to do anything; and to get a prizing-bar at the door-rabbate or even to get a second man to assist the first in any way, is impossible, simply for want of room.

The whole of the doors and all the surfaces of such passage should be painted a dull, lustreless black. No one who has not tried it, has any idea of the difficulty of illuminating such a black passage, by even several candles, sufficiently to perform any delicate mechanical operation; and good light is essential to the safe-breaker.

In banks there is no better plan than has been here now adopted of making the iron safe a great cube, with the door at one side, placing the whole safe with its bottom resting upon the stem or plunger of a hydraulic press, the cylinder of which is fixed in the bottom of the pit in the solid earth, of a size capable of enabling the whole safe to be bodily lowered down into the cavity at the end of the day's work, and pumped up again out of its hiding-place the next morning.

The lever of the hydraulic pump is taken away, and the socket into which it fits is plugged, and the plug locked into its place, and then the pump, situated in a recess in solid masonry, is itself locked up. The top of the safe itself, when it has been lowered to the bottom of its chamber, stands ten or twelve inches below the floor-level of the stone floor, and a pair of iron doors is then closed over it and locked down.

A safe executed in this way, though requiring a considerable expenditure at first, if well done, might bid defiance to anything almost, even unlimited gunpowder, for some days. The only addition of safety that almost could be conceived would be that adopted at the bullion vaults of the Bank of France in Paris, where these, situated in casemates two stories under ground, are only approachable by one narrow, winding staircase, which can be itself, in case of emergency, rapidly rendered useless, and the cylindrical well in which it is placed filled up with about thirty feet in depth of water, which cannot be pumped out until a continuous supply be shut off by distant means only known to one or two trusted employee.

Since this revision has been in type the great "safes” contest or wager of battle between the rival safes of Mr. Herring of New York, and Mr. Chatwood of Bolton, for £600 a side, has come off, at the International Exhibition, Paris, Mr. R. Mallet and Mr.

Robert F. Fairlie, C.E., being the representatives of the English interests upon the occasion.

The result, which, owing to the conduct of some of the parties concerned, assumed an unpleasant and incomplete form, may be found detailed fully in a pamphlet published by Tinsley Brothers, London. It is referred to here because, although no decision of the wager made could be come to, the facts ascertained are of great interest and importance as respects the proper construction of safes. They show conclusively that an effectively constructed door and jambs is really the one thing needful to absolute security, provided the safe itself be built up, as we have urged, into masonry.

They also show that there are good grounds for doubting that the American (Herring's) "safe within safe" construction, with a thick mass of so-called fire-proofing powdery composition between them, is at all as protective against mere violence and the persevering use of wedges, as Chatwood's simpler but far more effective construction, especially of his door and jambs. If one of the latter safes, wholly of steel plating, be fairly embedded into masonry, and another outside flush door of his construction, with curved rabbates and hooking locking bolts, be supplied to the masonry open itself, it is scarcely an exaggeration to call such a safe "Invincible," so far as anything that burglars, in any civilized place in Europe at least, can effect.

LONDON: Simpkin, Marshall, and Co.

The First Edition was published in 1856

The original work was edited and rereleased by Marc Weber Tobias in 2002, in conjunction with the publication of Locks, Safes, and Security, Second Edition.

Master Exhibit Summary

Chapter 9 The best place for a Fire-Proof Safe to Occupy

Chapter 10 On Powder-Proof Locks

Chapter 11 On the Comparative Prices of Wrought-Iron Fire-Resisting and Thief-Proof Safes

Chapter 12 On Testimonials

Chapter 13 Early History

Chapter 14 On the Old Locks and Keys

Chapter 15 The Lock Controversy previous to and during the Great Exhibition of 1851

Chapter 16 On the Modern Locks

Chapter 17 The Lock Controversy since the closing of the Great Exhibition of 1851

Chapter 18 On Keys

Chapter 19 The various kinds of Locks and their Comparative Prices

PREFACE to the FIRST EDITION

The substance of the chapters in "Fire and Thief-Proof Depositories" was Dublin, and in the town of Belfast. But for ill health, they would have been delivered in some of the cities and towns of England.

Having been repeatedly requested to publish it, and the press having given it a complimentary and approving notice, I have done so, in the hope that it may throw some light upon a subject very imperfectly understood, not only by the general public, but by those whose interests ought to make it a subject of deep

consideration.

It is almost incredible in these days, when the arts and sciences are lectured upon in almost every Provincial town in the Kingdom, when the artisan is taught not only that such a result follows a certain law, but the why and wherefore, the cause as well as the effect, that persons of general intelligence and scientific knowledge should place their valuable convertible property in a cast-iron safe, with a box of wards for a lock, expecting that it will preserve such contents from destruction by fire and abstraction by thieves.

That others for the sake of saving a few shillings in the primary cost of a lock for the safe keeping of their property in an iron safe or other receptacle, will purchase one that can be readily picked with a quill or a skewer, not only by the accomplished burglar, but by any ordinary mechanic or intelligent artisan, as well as by the amateur lock-picker.

As there are no works in our language, except a few pamphlets and a rudimentary treatise on the subject of locks, I have added the chapters on locks and keys, in order to make this treatise as complete and useful as possible.

I am especially indebted for many extracts to Mr. Granville Sharp's "Prize Essay on Practical Banking," Mr. Chubb's paper "On the Construction of Locks and Keys," and the **"Rudimentary Treatise on the Construction of Locks,"** by Messrs. Tomlinson and Hobbs, works of such an interesting character that they should be read by all. Other general works have afforded me considerable information.

Mr. Chubb, in the work before-named published in 1850, says, without intending in any way to depreciate the numerous inventions for the improvement of locks (many of which possess great merit), "it will be sufficient to describe particularly the three principal locks which are well known and generally appreciated, viz., Barron's, Bramah's, and Chubb's."

In Messrs. Tomlinson and Hobbs' work, published in 1853 (and 1868), the only principal modern locks described are the American inventions. It will, therefore, be seen that the improved locks which were the fruit of the lock controversy produced by the Great Exhibition of 1851 have not been described, with two or three exceptions, in any work hitherto published.

Many of these inventions possess considerable merit, and for security are far superior to nearly the whole of the locks known prior to the year 1851.

Portions of the first part, which is written in the first person singular, may be considered as somewhat egotistical, but the extraordinary opposition which the author experienced, and the strange course of conduct adopted towards him in certain instances by the agents and representatives, and in one case by the foreman of a competitor in the same trade, rendered such a tone imperative, and it is hoped will be deemed a sufficient excuse for it, as such parts were really written in self-defense.

As manufacturers are not expected to be also authors, and as the subject was beset with considerable difficulty in point of interest, especially as regarded scantiness of materials for illustration, I felt bound to spare no pains in acquiring all the available information that could be obtained to render it at least as clear and intelligible as possible.

How far I have succeeded it is for my readers to determine; but whatever may be thought of this humble work, thrown off during the intervals of absorbing avocations, none, I am sure, will feel disposed to question the importance of the subjects treated of.

GEORGE PRICE

PREFACE to the SECOND EDITION

George Price wrote an extremely comprehensive work on the history and development of locks and safes during the time of the Great Exhibition in London. This was a period of significant advancements in the design of locks, safes, and vaults. His treatise provides a rich insight into the state of security technology of his day. When I was first introduced to this work by Horace Smith in England, I was fascinated by the chronicle of historical development of the forerunners to modern locking systems.

It was immediately obvious that this work should be updated and integrated into the Electronic edition of ***Locks, Safes and Security***. Although I have taken license to change some of the traditional English verbiage in order to enhance readability in our modern world, I have also attempted to insure that the

excitement, intrigue, and ingenuity of the era and its pioneers remains intact.

The Electronic Infobase Edition of ***Locks, Safes, and Security*** allows the flexibility to link and combine the information within these two books with a third by Alfred C. Hobbs. I hope that this allows the reader to gain a deeper understanding of how locks and safes were developed, and the difficulties that were encountered by the craftsmen in Wolverhampton, Willenhall, and throughout Europe and America. Links to other areas of the Infobase are designated by **[**brackets**]**.

One of the video segments that can be found within this infobase was shot in London with Jeremy Bramah, a distant relative of Joseph Bramah. I believe that the reader will find that this provides more insight into the era of the Great Exhibition and complements the work of George Price.

Mr. Price provided a timeless and valuable chronicle of events that ultimately resulted in the security principles and devices of the twentieth century. I hope that the availability of his work furthers an understanding of the locksmith profession, and an appreciation of the difficulties in bridging the forty centuries from the first Egyptian lock, to the modern highly technical world of security and its practitioners.

MARC WEBER TOBIAS

BOOK ONE: Locks and Safes

CHAPTER ONE: Introduction to Locks and Safes

I have frequently been asked for advice regarding safes that are suitable for specific uses and situations, and for information regarding many facets of their design and construction, including:

- **The thickness of the plates forming the body and door;**
- **Upon what principle they are made fire-proof;**
- **How long they will resist fire;**
- **Whether the locks are resistant to picking and powder-proof;**
- **If the door will resist drilling;**
- **The best place to fix them;**
- **Other technical questions.**

I conceived that a treatise giving a short history of the Iron Safe Trade would be of benefit. I determined that this treatise should include a description of all the patents taken out in connection therewith, especially of those improvements recently introduced by myself, as well as the details of their construction, and illustrated by diagrams and engravings.

I believe that such a book would be well received to those in want of current information. The details are considered essential to the peace of mind and comfort of not only the banker and merchant, but of every trader who has books to preserve, or the householder who has cash and plate to protect.

The public can benefit as well, especially when one considers the immense value of the precious metals, specie, bank-notes, deeds, and commercial books already entrusted to the custody of iron safes, boxes, and strong rooms. [See **Chapters 1**, **2**, and **33**.]

Mr. Granville Sharp, in his "Prize Essay on Practical Banking," says, in the Article on Safes, at page 315, "For the purpose of awakening attention to the importance of locks and safes, it may be suitable here to quote a passage from the Bankers Magazine, for April, 1845:

'In a country where a large class subsist by robbery, and where the means of effecting it securely is the constant study of skillful and ingenious thieves, the only means of baffling them, and of protecting the ordinary depositories of valuables from their felonious attacks, is to call in the aid of the greatest mechanical skill with respect to locks and fastenings, and to exercise unceasing care and vigilance.

[See **Chapter 38**, regarding casing and surveillance.]

The bank robberies during late years show that they have been planned with extraordinary sagacity and have been effected with a

degree of skill which proves that they are not undertaken by ordinary thieves. The large amount of money which the house-breakers are confident of obtaining in the case of a successful burglary at a bank, induces them to act with a degree of skill and caution proportionate to the expected booty; and it is for a bank is seldom heard of.

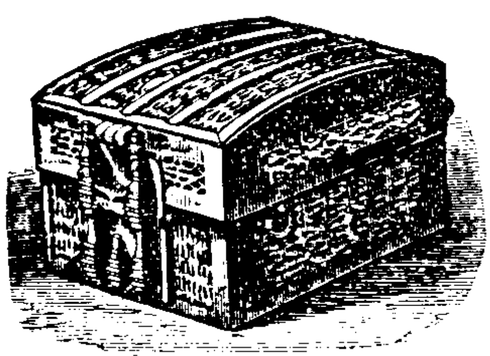
When **'a set'(443)** is made at a bank, every information is in the first place sought for by the burglars of the means of security adopted, and it has been ascertained that many weeks and even months have been occupied in this manner.

Attempts are made to tamper with the servants, and an acquaintance is formed, if possible, with some of the female domestics. If, upon inquiry, it is found that the means of security are so numerous and inviolable as to give no chance of success, the matter is quietly dropped.

However, if any opportunity presents itself, no time is deemed too long to wait for the proper moment when the bank may be entered, the misnamed safe or strong room be opened, and a clean sweep made of all the convertible securities and money it may contain.'

[See **Chapter 8**, on false keys and impressions of keys.]

This was exemplified in the bank robbery at Glasgow some years since. When the Dorchester Bank was robbed some years ago, the burglars were in the house ninety-two nights before they succeeded in opening all the locks, which they did by fitting false keys that would unlock and relock them."



CHAPTER TWO: The Early History

of the Iron Safe Trade

[See **Chapter 1** and **33** on the development of safes, and **Chapter 13** on warded locks.]

Fire-proof Iron safes and chests are of modern date not having been introduced until this present century. Our forefathers were satisfied to place their valuables in an oak chest secured by one or more locks on the front. If they did not utilize that they would have a special room made of brick or stone. The entrance to that room was secured either by an iron door or solid wood door which would have a common warded lock, or a lock without wards, and not uncommonly just be padlocked using a hasp and staples.

The most interesting specimen of the oak chest is the celebrated oak chest in which the crown jewels of Scotland were deposited in the year 1707. The lid was secured by three locks. These locks were thought to be so intricate and secure that no common locksmith or mechanic could open them. In 1818 the keys to these locks had been lost so the lid had to be forced open doing great violence to the lid. In reality these locks could have been picked with a skewer and thereby this ancient relic could have been saved from such unhallowed violence.

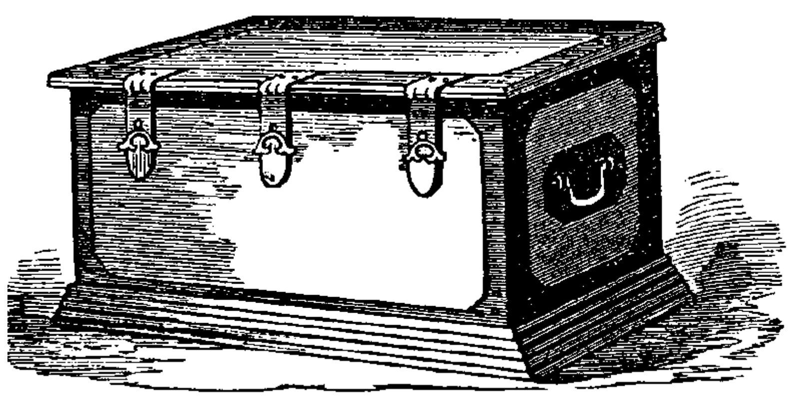


Figure 1. The Oak Chest

Many of these oak chests are still in existence and in a state of perfect preservation. They are prized for their antiquity and the fine carving that usually adorns them. The locks upon these

chests are also interesting. These are very simplistic locks and many may wonder how these locks and the chests they secured kept thieves from breaking in and stealing the contents.

The answer is that if the locks and chests were simple and made of wood, the thieves who would seek to gain access were also simple and had only crude tools with which to accomplish their purpose. In those days, the oak chest was quite as safe as the iron one is now. The strength of the chest itself would generally resist violence, while a lock of the most simple construction afforded sufficient security.

The first examples of the manufacture of iron safes or chests are the foreign coffers. The one illustrated below is 35" long, 21" wide, and 23" deep. It is made of sheet iron strongly riveted to hoop iron crossed at right angles on the outside. It has strong handles at each end, with a multiple lock, which throws eight bolts inside, and it has two doors at the back and two bars and staples for padlocks outside.

The whole of the iron composing it has been hammered and hot rolled, which circumstance goes far to prove that the date of its manufacture must have been before rolls were introduced into the country in which it was made. The plate covering the bolts is beautifully pierced and chased, and bears the date 1793 with the initials "C.H.".

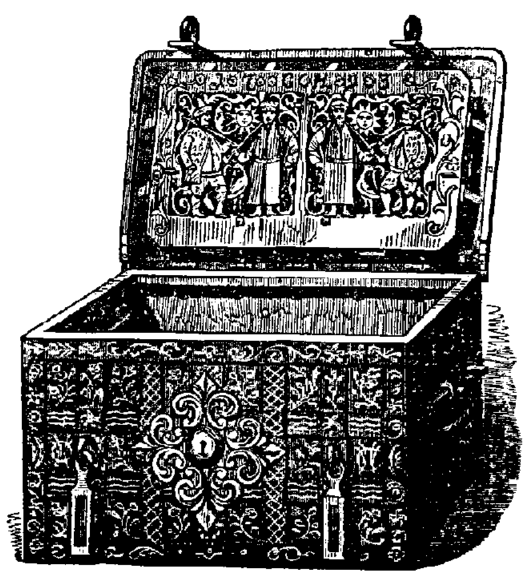


Figure 2 Foreign Coffer; a container utilized to store money

Another peculiarity about this coffer is the escutcheon over the keyhole in the lid. This has to be moved half round with a turn-screw and then it springs up. The key is then inserted, and with the turn-screw put through the bow for a lever. The lock then opens.

Another specimen is known in Paris by the name of the "Strong German Coffer". Reaumer says, "Nothing is wanting on these coffers on the score of solidity. They are made entirely of iron, or if of wood they are banded both within and without with iron, and can only be broken open by very great violence. Their locks are almost as large as the top of the coffer and close with a great number of bolts."

The spring attached to each bolt, though of such rude manufacture, is as effective as the best constructed of the present day. These coffers, taken as a whole, are creditable productions for that period. Every part was made by hand labor. Machinery was unknown.

These were an improvement upon the oak chest, as regards both the material of which they were composed and the locks by which they were secured. Their problem lie in the fact that the locks were easily "picked". But that notwithstanding these are the root from which all the improvements introduced up to the present time have grown.

It is my belief that cast or wrought iron safes were not made in this country before the present century. If they were, they must have been considered curiosities. They were certainly not in use for commercial purpose, and the possession of them must have been confined to a very few.

Cast iron chests have been made for many years at Coalbrookdale, Birmingham, Wolverhampton, and at some other places in England. Wrought iron safes were first made in London, and the trade was confined to the metropolis until within the last twenty years but are now made in other parts of England.

CHAPTER THREE: On Fire-resisting and Thiefproof Safes, and the Specifications of all the

Patents in Connection Therewith

The making of iron safes that are fire-proof does not appear to have been thought of until about the year 1834. As can he seen from the following list of patents, Mr. Marr was the first to introduce the improvement:

1. **William Marr, London, February 13, 1834.**
2. **Charles Chubb, London, May 13, 1838.**
3. **Thomas Milner, Liverpool February 26, 1840.**
4. **Edward Tann, Edward Tann, jr., and John Tann, London, November 25, 1843.**
5. **William Milner, Liverpool, March 3, 1851.**
6. **George Price, Wolverhampton, January 31, 1855.**

The first idea that presented itself to the mind of the manufacturer was to use a substance in the chambers of the safe that would retard the transmission of heat or neutralize the transmission of heat. This idea was adopted by Mr. Marr and he stated:

"My improved inner fire-proof case within which any combustible property may be placed, has a lining or covering of mica or talc, split into very thin lamina, and fixed to sheets of thin paper by gum arabic, and in that state is used to line or cover the two surfaces of the metal plates that form the inner fire-proof case."

"The space formed between the two surfaces of mica or talc should be completely filled or packed full of any suitable non-conductor of heat. The substance or compound represented in the drawing annexed to the specification is burned clay and powdered charcoal; but the chambers may be also, and with equal advantage, filled with dust or very small particles of marble, porcelain, slightly burned clay, etc., or any other suitable non-conductor of heat, either natural, artificial, or compound; and which being applied and combined with my improved lining or covering of mica or talc will assist in keeping it spread and stationary over the surfaces of the plates that form the inner fire-proof case."

Mr. Chubb, who secured the next patent, says, in his specification:

"My invention consists in applying tow or three internal linings of iron plate to the receptacle, one lining within another, leaving narrow spaces between each lining, and filling up those spaces with some such slow conducting, materials as will retard the transmission of the heat such as baled woodashes or charcoal, fragments of earthenware, pottery, tiles or bricks or sand-stone, broken small and rammed into such places, or coarse sand or small gravel sifted, or fragments of slate put in edge-ways, or other slow conducting material, to be applied in the shape of grains and powder. The non-conducting materials may be put into bags or cases made of cartridge paper, and put into the spaces. The materials may also be put into metal cases."

The reader will most likely smile at the simplicity of these specifications; but the early efforts of most inventors have generally been of a similar character.

{See **Chapter 33**, Development of fire safes.]

Thomas Milner received the third patent in 1840. It was described as:

"Construction, forming, or manufacturing boxes, safes, or other depositories, of an outer case of iron or other metal, or material, enclosing one, two, or more inner cases, with spaces or chambers between them, containing an absorbent material or composition, such as porous-wood, dust of wood, dust of bones, or similar substances, in which are distributed vessels, pipes, or tubes, filled with an alkaline solution or any other liquid or matter evolving steam or moisture, the tubes or vessels bursting or otherwise discharging themselves on the exposure of the box or other depository to heat or fire, into the surrounding absorbent matter, which thus pervaded with moisture, and rendered difficult of destruction, protects the inner cases or boxes and their contents."

The specification states that the inventor does not claim the making boxes with compartments filled with non-conducting substances for the purposes of resisting fire, "as that has been done before;" but he claims:

"The introduction or application of the combined effect in chambered boxes or depositories of the materials kept humid in the space surrounding the innermost box and its contents, without in any way being confined to the materials or liquid employed, or

to the manner in which it may be distributed or arranged in order to introduce the desired effect."

This unquestionably was an improvement far in advance of the previous ones, and is the principle upon which the majority of present day manufacturers make their chests and safes fire-proof.

But in 1843, Messrs. Tann took out the fourth patent. This fourth patent was founded upon the same principle, but effected in a simpler and different means. Their invention "consisted in forming the chests with triple bodies, one within the other, leaving spaces between the bodies, and filling up such space with the following compound: ground alum finely sifted, and Austin's cement or gypsum, finely sifted.

Either of the two latter substances were mixed with the alum, and heated to liquefaction in an iron pot, stirring the mixture carefully during the process. The mixture was then poured into an iron tray to cool. It then turned into a solid which was coarsely pounded when required for use."

This mixture the patentees prefer; but "any non-conductors of heat may be used, and for alum may be substituted sulphate of potash, murate of ammonia, borax, impure potash, nitrate of soda, soda in cake, pearl ash, or any of the known alkalis."

The principle having already been patented by Milner, in 1840, he considered Tann's method an infringement, and commenced an action against a Mr. Harrison, of Liverpool, who was selling Tann's safes and boxes, and advertising himself as the sole proprietor of the same. This case went to Court on June 23, 1851. A verdict was rendered in favor of the plaintiff, Mr. Milner and against the defendant, Harrison.

But this did not deter the defendant, Harrison, from continuing to sell Tann safes and boxes. So Mr. Milner applied for an injunction to restrain the defendant, Harrison, or any of his agents, servants, etc., from making, using, vending, etc., during the remainder of the term mentioned in the Letters Patent granted to Mr. Thomas Milner, regarding any boxes, safes, or other depositories that were made in such or the like manner, or on the same or the like principle, or in anywise counterfeiting, imitating, or resembling the said invention."

On August 2, 1841 the injunction was made perpetual against the defendant, Harrison and any of his agents, or makers, or any

others using such materials for the life of Mr. Milner's patent. Mr. Milner's patent did not expire until 1854 and he enjoyed the sole right during this term to exclusively manufacture and sell safes using the above principle until that time.

The Messrs. Tann, were compelled to relinquish their invention, and in their disclaimer, stated, that "having in their specification claimed the construction and adaptation of compound and double or triple bodies or cases placed one within side the other in succession, leaving spaces between the contiguous bodies, and closing and filling such spaces with the heat-resisting composition therein described, and having since learnt that that part of the invention is not new, they disclaim:

"Making iron rooms, safes, etc., with separate spaces between the contiguous bodies;" also, " they disclaim the use of muriate of ammonia, impure potash, nitrate of soda, soda in cake, pearl ash, or any other of the known alkalis."

In other words, they gave up the fight and ceased making safes and boxes based upon those principles. Mr. Milner was the victor and to the victor went the spoils. That being the sole right to manufacture fire-proof safes using the above principal.

The fifth patent, by William Milner, (1851) was for: "closing the door of safes and boxes by means of a continuous bolt or bolts on all sides of the same, extending or expanding into suitable continuous grooves, rebates, or recesses, formed within the front of such safe or box," which he terms "flame protectors." Also "to coat or cover the inside of the outer plate of the safe with a preparation of pulverized quartz, or other similar infusible material, mixed with a small proportion of hardwood dust, to be made into a cement, applied wet and then dated, for the purpose of more effectively resisting the action of intense fire in the interior of such safes."

This invention was the most useless of any of the developments, either before or since introduced. Flame always follows the direction of the air, it could not possibly get inside the safe or chest without first making a hole in some other part to cause a draught.

The final patent, dated January 31, 1855, by George Price contained six claims. These included:

- ***Painting internal surfaces to prevent rust;***

- **Case-hardening of barrier materials;**
- **Protection of lock from the use of gunpowder;**
- **Protection of lock and bolts from effects of the introduction of gunpowder;**
- **Lock-case protection from explosives.**

Price patent claims:

"First to paint or coat the inside of the body and the inside lining or casing, and the iron sheets or plates forming the chamber of the lock-case of fire-proof safes, chests, and boxes, with a composition to prevent the oxidation or eating-away of the iron by the action of the salt or moisture contained in such chambers."

I was induced to adopt this remedy from having, on examining a safe made fire-proof on the steam generating principle, discovered that the iron plates and sheets enclosing the composition were considerably weakened by oxidation, produced by the chemical employed.

Another claim in the patent was for case-hardening the doors or lids and outer body of iron safes, chests, and boxes, or any part thereof, which gives to the surface of the iron plates the hardness of steel, and thereby renders them drill-proof.

The third claim was for inserting within locks used for iron safes, chests, and boxes, a series of compartments formed of strips of iron or other metal that were divided transversely, or of metal cast in the honey-combed form in those parts of such locks not occupied by the works, so as to prevent a sufficient quantity of gunpowder being placed therein for the purpose of blowing them open.

Another related claim was granted for the protection of the lock and boltwork from the effects of the introduction of gunpowder. The design described "for inserting in that part of iron safes, chests, and boxes, called the lock-chamber, wherein the large bolts are enclosed, a series of compartments or cellular work, so that were a hole to be drilled through the front plate of the door, there could not be inserted through the aperture, a quantity of gunpowder, which, if exploded, would be sufficient to force the lock-case inwards or the door outwards.

A patent obtained by William Milner, dated February 20, 1854, and

another dated December 20, 1854, though more particularly belonging to the chapter on powder-proof locks, may also be noticed here, as the latter comprises the filling of the large lock-chambers of iron safes with a solid substance, as " hard wooden packing." The former specification states:

"This invention is designed for the purpose of protecting locks, of whatever construction they may be, from the destructive effect of gunpowder, or other explosive compound or agent, and is more particularly intended to be applied to safes or such strong depositories as are required to be secured from the invasion of burglars or others."

"My improvement in locks consists in filling up all the open space or spaces usually left around the 'tumblers and other working parts of locks, leaving only sufficient space for the turning of the key, the slight lift of the tumblers, and the limited action of the springs, etc.; thus substituting for what has commonly been the 'box' of the lock almost a solid block of metal."

"This 'filling' may be effected either by casting or forming the lock solid with the exception only of exactly the open space required for the working or operative portions of the lock; or it may be made so as to be formed upon the 'cap' of the lock and fitted into the ordinary box of the lock, and thus also leave only the sufficient space required for working or opening and closing the lock."

"It will be evident, therefore, that the space which has ordinarily formed a receptacle for a large and destructive quantity of gunpowder being by my invention reduced to the smallest possible capacity, and the resistance also thus afforded to the effect of explosion will preserve the lock from destruction by any such means, and will necessarily cause the discharge of the violence through the keyhole."

It may be as well to remark here, that it is usual with burglars in operating upon a lock with gunpowder, to plug the keyhole, so as to cause the force of the explosion to "tell" against the lock or lock-case, and thus prevent "the discharge of the violence through the keyhole."

The other Price specification states:

"These improvements apply principally to that part of the door of

fire-proof or fire-resisting safes called the "lock case" that is, the chamber between the inner and outer door plates, in which the large bolts are usually placed and secured by the lock when shot or thrown into their corresponding recesses or bolt-holes in the top, bottom, and side of the safe.

The first part of my improvement is designed to extend the principle of preventing the destructive effect of gunpowder or other explosive compound or agent, in a similar manner as that secured to me by Letters Patent, dated the 20th day of February, 1854, as therein particularly applied to 'locks of safes.'

"The present improvement consists in filling up all the open space or spaces usually left between the inner and outer plates forming the door, with wood or other similar suitable material, leaving only sufficient space for the seat or position of the lock, and the working or passage of the bolts."

"It will therefore be evident that the great space forming the "lock-case" in doors of safes, etc., which has heretofore been a receptacle for a large and destructive quantity of gunpowder, is by this invention prevented from being available, as it is filled or reduced to the smallest practicable capacity."

"The second part of my improvements is a further reduction of the space or room for the action or presence of gunpowder, and applicable to the description of lock before-mentioned as the subject matter of the patent herein recited, and is effected by filling up nearly two-thirds of the space ordinarily left in locks for the passage of the key, and leaving only sufficient room to pass the key in, perform the operation of locking or unlocking, and withdrawing the key immediately after it has performed these operations, instead of turning the key around a complete revolution, as hitherto done, and by this improvement the available space for the presence or action of gunpowder is reduced to a minimum."

I am unable to discern any difference in principle between Milner's first and second patents and Walter H. Tucker's, dated October 1st, 1852, except, that in Milner's first patent "the space which has ordinarily formed a receptacle for a large and destructive quantity of gunpowder being by "his" invention reduced to the smallest possible capacity, is in his second "reduced to a minimum." The specifications of both these patents, together with Tucker's, will be fully described and illustrated by diagrams in the chapter on powder-proof locks.

CHAPTER FOUR: Requirements of an Iron Safe to make it Secure against Thieves and Fire

In deciding upon what means to employ to secure our valuables from thieves, we must not forget that as improvements take place in the arts and sciences, in the same proportion does the thief increase in ingenuity and intelligence. Therefore, even the improved safes and locks made have been found faulty and wanting, when operated upon by the present genre of skillful and scientific burglars.

An iron safe, to be secure against fire and thieves, must possess the following merits:

The iron plates forming the body should be of sufficient thickness and put together so that no violence or ingenuity could easily defeat them;

- **The door should be carefully fitted so that no instrument could be inserted between the edge and the outside of the safe. The iron of the door should be so hardened that no drill can penetrate it for drilling a hole to insert gunpowder into the lock mechanism. The lock-studs, by which the lock-case is secured to the interior surface of the door, should not be capable of observation from the outside or front of the container.**

- **The large lock, the bolts of which are thrown by a knob or handle, should be well made and of simple construction. This will negate the requirement that the case be taken off after it is once fastened to the back of the door. The large lock should be so contrived that in event of one or more holes being drilled through the door, there should be no space inside the chamber sufficiently large to contain enough gunpowder to blow it open. There should be bolts at the back and front in large safes. In those with double doors, there should be bolts all round.**

- **The case at the back of the door containing the lock and fire-proof composition should fit the interior of the safe as tightly as the opening and closing will allow. This is to keep out external heat, and prevent the escape of that moisture evolved by vaporizing material.**

- **The inside case that forms the chambers for the fire-resisting material should fit the inside of the outer body tightly and prevent the undue escape of the vapor in a fire. It should be so secured to the outer frame that no violence exerted upon the door should force the removal of such lining.**

- **The non-conducting and steam-generating composition placed in the chambers or within casings and at the back of the lock-chamber should be prevented from having any harmful effect upon the iron. When subjected to the action of fire, whilst the vapor would preserve the contents from combustion or damage of that kind, it should not injure plate or specie, or affect the writing upon, or substance of, papers or books. The thickness or quantity of the composition should be in proportion to the risk or probable duration of a fire.**

- **The small lock which secures the bolts should be one that would be easy to use, not liable to disarrangement, likely to wear well, gun-powder-proof, and above all, one that could not be picked. The key should be small enough to be carried without inconvenience.**

Although iron safes are not required or expected to be placed in a drawing room, they should be of such a design and so neatly finished as to please. They might be considered an ornament to the counting house.

Safes possessing all these qualities, and obtainable at a price within the reach of every shopkeeper is the goal that needs be achieved.

Mr. Granville Sharp, in his article on “Safes” in the work before referred to, says:

"It must, however, be observed, that the 'Safes' of the Great Exhibition (1851) *as a whole*, are distinguished rather by ornament and beautiful workmanship than by strength and practical

utility for banking purposes; they are too small, and they are too handsome, and, as a consequence, they are (proportioned to the accommodation afforded) far too costly."

CHAPTER FIVE: On the Iron Safes in General Use

Having in the previous chapters gone through the historical part of the subject, and having described all the improvements in iron safes for which patents have been granted, and having also stated what is required to make them really secure against both thieves and fire, I will next describe the various kinds in general use, explain their construction, and particularize those that afford the necessary security.

Cast-iron safes, the bodies of which are cast in one piece and the doors in another, are utterly worthless as preservers of their contents against fire or thieves. As a rule, no safe made of iron, without some other contrivance, can resist the effects of fire. Safes made of cast-iron, because of the brittleness of the material, readily yield to the blow of a hammer. They may be easily opened by the use of the drill, as well.

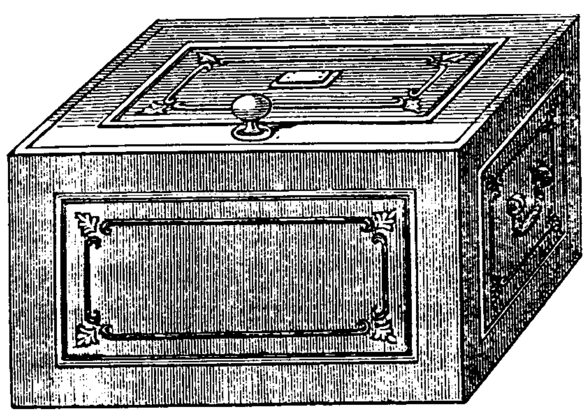


Figure 3. Cast-iron Safe

The locks for this class of safe are generally warded ones, which can be picked with a very simple instrument. As has been repeatedly proved, the large quantity of gunpowder that may be readily poured into the lock or lock-chamber through the monstrous keyhole can enable the burglar to blow it open at once.

They have seldom any bolts or fastenings at the back, and the doors or lids are hung with hinges.

To entrust valuables of any kind to the custody of such chests, is as bad as leaving gold watches and jewelry in a shop window at night without further protection than the wooden shutter. It is, indeed, offering a premium to the most ordinary thief or burglar.

Common wrought-iron safes with inside linings or casings left hollow are also valueless against fire. The linings in such safes not only take up the inside room, which is a disadvantage without an equivalent, but really deceives the purchaser, as he would reasonably suppose they contained some composition to give them the desired security. Many are made in this way, and as there is no external difference in appearance between these and those with filled chambers, the ignorant buy and sell them for fire-proof safes.

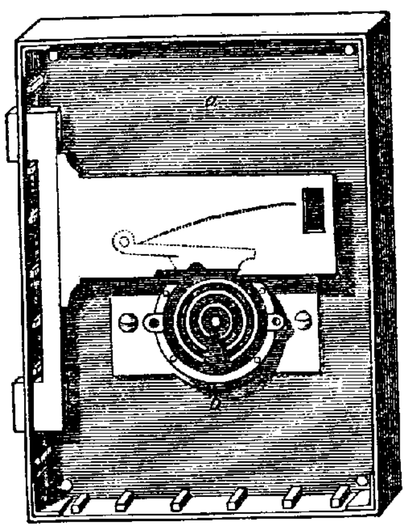


Figure 4. Lock-case with box of wards, as used for cast-iron safes and chests

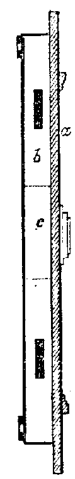
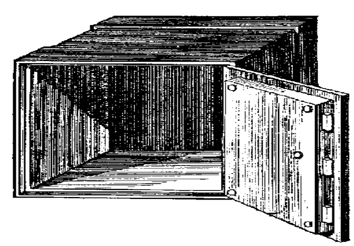


Figure 5. Section of door plat and lock-case-not fire-proof

Many safes are made of wrought-iron of great strength, having plates of 3/8"-5/8" thick. These containers do not have any inside linings at all, however, and are intended to be specially thief-proof.



If the doors of these are properly made, and

secured by an pick resistant and powder-proof lock, no serious objection can be brought against them, so long as they are not required to be also fire-proof.

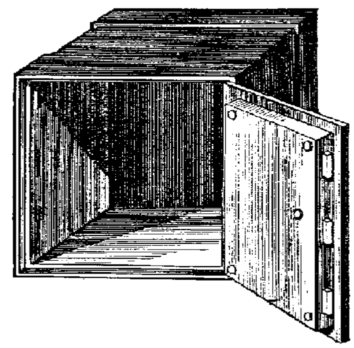


Figure 6. Strong wrough Safe, "hold-fast"pat

When a safe is constructed in such a manner that the case containing the look and bolts at the back of the door comprises only the plate that enclose them, the small lock is very liable to be forced from its place.

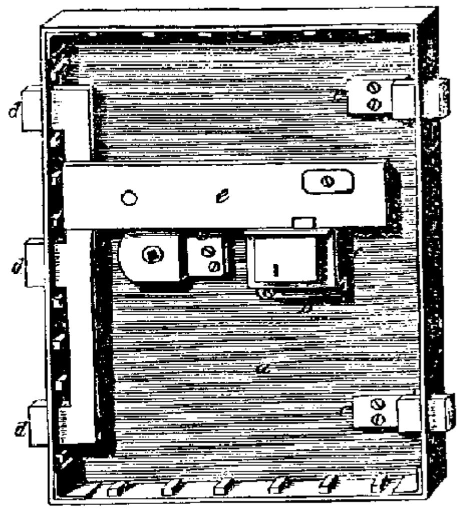


Figure 7. Lock-case as used for safes not fire-proof, and also for fire-proof safes where the door is not fire-proof-i.e., it has no composition at the back of the lock-chamber

Some years ago, one of Chubb's locks, fixed on a common iron safe, was forced open by the instrument before-mentioned a "jack-in-the-box." As this instrument is said to have the power of lifting three tons' weight, it is evident that some part of the door must give way under its pressure, and in doors made on the common principle, the lock and a portion of the lock-case must be torn away; then, by throwing back the bolts, the contents of the safe would be in the power of the burglars.

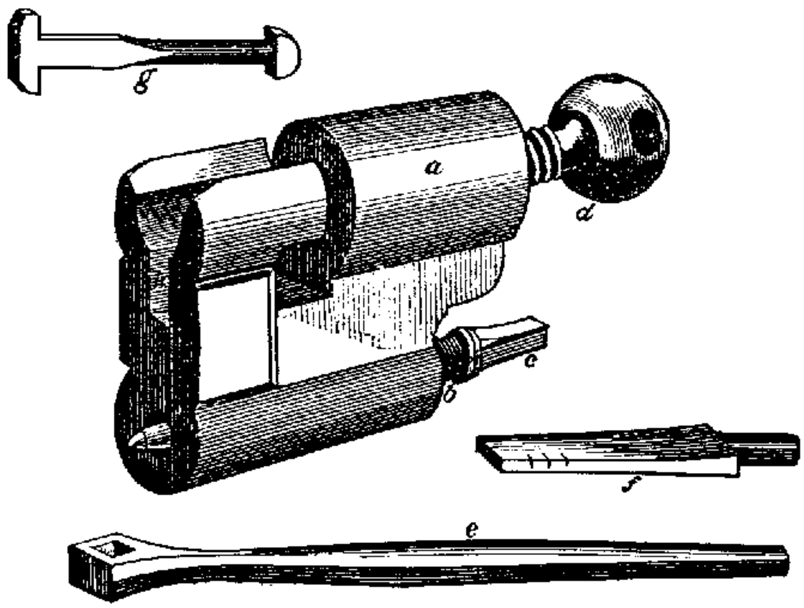


Figure 8. "Jack-in-the-box."

Since the occurrence of the before-mentioned accident, Mr. Chubb has adopted the plan, in his recent safe locks, of cutting a square piece out of the back of the keyhole and reaffixing it only by small screws, so that, on the application of the "jack-in-the-box," that single piece only would be removed.

Because the inside depth of the lock chamber is usually 1.5" and that of the lock, at most, only 1", it follows that if the latter, with this square piece at the back, must be let into the back plate of the lock chamber, (see figures 5 and 7) it would leave a space of ½"between the face of the small lock and the front door plate.

The result of this design, intended to prevent the safe from being compromised by the "jack-in-the-box," actually permits it to be opened by pouring gunpowder through the keyhole into the lock chamber and exploding it.

In fire-proof doors, the former contrivance would be useless, as such a result is prevented by the aid of another plate of iron enclosing the fire-resisting composition. (See figure 21.)

Wrought-iron safes made fire-proof by the use of a non-conductor only, are far less secure than those constructed upon the combined principle of non-conduction and steam generation. The

non-conducting power of asbestos, talc or mica, gypsum, plaster of Paris, cement, sand, and all the other materials which have been variously used, is, when subjected to intense heat, very soon overcome, and the contents of such safes are at once sacrificed. The heat having penetrated through the lining substance, finds the articles enclosed only too ready for combustion, and they are soon reduced to ashes.

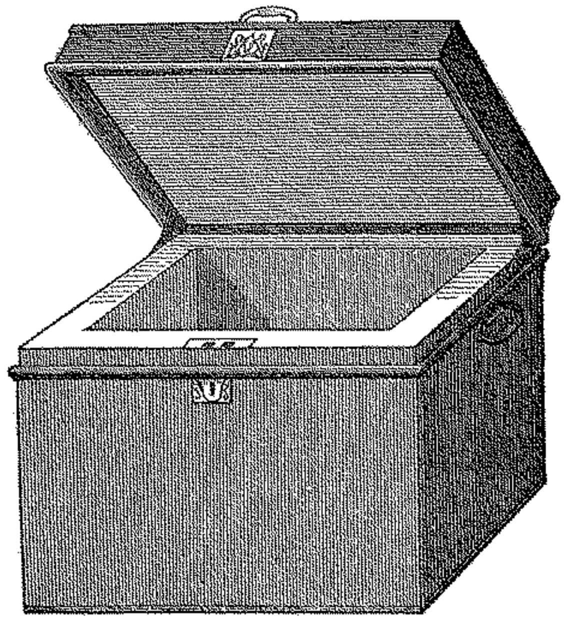


Figure 9. Sheet-iron Fire-proof Deed Chest

Deed chests made of sheet iron of the strength of 18 to 24 gauge, and filled with the steam-generating composition, however thick this may be, can never be secure either against fire or thieves. They are easily crushed or otherwise injured by the fall of building materials in a fire, and this not only allows the escape of the neutralizing vapor, but permits the destruction of their contents by the water used in extinguishing the fire; moreover, they cannot offer much resistance to violence. The large fires at Newcastle, Manchester, and other places, have sufficiently demonstrated that such chests and boxes are utterly worthless as fire-proof depositories, except for being placed inside stronger ones.

Another variety of safe, like the deed box, figure 9, is made of sheet-iron. These are manufactured in a similar manner to the ordinary japanned tinplate boxes, and the lining for the fire-proof composition is fastened to the outer body with solder.

As thief-proof receptacles for cash and plate, these safes are absolutely deceptive, and afford no better security than the cast-iron chests. Beside the insecurity arising from the thinness of the sheet-iron forming the body and door, the latter is secured by a lock with but one bolt; and the only security at the back, besides the hinges, consists in having two small studs projecting from the rim of the lock-chamber, which go into corresponding holes formed in the inner case.

These containers can be easily cut open with an iron bar or strong chisel, as well as by the drill, and one can be cut open with a steel chisel in a few minutes.

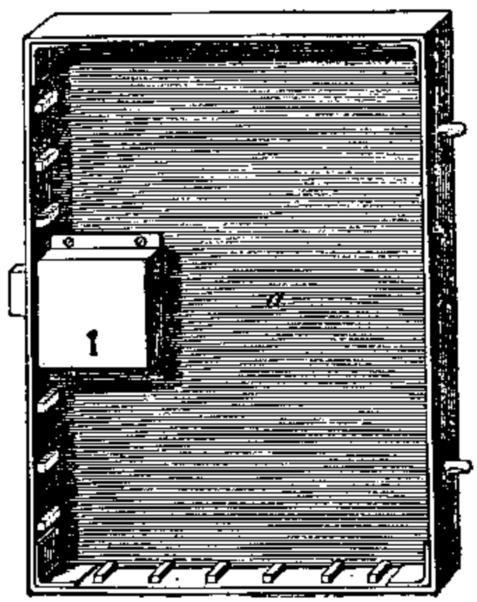
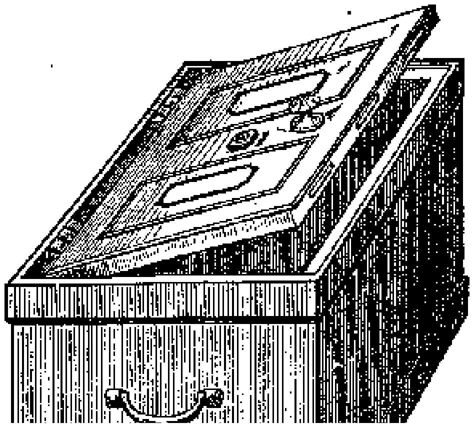
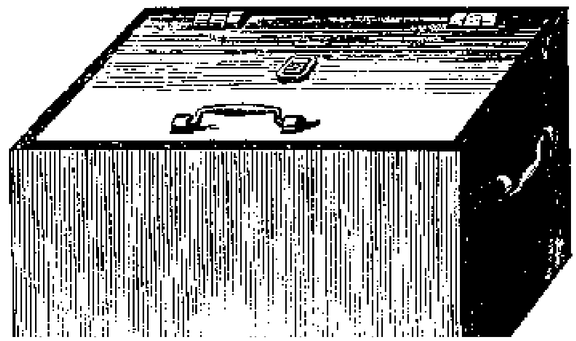


Figure 10. Lock and lock-chamber as used for sheet-iron Safes

Great numbers of chests or boxes for holding treasure are made of wrought iron of various strengths, of the patterns shown in figures 11-12, and are exported to several foreign countries, but principally to South America. Although these containers may prove secure against ordinary violence, they can readily be opened by means of the drill or gunpowder. The majority of those exported are of inferior quality, in consequence of the low price obtained for them. Consequently, they are but little better than the cast-iron safes. In many of them the lock-cases are made of cast-iron.

cast-iron.





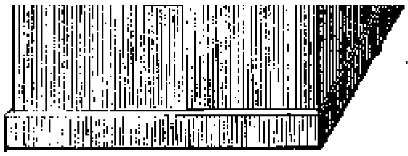


Figure 11. Money Chest, with outside bands



Figure 12. Plain Money Chest. The plates of body are riveted to angle-iron inside.

The door or lid is secured by two or three large bolts at the front, which are fastened on to the projecting bit of a 4" iron-door lock, and which, consequently are thrown by the key. This necessitates the latter being large and strong. The only security at the back is the hinges. The locks, also, in order to bring the chests at a lower price, although superior to the box of wards, are of an inferior character, and can be picked without much difficulty by those who understand their construction.

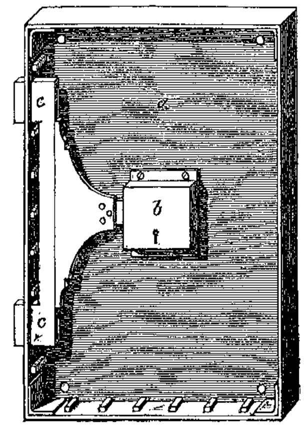


Figure 13. Lock-case as used money chests, containing a 4 the key of which throws

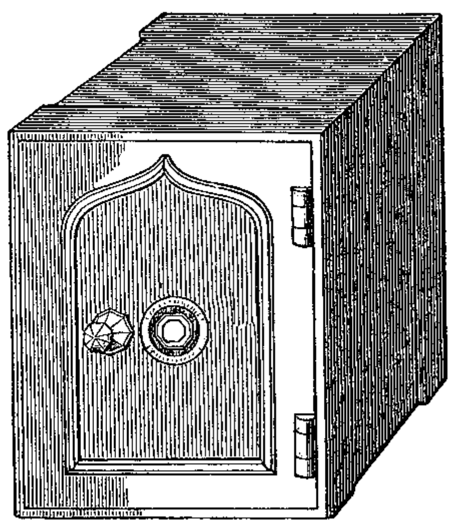


Figure 14. "Holdfast" pattern

Safes made on this plan, with outside bands and massive hinges, are very generally, but erroneously, considered stronger than those made with inside strips and angle iron; but supposing the thickness of the plates the same in both cases, the outside bands on the former certainly lessen the security of the safe, unless

it be built in masonry and the door case-hardened, as they afford a purchase for clamps and drilling, tackle being applied to the front.

There is no advantage in making a safe in this manner, except, where such is not required to be fire-proof, it allows the interior of the safe to be quite square, (see Figure 5), there being no angle-iron riveted to the corners.

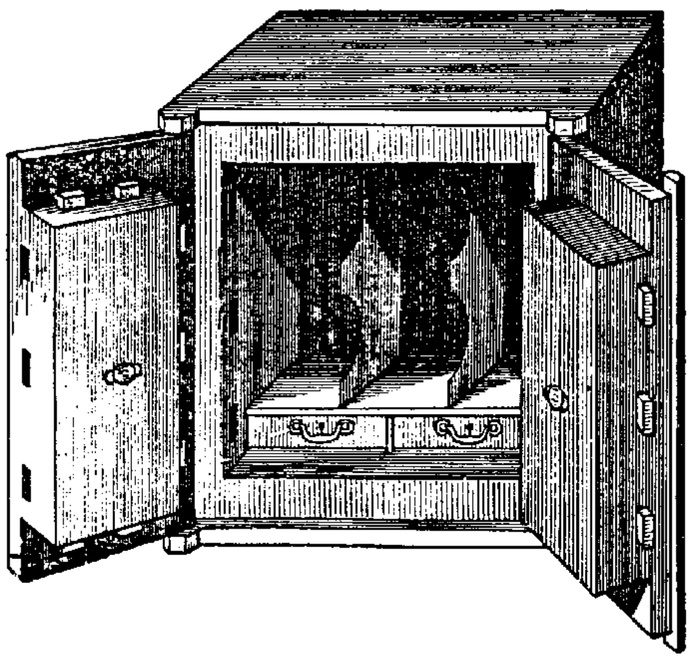
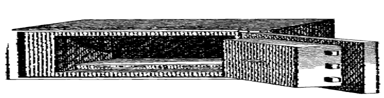
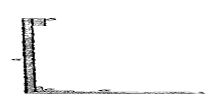


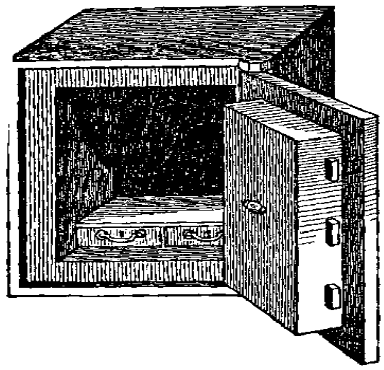
Figure 15. Double-door Safe, which was a welcome improvement

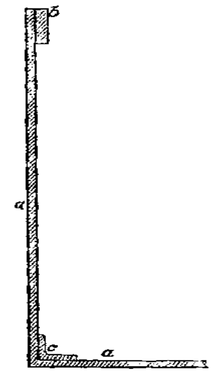
Safes with the plates both dove-tailed and riveted to angle-iron inside the doors that are hung upon centers are preferable. Besides offering no projections for attaching drilling tackle thereto, they are much neater in appearance, and the doors of the largest safes open and close without difficulty.

PRICE'S PATENT FIRST-CLASS FIRE RESISTING AND THIEF-PROOF SAFES.









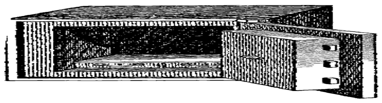


Figure 16. A safe with a single set of doors.

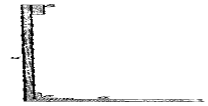


Figure 17. Section of body of a typical safe

These safes, which contain all the recent improvements, are made of the best boiler plates, the thickness of those forming the body being not less than a quarter of an inch, and are both dove-tailed and riveted to strong angle-iron inside. The entire configuration has been strengthened with bar iron and corner plates riveted to the inside of the front. For solidity, nothing can surpass this plan. Another technique is either to dove-tail the plates together, or rivet them to angle-iron alone.

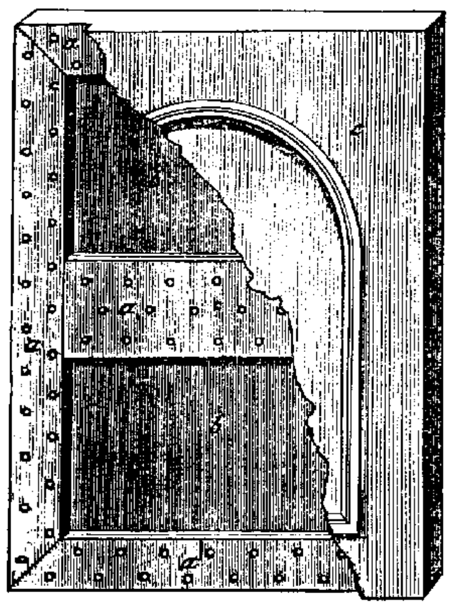


Figure 18. a a, The bar iron between the top and bottom plates. b b, The spaces or chambers filled with a non-conductor. c, The top plate

Either plan is sufficient for small or light safes, but should never be used singly in heavy or large ones. For the requisite security, both means must be employed. The doors are made of two plates, and paneled between with bar iron; thus making that part immediately over the small lock 1” thick of solid iron. (See figure 21a). The object in making the doors of two plates is for filling the hollow spaces (b b) with a non-conductor in order to make them somewhat fire-proof and to lessen their weight.

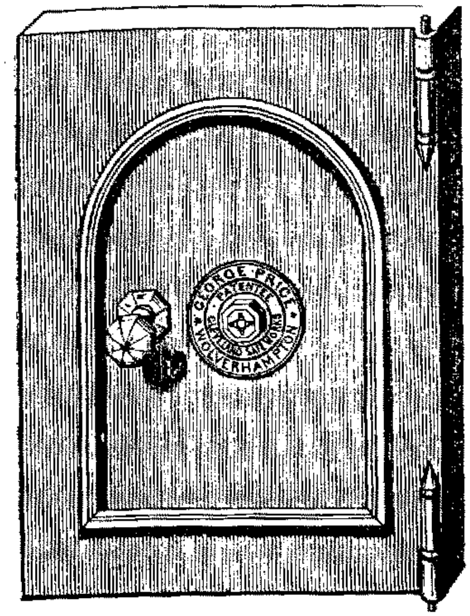


Figure 19. The same door complete

The cost of manufacturing such a door is much more than that made of one plate only, resulting from the extra amount of drilling, riveting, cutting, and filing of the former. The plates being each ¼″ thick, and the bars between ½″inch, make it, as stated before, 1″ thick of solid iron over the lock, and also for 2″ around the edge.

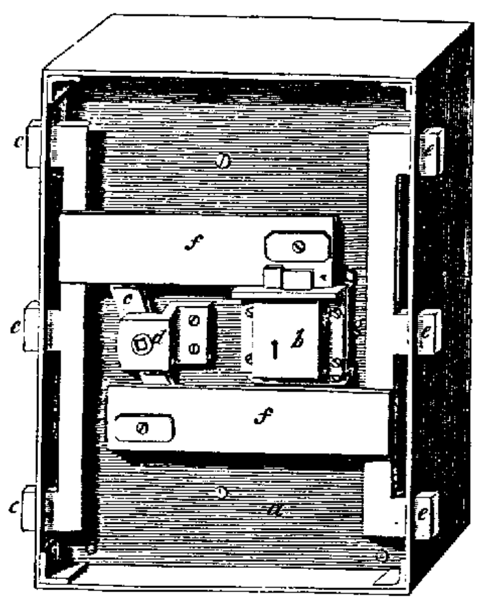


Figure 20. Modern lock-case, with small lock for fire-proof safes.

The modern safe-door locks now generally used are 3 ½" or 4" square, and the object of a mechanical and scientific thief is either to cut the lock out and remove it with a chisel, or by drilling or cutting away the bolt (see figures 20 and 21) which locks into the arm of the large bolts to open the door and thus get at the contents.

It follows, then, that the door is the vulnerable part of the safe and that the most vulnerable area is the square over the small lock. To provide against such a contingency, it has been customary in some special cases to screw a steel plate, the size of the small lock at the back of the door, or case-harden the plate of the lock itself.

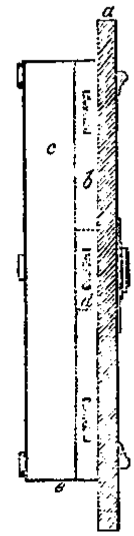


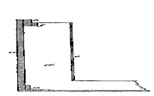
Figure 21. Modern lock small lock for fire-p

Unfortunately, as this only protects the small square over the lock, it merely obliges the operator to cut around it and take the lock and steel plate out together. In the alternative, the burglar must drill a hole under the small lock and fill the chamber containing it and the large bolts with gunpowder, and by exploding it, blow off the door.

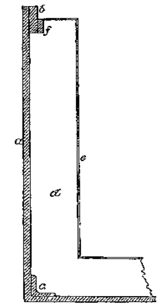
The lock-chamber (see **Figures** 4,7,10,13,20a) will hold from five to thirty pounds weight of gunpowder, according to the size of the safe.

Another way is to screw a steel plate, the full size of the door, at the back of it, covering the whole of the small lock and the works of the large lock contained in the chamber; but this, besides considerably increasing the cost, adds little to the security, for, by drilling a hole in the door-plate, as previously described, the steel plate, from its brittleness, is easily broken with a punch, and the gunpowder is inserted as before in the lock-chamber.

In the process of manufacture, the body is first made, as before described, (see figure 17) by



riveting and dovetailing the plates together; the lining, (figure 22, e,) if a fire-proof safe, forming the chambers for the vaporizing material, is next made, and fastened to the inside with screws, and then the door is carefully fitted, and hung either with hinges or upon centers. However strong these may be, they add nothing to the real security of the safe, as many erroneously suppose, being used simply to hang the door with. The safety of the door depends altogether upon the



with bolts and back fastenings, the door would be just as secure, even were the hinges cut through or the centers knocked off.

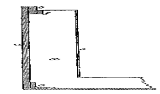


Figure 22. Se of fire-proof

A great improvement in the doors of safes consists in having two locks to secure them. In the old safes, the key (which, in consequence, must be very large, and the lock and keyhole in proportion) throws the bolts (see figure 4) at front, and there are sometimes iron dogs or studs at back; but more frequently there are none at all. In the modern safes, the bolts, from three to sixteen, according to the size of the door and the security required, constitute the large lock, and are thrown into the corresponding holes at the sides of the safe by a knob or handle, as shown in figure 20, and these are secured by the bolt of the small lock. This method I have proved by applying the force of several tons' weight upon the lock through the keyhole to endeavor to force the small bolt out of its place in the arm of the large bolts, but without accomplishing it to be perfectly safe and effectual, and it possesses the great advantage of requiring only a small lock with a small key.

Besides the convenience and comfort of a small key, as compared with the monstrous keys of the old safes, it considerably lessens the liability of the lock being destroyed or injured by burglars' instruments.

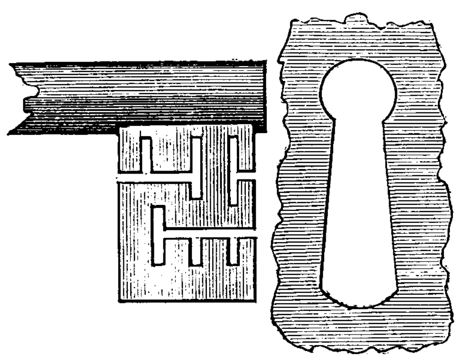


Figure 23. Key and keyhole of box of wards

There are two ways of securing the lock-case to the back of the door. In one method, studs or blocks are screwed into the door, (but should never go through it). If seen on the outside or front of the door, there is no security in this design. By punching these studs out, the door plate is opened, the lock unscrewed from its place, the bolts moved back, the lock-case lifted out,

and the contents exposed to view.

In doors of only ¼”or 3/8” thick, these studs must go through, and are generally riveted on the outside into a counter-sunk screw-hole. Figure 24 represents one of the studs, which, being screwed into the door, receives the lock-case upon it. In order to secure the lock-case in its position, small screws go through the corresponding holes in the rim, which are screwed tight into the studs.

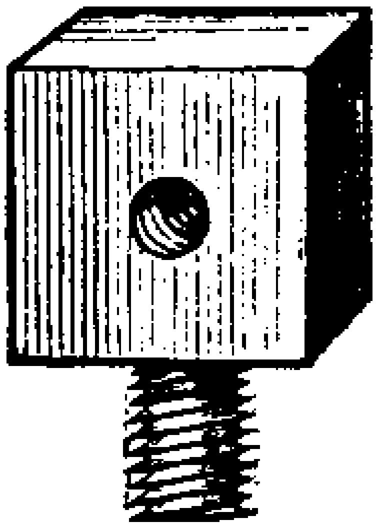


Figure 24. Flat lock-case stud

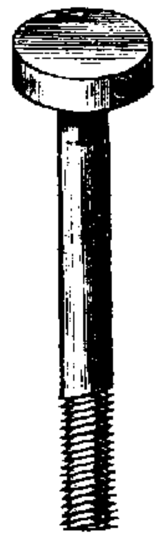


Figure 25. Cheese-headed screw. This was an early form of security fastening device

The heads of the small screws are then cut off and filed down level with the surface. This method gives a very neat appearance to the lock-case, and answers very well where the latter is not likely to require removing for any purpose.

As it sometimes occurs from various causes, the lock-case has to be taken off. In such a case, the studs or blocks (figure 26) to which cheese-headed screws (figure 25) firmly secure the lock-case to the door by going through the back plate are preferable.

The latter are easily removed without injury to any part of the lock-case by a key or spanner, made for the purpose; but in the other the lock-case is



disfigured by removing the paint to discover the screw-heads, which are more or less injured in getting them out.

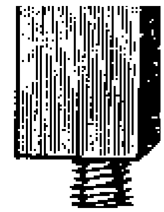


Figure 26. Square block

Figures **15-16** show the lock-cases secured by the latter means, and figures **6-9**, those with cheese-headed screws. The latter plan binds the whole fabric of the door together in a superior manner.



Figure 27. Key for cheese-headed screws

Frequent and extensive robberies have recently been effected by the two means before described, using drilling and gunpowder. One technique relies upon drilling or cutting a piece of the iron out of that part of the door covering the small lock, and taking it out. The other method requires drilling a hole through the door-plate into the lock-case, and then filling it with gunpowder and blowing it off the door.

These methods prove the insecurity of all safes, however well and strongly made in other respects, and shows the necessity of introducing such improvements as to make it next to impossible for the most persevering and accomplished thief to open one by those means.

To frustrate such a design, I have adopted the principle of case-hardening the exterior of the door or other parts of the safe, which gives to the iron plate the hardness of steel without its brittleness. The door is the most vulnerable part of the safe, and always a primary target of the thief. Thus, it must be evident that even were the operator provided with an unlimited number of steel drills and chisels, it would be no easy matter in the time permitted to thieves, to drill or cut through, by even combined manual power, a door of ½″, 5/8″, or 1″ thick.

The steel surface offers such a resistance to the drill as not only to receive no damage itself by the attempt, but the

operation takes off the cutting edge of such instrument, and renders further perseverance futile. The very fact of the door being case-hardened would doubtless of itself be sufficient to deter the most determined thief from attempting to open the safe by such a method.

Suppose, however, that a hole should be drilled through the door for the purpose of filling the lock chamber with gunpowder. In that case, from the cellular construction of the vacant parts of such chamber as shown in figure 28, it will be seen that it could only be forced into one or at most three cells, and that only to the level of the hole in the door.

If the gunpowder exploded, its power would be lost by the cellular filling giving way, from the circumstance of its being the weakest part. It would force neither the lock-case inwards nor the door outwards, and would therefore be quite inoperative.

The method of filling such vacant space with a solid substance is very inferior to this plan, as the power of only a few grains of gunpowder when exploded between two flat surfaces is well known.

The face of the small lock, by being supported in the lock-chamber upon a bridge of iron, (see figures 20-28) is brought in contact with the inside face of the door. This prevents gun-powder being poured through the keyhole into the lock-chamber, as may be done in most of the safes made until within the last two or three years.

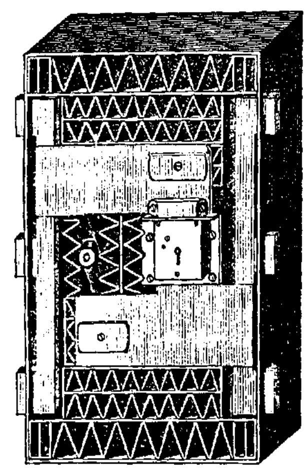


Figure 28. Price's pa gunpowder-proof lock-

In such safes the lock or box of wards is screwed to the back-plate of the lock-case, as shown in figure 13. This allows any quantity of gunpowder to be poured therein, **through the keyhole**, with facility by means of a small tube or bit of folded paper.

All **till** locks, unless specially ordered to the contrary, have a margin of 1/8”-1/4” which projects above the “cap” of the lock. Unless it is taken off, it allows an equal space between the back of the door plate and the face of the lock. This also permits gunpowder to be poured into the lock-chamber through the keyhole,

however small the latter may be.

From the insecure way in which hundreds of safes are constructed and are in daily use, protecting an enormous amount of convertible property, it is somewhat surprising that the public prints do not contain more accounts of robberies of these depositories effected by the most *ordinary* thieves, as hitherto, with few exceptions, such robberies have been the work of **scientific** thieves.

The absolute necessity for the doors of safes and strong rooms containing valuable property being made impervious to the drill is shown by the following account of one of the many robberies of iron safes recently effected in various parts of the Kingdom by that instrument:

"During the night of Friday, December 15th, 1854, the counting-house of Messrs. R. H. Greg and Co, at Quarry Bank, Wilmslow, Cheshire, was broken into, the iron safe opened by means of steel drills, and nearly £300 Sterling, in gold and silver, carried away."

"Both the Counting-house door and the outer door of the building were locked as usual, and the private watchman patrolled the yard, passing the front door at frequent intervals during the night, and yet, from all that we have heard, it appears probable that the thieves, who it is conjectured, were only two in number, must have been within the premises for five or six hours, and they appear to have got clear off with their booty."

"They had picked the lock of the outer door, and as soon as they had got within had shut and bolted it. Hence the private watchman, who tried this door several times during the night, always found it fast, the latest time at which he so tried it being three O'clock on Saturday morning, and it was found open by the box-keeper shortly after six O'clock, that morning."

"The Bollin flows near, and as that river was flooded and rising fast, there were men about at different times during the night looking after the paddles at the weir communicating with the works. Two of these men, in the employ of Messrs. Greg and Co., were sitting for a considerable time upon a rail close before one of the windows of the building within which during the whole of this time the robbers must have been at work, and yet they never made such a noise as at all to arouse suspicion."

"It appears that the thieves forced open the door of the counting-house at the head of the stairs, and that they then proceeded to work with the coolness and deliberation which shows that they knew well what they were about."

"The counting-house contains three windows; and as they could not 'operate' in the dark, the thieves had managed to provide and bring with them three curtains, one for each window, and a number of iron skewers to fasten up these curtains, so that no one from without would see any light, which, in the middle of the night would have doubtless excited suspicion at once and let to detection."

"The thieves appear to have carried with them to their 'work' everything they were likely to need, from the pick-lock for the outer door to the curtains and skewers for the windows, the steel drills for operating on the safe, and even to the oil for the drills!"

"When they gained access to the safe, which appears to have been the main if not the sole object of their labors, they seem to have made an exceedingly cautious scrutiny into its contents, one in which low cunning is strikingly blended with ignorance, amounting almost to stupidity."

"With a fear of detection not uncommon among raw 'cracksmen,' they looked at and handled a considerable parcel of bank notes, chiefly of five pounds each, and they quietly put them back again as dangerous articles to deal with. In 'collecting' the silver money, of which a considerable quantity was provided as necessary change for the wages on Saturday, they found in one drawer some base half-crowns. These they had handled and returned and their caution is not to be wondered at."

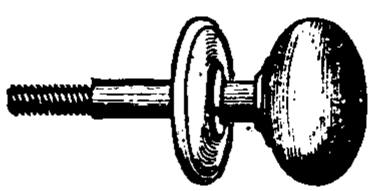


Figure 29. Knob to screw into the follow of the large lock.

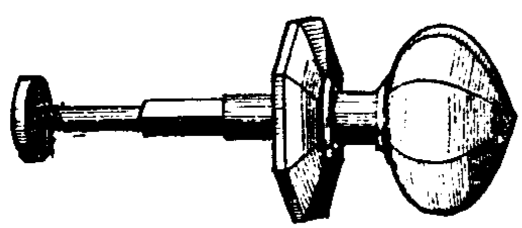


Figure 30. Octagon knob, with spindle to fasten into a nut at the back of the door.

Various kinds of knobs and handles for throwing the bolts and pulling open the door, and escutcheons for securing, the keyhole

from any foreign substance which might by accident get into the lock, and also from the prying curiosity of children and servants, are used. A knob of an octagon shape does very well for small doors; but large ones require a handle in the form of a 'T', which gives more purchase.

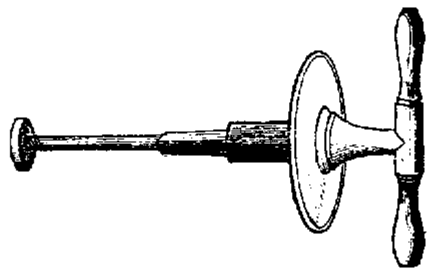


Figure 31. 'T' Handle for large safes and strong-room doors

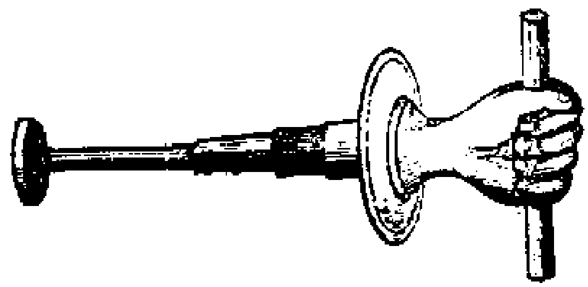


Figure 32. Fist handle, applicable for safes or strong room doors

One method of fastening these to the large lock is to screw them tightly into it; but it is very objectionable. The knob having to turn both ways, soon loosens and wears the screw. In turning, the bolts to fasten the door unscrews from the "follow," leaving the bolts unmoved. It is a neat plan; but that is all which can be said in its favor.

The best way is for a square spindle to go through the door, **"follow,"(444)** and lock-case, and to fasten at the back with a nut. By leaving a shoulder on the knob end of the spindle, the possibility of its being driven inside the safe, by breaking the knob off, is prevented.

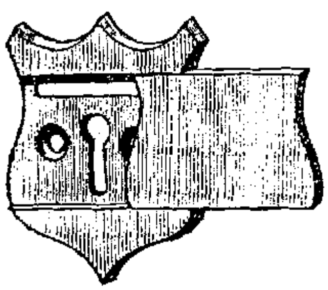


Figure 33. Slide Escutcheon-open

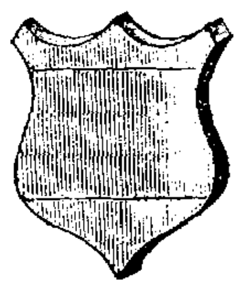


Figure 34. Slide Escutcheon-shut

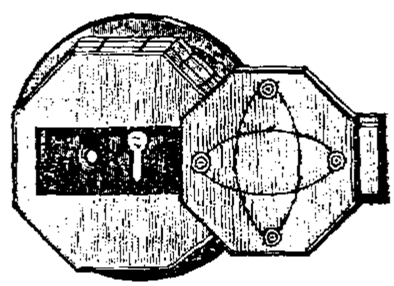


Figure 35. Secret Escutcheon-open

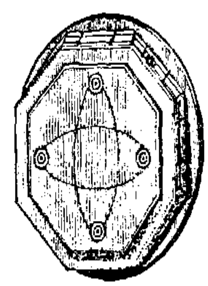
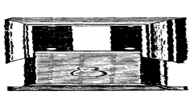
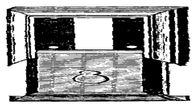
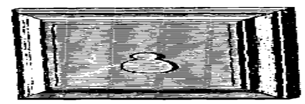


Figure 36. Se Escutcheon-s









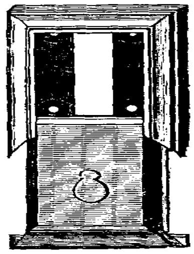


Figure 37. Lock Escutcheon-open

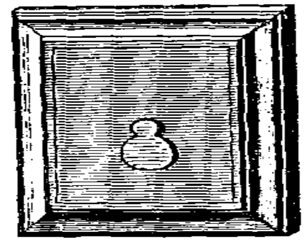


Figure 38. Lock Escutcheon-shut

The escutcheons most generally used on safes comprise the **"slide," "secret,"** and **"lock."** The "slide" is the most simple, convenient, and pleasant to use.

The "secret" has a spring that must be liberated by pressing on some particular spot with a pointed instrument such as a nail, or which is more frequently but improperly used, the key-bit, before it can be opened.

The lock escutcheon, though it does not give to the door any further protection against a burglar, is certainly useful in securing the keyhole from observation where many persons have access to the safe. It also preserves the lock from being tampered with by any person in the employ of its owner.

All these kinds are made of various designs, in the form of round or oval. Some are of the shield pattern, figure **34**, some octagon shape, as in figure **36**, and others square or oblong. For all escutcheon designs, one of the three principles is adopted.

In some escutcheons, similar to figures 37-38, the slide moves upwards; but this is very objectionable as after the key is inserted in the lock, the slide drops upon the pipe of the key and impedes it in the operation of locking and unlocking.

There is the same variation in the value of these escutcheons as there is in their design and construction; for one of an oval kind can be had for sixpence, whilst the lock escutcheons cost from twenty to thirty shillings each.

PRICE'S PATENT BANKERS' SAFES

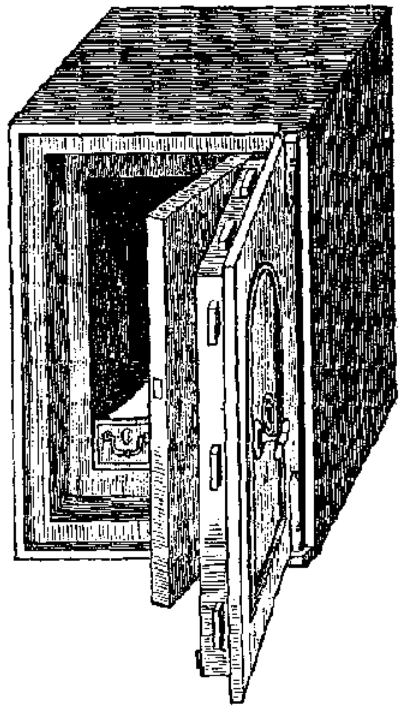


Figure 39. Bankers Safe with inner and outer fire-proof door

These safes are well adapted for the preservation of cash and other property of great value from burglars in detached buildings. They are utilized in locations where the burglar would have time, and could use noisy means by which to open the safe without fear of causing alarm.

An equal requirement would be for the preservation of books, bank notes, etc., from damage by fire, where the risk is unusually great, and the amount of combustibles contiguous to the safe would cause the fire to burn for many hours in succession.

The safe represented by figure 39 has an aggregate thickness of 6" of composition on every side, and would consequently preserve its contents in an intense fire from destruction for many hours.

The "bank locks" on many of these safes are said to be so constructed as to defy all attempts at **opening them(445)** by the most ingenious and accomplished pick-lock. Such locks were considered inviolable by both their inventors and owners until the year 1851.

The general knowledge acquired by most people of their construction, and which has resulted from the lock controversy

initiated by Mr. Hobbs picking Bramah's and Chubb's locks in that year has proven that very few made up to that period can be relied upon for their security.

This fact has so awakened the inventive and mechanical spirit of locksmiths and others, as to have produced improvements in these important articles, which not only combine all the essential properties of security against picklocks and gunpowder, but enable the manufacturers to offer them at a price which makes them available for every purpose for which iron safes or chests are necessary or required.

PRICE'S PATENT MERCHANTS' DOUBLE BOOK-SAFE

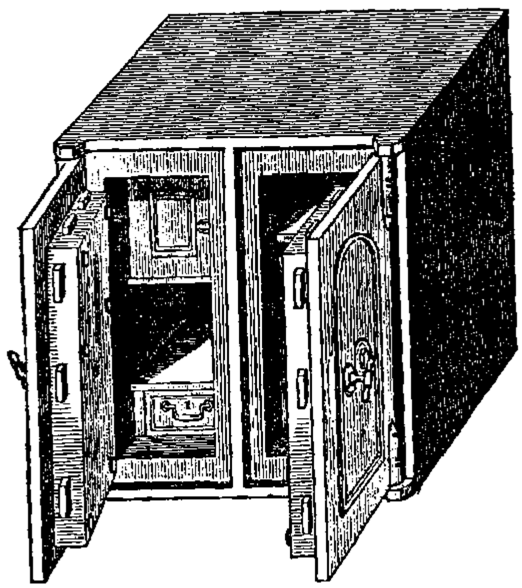


Figure 40. Merchants' double Book-Safe

This safe, which is the same as two distinct safes, is constructed precisely on the same principle as the others. It is particularly suited for a counting-house, and for establishments where the contents of one side would be required throughout the day by the various clerks employed, while the other side is intended for the use only of the principal. The locks are fitted so that the principal's key, as a master, will unlock both sides, whilst the clerk’s keys will unlock only their own. The cupboard on the principal's side is still more private and secure.

PRICE'S PATENT MODEL COUNTING-HOUSE SAFE

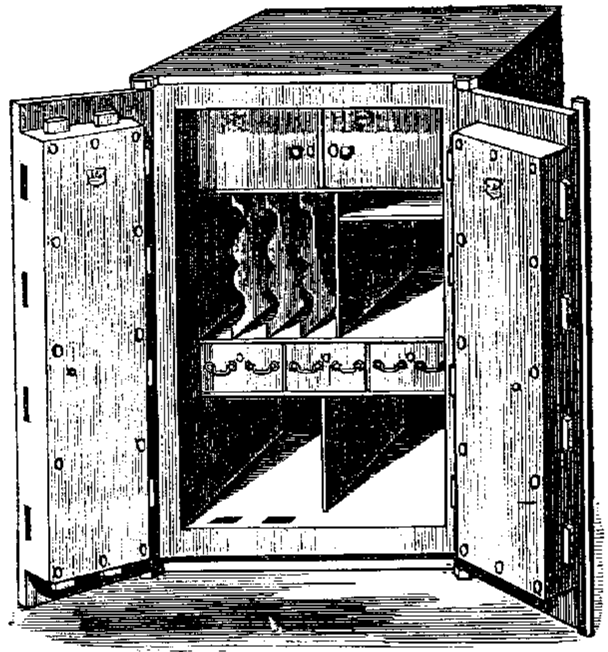


Figure 41. Model Counting-house Safe

This safe is constructed expressly for the counting-house or minor banking establishment, and is peculiarly adapted to preserve the contents both from fire and thieves. It contains all the improvements before-named. The lock of each drawer and cupboard is fitted with a different key, with a master key to pass all of them.

The left-hand door has four bolts at the side, with two each at the top and bottom; the right-hand door has four bolts at the right-hand side, and also four which shoot into corresponding holes or recesses in the rim of the lock-case of the left-hand door, with two each at the top and bottom.

The bolts of each door are moved with a 'T' handle, and secured by a 4" powder-proof unpickable lock of the best quality and construction, having two or more keys. It is thought by some that a safe with double doors, as shown in figure **15**, is less secure than one with a single door, as in figure 16.

By removing the astragal or iron strip, an instrument such as a saw-file could be inserted between the doors and the bolts cut through. This would thereby release the right-hand door. In these safes where such a space is left, and by giving the operator sufficient time, such a result might be obtained.

However, the labor and time required, are, in my opinion, a sufficient guarantee for their security in respect to such an operation. I have heard of several safes having been attempted to be opened in this manner, but in each case, the burglars were unsuccessful.

To effectively prevent such a contingency, it is only necessary to put bolts at the top and bottom of the right-hand door, identical to the left-hand one.

PRICE'S PATENT FIRE-RESISTING AND THIEF-PROOF PLATE CABINET AND CASH AND DEED SAFE.

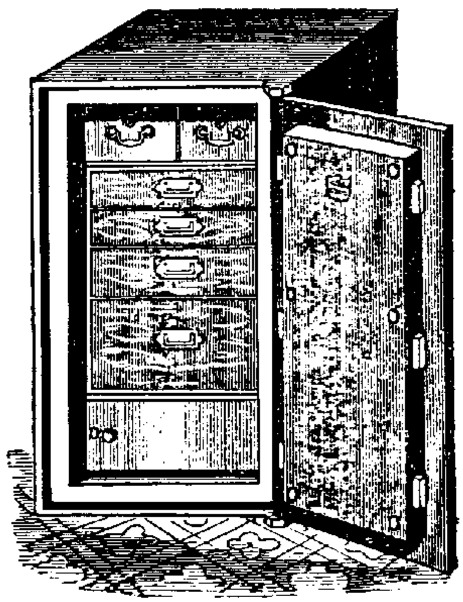


Figure 42. Plate Cabinet and Cash and Deed Safe

Figure 42 represents one of these useful depositories, which can be made of any required size and to any plan. This is constructed to hold any configuration of plates, silverware, and china.

The cabinet is made of oak with brass sunk handles. The iron safe enclosing it can be made of any desired strength to suit the risk, locality, and position it is intended to occupy. The two drawers, at the top are fitted in the safe, and are intended for cash, etc. The cupboard at the bottom is for deeds.

As wood is a bad conductor of heat, and as there is seldom a great amount of combustible material in any single room of a dwelling-house, the fire-proof composition in these chests need not be so thick as in the ordinary book safes.

It is customary with many to procure iron safes both for plate and books, and fit them up to their own taste and requirements with wood. This is an excellent method, as in a fire it would assist the chemical composition in preserving the contents from injury for a longer period.

PRICE'S PATENT FIRE-RESISTING DEED CHESTS.

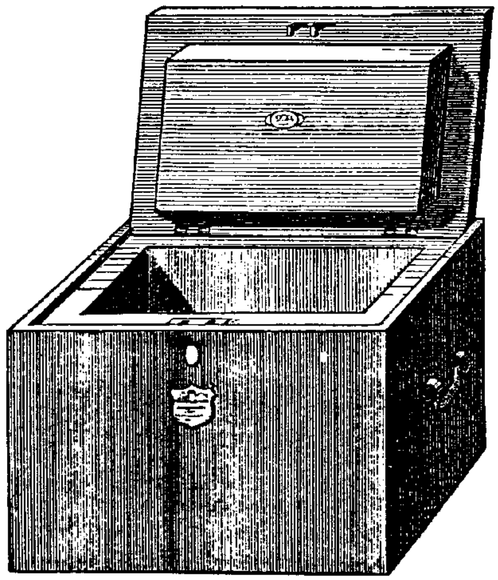


Figure 43. Fire-resisting Deed Chest for books and papers

These chests are constructed with special regard to the preservation of their contents against fire rather than against theft. Consequently, they are made of lighter iron than the safes; but although weaker, the plates of the smallest size are not less than 1/8″ thick.

They are strengthened with bar iron round the top, and are riveted to angle-iron inside, which enables the chests to stand a fall from upper stories without injury to the contents.

Deed chests made of **sheet iron** are utterly worthless, as they are so easily crushed, thereby exposing the contents. In many fires, the books and papers enclosed in such boxes have been more injured by the water used in putting out the fire, than by the fire itself.

A great fault with most of the safes and chests made in London is that the outer plates are much too light to resist violence of any kind. Hundreds of safes are hawked about the streets of the

City, the plates of which are only 1/16” thick. They are neatly painted and thus they are readily purchased by the brokers and sold at a rate accordingly. However low in price, they are the dearest that can be bought from the fact of their wanting those essential properties which make a safe secure.

CHAPTER SIX: Two Principles on which Safes are made Fireproof(446)

There are but two modes of making a safe fire resistant. The first is by using a simple non-conductor. The second is by using a combination of a non-conductor with a chemical, which, upon application of intense heat, generates steam.

Experience, and repeated experiments have proved that the use of the following substances, all simple non-conductors of various degrees, are capable of resisting fire for a very limited period of time: burned clay, powdered charcoal, dust, marble, porcelain, slightly burned clay, baked wood-ashes, fragments of earthenware, pottery, tiles, or bricks, sandstone, coarse sand, or gravel finely sifted, and fragments of slate. The combined principle of non-conduction and vaporization is the only plan by which bank-notes, books, papers, plate and specie, and other similar valuables can be preserved uninjured, when the receptacles containing them are subjected to the influence of fire.

Mr. Granville Sharp says: "The discoveries in chemistry have done much to promote security from fire. The sides of safes, when constructed with highly non-conducting chemical preparations, are capable of withstanding a great amount of heat for considerable periods." Now, Mr. Sharp's opinion of the value of such a plan is quite correct but he is quite wrong as to his estimate of the labor and expense of preparing such compounds. As it so happens, the best known and most effective chemical for such a purpose is one of the cheapest. That chemical is alum, a triple salt, being always either a sulfate of alumina and potash, or a sulfate of alumina and ammonia.

Professor Turner says: "It crystallizes readily in octahedrons, or in segments of the octahedron, and the crystals contain about fifty per cent of water of crystallization. On being exposed to

heat, they froth up remarkably and part with all the water forming anhydrous alum, the **alumen ustum(447)** of the Pharmacopaeia."

This, then, is the chemical I use. After grinding or crushing, it is mixed with sawdust. Sawdust is not only a non-conductor but an absorbant which is another important property for such purpose. Some makers use mahogany or other hardwood dust in preference to pine dust, as the latter is said to contain a large amount of resinous spirit.

It is said that the hardwood dust contains essential oil but it is also said that in some public tests of fire-proof safes, the paper contained therein were soiled (or singed) and the stain attributed to the "essential oil contained in the non-conductor." Both kinds may be used with equal advantage but pine dust is a better absorbant than mahogany, and I consider it the best as I attach great importance to its capability of absorbing more moisture than the other.

The linings, casings, or chambers which are made of sheet-iron, are well filled with this composition and firmly secured to the inside of the outer case by screws and not by solder, as solder melts at comparatively low temperatures. The back of the lock-chamber of the doors of safes and strong rooms is filled in the same manner. As soon as the outer case becomes sufficiently heated, the alum dissolves, and liberates its water of crystallization in the shape of steam or vapor. This is absorbed by the sawdust and thus becomes a wet fire-resisting and non-conducting medium. Surplus steam finds its way through the joints and angles of the linings or chambers, and saturates the contents of such safe, the whole being kept at the temperature of boiling water, 212°F. In such an atmosphere, books and papers will neither singe nor burn.

The capacity of the chambers and the quantity of alum and sawdust placed therein must always be in proportion to the probable intensity and duration of a fire. It is altogether a question of time for so long as the generation of steam can be kept up, so long the contents are safe. But the moment it is expended, and the interior of the depository exhausted of its protecting moisture, the fire then assumes its natural influence and the contents suffer accordingly. For this reason, where the risk is great, every assistance should be given to the safe by building it in a wall or otherwise surrounding it with masonry.

In private dwelling-houses, offices and counting-houses as well as premises where the amount of combustible materials is limited, an ordinary fire-proof safe, made upon the vaporizing principle, with two to three-inch chambers, is amply sufficient, and would be safe "for a much longer period than that during which a safe would be in direct contact with fire, in the successive conflagration of the parts of such building. In rooms forming part of or adjoining such warehouse as those in London, at Newcastle-upon-Tyne, Manchester, Glasgow, and Belfast, which are generally full of combustible stock, the safe should be of the most secure kind. It must be remembered that the space occupied by the fire-proof composition is always at the expense of the internal room.

The following extract from Messrs. T. Milner and Son's Pamphlet,(page 16), will explain their views on this subject: "Thomas Milner and Son having now had upwards of four years' experience of working their new patent, have equal satisfaction and confidence in laying their views before the public in reference to the important subject of the **preservation of documents(448)** from fire. After having submitted their manufactures to the most searching private and public investigations, in which they have had the kind assistance of scientific and practical men in the principal towns of the three kingdoms, they feel convinced that, within the various thicknesses of chambers tested at the London and Birmingham Station in April last, (say from one and a quarter to six inches in thickness), their depositories are equal to any degree of risk, and offer perfect security to valuable but uninsurable property, in all classes of buildings.

"The proprietors recommend their portable deed boxes, of not less than one foot inside measurement, such as tested from one to two hours in various towns for ordinary office buildings, dwelling houses, etc.; their double-chambered safes and boxes for warehouses and large buildings of ordinary risk."

The same, with an additional inner chamber, where the quantity of material or stock to burn is great, and the duration of fire likely to be increased; whilst, to the nobility and gentry, for their mansions, to bankers, merchants, and solicitors, where the risk may be still greater, they would recommend their double bankers' safe, as far exceeding in capability of resistance, any danger of degree or duration heat that might surround it in the conflagration of an extensive building. With 1000°F of heat (red heat) enveloping this safe for twenty-four hours, its contents

would not reach the temperatures of boiling water.

"The advantage of this principle over any other is the superiority of the non-conductor used, and the advantage that water or its vapor has, so shut up within the box or safe for use whenever wanted, over anything else in quenching or preventing fire. Iron, brick, or stone safes, however strong, will soon sympathize with the temperature of the surrounding fire; the barrier here used is that of nature herself, water, or the vapor under the control of chemical non-conductors, which cannot be made, excepting under artificial pressure, hotter than boiling water, and in this medium, papers will not burn."

It must be observed that in the second paragraph Messrs. Milner state, that although the exterior of the safe, when subject to red-hot 1000°F for twenty-four hours, would not cause the interior to arrive at "the temperature of boiling water". In the last paragraph, they state that the vapor thus generated by the external heat, 1000°F, acting on the chemical, "cannot be made, excepting under artificial pressure, hotter than boiling water".

Here is one of those contradictions and ambiguous explanations which abound in the pamphlet referred to. Why not have stated that the vapor or steam could not be generated except at red-heat, (1000°F) and that the temperature of this vapour under all circumstances, except when "under artificial pressure," (as in the steam-engine boiler) is neither cooler nor "hotter than boiling water," 212°F?

From various public tests which have been had by safe manufacturers, it appears that to make a safe resist the effects of red-heat for two hours and a half, the thickness of the alum and sawdust must be not less than three inches. To stand a fire for five hours, it requires a banker's safe, i.e., either one safe placed within another, thus making the composition from five to six inches in thickness, or else the chambers of the single safe must comprise the same thickness of composition. (See figure **39**)

The following account of an "extended demonstration of the security against fire," of Milner's patent fire-resisting safes, from the Edinburgh Courant, of October 23rd, 1855, fully confirms this opinion, and may be considered as a further explanation of the principle of steam-generation.

"We, the undersigned, have much pleasure in certifying that

we have this day attended the above public trials, during which Milners' No. 1 Safe and Double Banker's Safe have been submitted to a strong fire, and taken out in a red-hot state. The smaller one, in which was deposited a one hundred pound Bank of England note, and sundry documents, remained in the fire two hours and a half; and the Double Banker's Safe, containing a one hundred pound Bank of England note, and one pound note of the City of Glasgow Bank, several watches, plate jewelry, books, papers, etc., was kept five hours; and the contents of both, when taken out, were quite perfect."

....."It still remains for us to notice the construction and Principle of fire-resisting safes which Messrs. Milner, after a succession of improvements and patents, have now brought to so great perfection. The safe, of whatever dimensions, is usually composed of a double chamber on all sides of about three inches in thickness.

The exterior is of boiler-plate iron; another iron plate separates the two chambers, and a third constitutes the interior lining. These chambers are filled with a chemical mixture, composed of soda, alum, potash, and other alkalis mingled in undissolved particles with mahogany or cedar dust.

On the application of heat from without, these alkalis begin to dissolve, and the steam thus generated within the chambers finds its way into the interior of the safe, where it finally becomes condensed in the books and papers inside, keeping them in a moist condition. The hardwood dust, (of various kinds, carefully selected for their suitable chemical properties), though it does not assist in generating the steam, helps materially retain it, and prevent its too rapid escape, and too early expenditure.

The alkalis of the outer chamber are almost entirely dissolved and evaporated before the heat begins to operate upon the contents of the inner one, thus prolonging the security afforded in the event of the fire not being early extinguished. It is, of course, on the continuance of the supply of steam within, thus keeping the internal heat down to the temperature of boiling water, or 212°F, that the safety of the contents under prolonged exposure to fire depends.

It is evident that the merely partial exposure of the safe to fire would incur a proportionately smaller expenditure of the resisting power, and that, however merged for the time in any conflagration, it would seldom, indeed, be surrounded by the

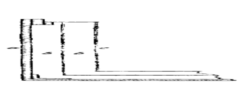
intensified and accumulated heat by which it was on this occasion tested. The fact, therefore, that the safes were taken from the furnace with little exterior injury, and with their contents, though necessarily somewhat soiled by the condensed steam from chemical mixtures in a perfect state of preservation, may be taken as a complete test of their capabilities.

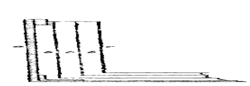
In numerous great fires, particularly in the destructive conflagration a year ago, the safes of Messrs. Milner have been exposed to red-heat for many hours, and have brought out their valuable contents in safety. In all ordinary fires, therefore, it might almost be said in all possible cases, these safes afford ample guarantee for the preservation of their contents, their Phoenix-like capacity having hitherto successfully stood the most trying ordeal."

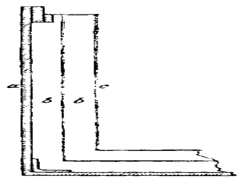
If, as the writer of this article states, the chambers of Messrs. Milners' safe are filled with "a chemical mixture, composed of soda, alum, potash, and other alkalis, mingled in undissolved particles with mahogany or cedar dust," such safes cannot resist fire for so long a period as those, the chambers of which are filled with alum and sawdust only.

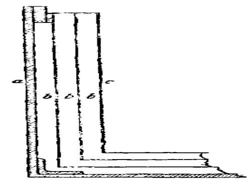
As before stated, alum contains more water of crystallization than any other salt or alkali known, viz. fifty per cent. This water being the saving principle, it follows, that whatever the chemical may be that is used, and which contains less water of crystallization than alum, it cannot be so effective for the same period of time. "The quantity of this water varies much in different salts. Some salts take up very little or no water, other combine with more than their own weight, which is the case with alum, sub-carbonate of soda, and some others."

It will have been observed that in several specifications, double and triple chambers are named, and also in the various price lists of safe manufacturers, double chambers are also mentioned. Others have given this point much consideration, and have come to the conclusion, that such a contrivance does not add anything to the fire-resisting capability of a safe.









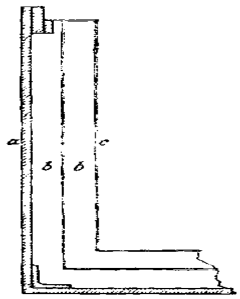


Figure 44. Section of fire proof safe, with double chambers

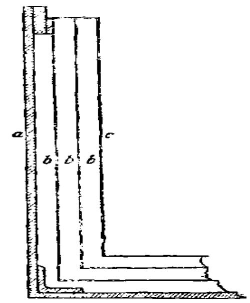


Figure 45. Section of fire proof safe With triple chambers

I cannot agree with the writer of the before-mentioned article in the Edinburgh Courant, that "the alkalis of the outer chamber are almost entirely dissolved and evaporated before the heat begins to operate upon the contents of the inner one". This is simply stating that if a kettle on a fire were divided in the middle so as to form two distinct cavities or chambers, the water would boil in the one, while in the other it would be only warm. The divisions forming the lining into separate chambers being made of iron, a good conductor of heat, can offer no resistance to the onward course of the heat.

Besides, the moment the steam is generated in the outer chamber, it finds its way through the other chambers into the interior of the safe, and by saturating the contents with moisture, preserves then from further injury. I can only account for its being adopted in the present day most, if not all, of the manufacturers, upon the supposition that as it was an early idea (being mentioned in Chubb's Specification, 1838), some advantage was supposed to be obtained by it.

Some safes with these double chambers have one filled with the fire-proof composition and the other left empty. This is decidedly wrong. The power of resistance consists in the thickness and quantity of the composition, and not in the number of compartments the space is divided into.

Messrs. Milner, in speaking of this non-conducting chemical compound say, "In long continued heat, the non-conductor discharges its pyrolignuous acid, which, combining with the alkali, forms a carbonaceous crust, pyrolignate of potass, the worst conductor of heat known; and from within this shelter the papers or books slowly give out again the large volume of steam that has been passed into and condensed in them, reacting most favorably in keeping down their own temperature, that of the box,

and the surrounding fire."

As pyrolignous acid can only be formed by the destructive distillation of the wood, consequently its production can only take place after the fire-resisting properties of the sawdust and alum are exhausted. I attach no importance whatever to Messrs. Milners' statement. I consider it too far fetched, as the essence of the principle is simply the steam or vapour, and I place no reliance upon the "carbonacceous crust" said to be formed. Indeed, the next step after its formation would be the destruction of the contents.

The vapour does not affect the writing or printing of books or bank-notes, neither does it injure their substance. Gold and silver may become somewhat tarnished, and would simply require cleaning. Even the delicate works of a watch receive no further damage than the liability of the steel parts to rust. This is obviated by being at once taken to pieces, and cleaned by a watchmaker.

The only substances which I have seen injuriously affected by the steam are the leather and forril bindings of books and parchment. The tenacity and cohesive properties of these materials, animal substances, appear to be destroyed. The former peel or drop off in bits, and latter all but disappear, while books bound in cloth, a vegetable production, remain unhurt.

In book-binding, leather and forril are applied with flour paste, and cloth with glue. The paper of ledgers and such like books is folded into sections, which are sewn with thread on parchment strips, and are fastened to the boards forming the cover. The result to these when enclosed in a safe, made fire-proof on the vaporizing principle and subjected to heat, is, that the steam annihilates the parchment strips, but leaves the paper and thread intact.

This is not to be wondered at, when it is known that for a long period, size has been made from parchment strips, simply by boiling them in water. It follows, then, that it is a physical impossibility to preserve a parchment deed from damage in an iron safe made fire-proof on the vaporizing principle, when such depository is subjected to intense heat, unless it be first placed in a steam-tight box. This astounding fact, first made known by me in the lecture I delivered in Scotland and Ireland in July last, I have proved by repeated experiments, and it has been fully confirmed by a great number of practical and scientific

individuals.

At a fire which occurred in January, 1849, in New Square, Lincoln's Inn, it was noticed, that whilst the parchment deeds were destroyed, or so much damaged as to be incapable of being read, (which accident settled more disputed titles than the Court of Chancery would do in half a century), the papers, although subjected to the same influence, were preserved.

The annexed lithograph shows the appearance of a parchment deed, after it was taken out of an iron safe made fire-proof on the vaporizing principle, which had been in a fire for two and a half hours. Before it was put in it measured 10 1/2" long, by 8 3/4" wide, when folded, comprised nine thicknesses, and was wrapped in a sheet of brown paper, and tied round with pink tape. The brown paper and pink tape are quite uninjured, as is also the piece of blue paper on which the stamp is impressed.

The deed itself, as will be noticed, is reduced to a cake of gelatin of the exact size of the drawing. Figure 47 is a piece, broken off the deed to show the fracture, and to expose to view the blue paper, which is in colour, appearance, and size, exactly the same as when first placed inside the safe.

For some time before this experiment was tried, my suspicion that these substances must be injured in some way was strengthened from having observed a safe which had been tested, and was exhibited in Mr. Milner's shop-window in Moorgate Street, London, containing books about an inch thick, being placed one above the other, and about half-way up the interior of the safe. All of which were stitched in paper covers, not one of them had a piece of leather or parchment about it.





Figure 46. Parchment Deed



Figure 47. Piece broken off to show the fracture and the stamp

The fact is, that leather and parchment constitute an irrefragable and positive test of the intensity of the fire surrounding a safe. For if the temperature of the interior attains that of boiling water (212°F) protecting medium of papers and books, plate and specie, the leather and parchment must inevitably suffer. Such a result is as certain and invariable as all the other laws of nature.

If such substances come out of a safe or chest uninjured, it simply proves that the temperature of the interior was below 212°, thereby showing that the fire had little power and intensity, and consequently was no test of the fire-resisting capability of the depository. When a book comes out of the fiery ordeal with its paper body perfect and its leather coat gone, it proves the test to have been a severe one, and consequently a fair one, and is the best testimony to the efficacy of the principle and the great value of the invention.

This important natural fact, if known by other safe manufacturers, has never been avowed. I cannot reconcile it with the various testimonials published, and numerously signed by the most respectable persons, the whole of which affirm that the parchments in the safes were severally tested in various parts of the kingdom, were preserved uninjured in some, that the wax seals "were not in the least injured".

Everybody must have noticed, in summer months, the sealing-wax placed in stationers' shop-windows, running at the temperature of summer heat, yet, in the chapter on testimonials are related several instances of the curious phenomenon of a fire-proof safe, the protecting medium of which to the contents is an atmosphere of 212°, of preserving this material from injury.

In all these tests one of two results must be admitted. If the temperature attained that of boiling water, (212°) the parchment and seals must have suffered beyond question. If they were uninjured, the temperature must have been below 100°, and consequently the tests were no tests at all. I must ask the reader's forbearance for having dwelt so much on this part of the subject. Its importance cannot be estimated to highly. It seriously concerns bankers and solicitors, and indeed all who enjoy possession of a parchment deed.

I shall conclude this chapter by copying from the Manchester Examiner and Times, a notice of a test of one of my safes made fire-proof on the vaporizing principle, which took place at Manchester, on the 12th October, 1854.

Milner's Patent, 1840, having then expired, and having been unsuccessful in making a safe fire resisting by the use of a simple non-conductor, I availed myself of the legitimate privilege of adopting his patent for the vaporizing material, and was anxious to test the quality of my safes by a public trial in that important commercial city.

Amongst the gentlemen who were present was an old inhabitant of the city, who bears a high character for integrity and honor. He stated, before the safe was placed in position, that he had been at several tests before, but that he did not consider them as such, and requested that he might be allowed to have the safe placed in the position he wished and elevated from the ground. I replied that I had not come there to act collusively. He was at perfect liberty to do as he pleased.

He then had the safe placed upon two rows of bricks, five courses high, and before locking the door, placed a piece of yellow blotting paper and a thin wood shaving in contact with the back-lining of the safe. He remained on the ground until within a quarter of an hour of the expiration of the allotted time for its remaining in the fire (two hours and a half) and until the last lot of fuel had been thrown on the fire, and returned in time to see the safe opened.

I may observe that having previously tried several safes made fire-proof on the same principle, both privately and publicly, I felt certain of the result. A safe of the same size, with the same amount of composition, and subjected to the same intensity of heat, for the same period of time, will always have the

contents affected in the same manner and in the same degree. To show my confidence in its capability, I placed my own watch on top of the books therein contained. The thickness of the composition in this safe was three inches.

"An experiment was made on Thursday last, with the view of testing the fire-resisting qualities of a book-safe, manufactured by Mr. George Price, of Wolverhampton. The trial took place in a yard near the Wesleyan Chapel, Lever Street. The safe was a 'No. 8,' being 28" high, 22" wide, and 22" deep. The chambers are filled with a steam-generating composition, the moisture from which, on the safe being heated, is forced within, in the form of vapour, a principle which has been found to answer by other makers. The door was fitted with one of "Tucker and Reeves" patent safeguard locks, the two inner drawers being secured by "Chubb's patent detector lock". Printed circulars were placed in the drawers, and six or seven volumes of books, chiefly 'Slater's Directories,' were arranged between the partitions above.

There were also loose papers, blotting paper, a wood shaving, and in addition to these, an account book, containing the signatures of parties present, who were witnesses to the various articles being inserted. Between the leaves of the account-book was inserted a five pound note. A gold watch was also wrapped up in paper, and placed inside. The door was then locked, and the key given to Mr. Councillor Warburton. The safe was raised in the center of the yard, upon two rows of bricks, (five courses,) so as to allow the fire to act underneath it. Shavings, wood, and coal were then thrown around it, the wood being arranged conically, so as to enclose the top of it, on which coal was also placed.

At a quarter to one O'clock the combustibles were lighted, and in a few minutes the safe was wholly enveloped in flame, which rose about two yards over the top, the heat compelling the spectators to retreat from its scorching influence. Mr. Alderman Heywood, Councillors Thackray, Thompson, Armitage, Worthington, and Howard, with agents of fire insurance offices, and other gentlemen taking an interest in the matter, were present.

The fire was kept up burning until a quarter-past three O'clock, two and a half hours from the commencement, and was then withdrawn. Being extremely hot, it required to be soused with water until four O'clock before it was sufficiently cooled to be opened. It appeared to unlock with little difficulty, although the door was slightly warped by the contracting influence of the

water. The brass handle seemed to have been partially melted, and broke on being pulled.

When the door was opened, the contents presented the following appearance: The vapour, supposed to be at a temperature of 212°F , had dissolved the glue on the backs of the volumes, and thus loosened the leather. The wood shaving was a little darker, the edges of a few of the circulars were slightly discolored, but most of them were untinged, and the books, with the exception of being dampened, presented no appearance of being near a fire; the papers in the drawers, opened half an hour later, were also safe. The watch was going, and indicated four O'clock; but on being taken out, the sudden transition from heat to cold seemed to paralyze its energies, for it held its hands over its face, as if for protection, and refused to move. The bank-note, with the book enclosing it were unsullied.

The five members of the city council named above, with a number of other gentlemen, placed their signatures to a document testifying their opinion of the fairness of the test, and stating the contents of the safe to have come out unscathed from the fiery ordeal. We may remark that so far as an artificial test can be made to resemble that of a building, the test was a fair one.

The conical mode in which the wood was made to surround the safe, threw the heat directly upon it, and from the length of time this was continued, the outer case must have been red-hot; indeed, the warping of the sides and door, and discoloration of the iron, were sufficient indication of this. We understand that Mr. Price rests his claim to a share of public support on two points. The fact is that he uses no solder, his object to it being, that it melts at a comparatively low temperature and then tends to allow the escape of what should be confined vapour. The second consideration is one of price, which will, no doubt, have its full weight with the public."

This faithful, intelligible, and scientific account of a most severe and honest trial, I insert in preference to anything I could say myself. The writer of it was a perfect stranger to me, and I do not now even know his name.

Mr. Granville Sharp says, at page 312 of the work before quoted, "There can be no uncertainty when a safe is made externally red-hot, (exposed to red-heat), and kept so for hours, with books and papers in it, which are afterwards brought out injured." "His

remark is very true, and when an iron safe is placed in an open space and elevated from the ground, and surrounded with fire on all sides, which is continually fed with combustibles so that the intensity of the heat is kept up for two or more hours in succession, and the contents, books and papers, bank notes and bills, plate and specie, are brought out uninjured, except that they are damped, such a trial is a scientific experiment of the greatest value, as it demonstrates beyond the possibility of doubt, that such property can be preserved in the hottest fire which should ever occur in any building.

I have frequently been asked whether fire-proof safes may be used with safety as magazines for gunpowder? To which I answer that those made upon the steam-generating principle will effectually protect it from ignition, when such safes are exposed to intense heat. From the moment the outer case becomes sufficiently heated, the water of crystallization is liberated from the chemical in the shape of steam, which at once enters the interior and saturates everything with moisture. The vapor is immediately condensed in and absorbed by the gunpowder, which thus becomes a wet mass, and will not explode until again dried.

Gunpowder should on no account be placed inside any safe or chest made fire-proof by the use of a non-conductor only. The two principles are diametrically opposite. On the vaporizing plan, everything in the safe, when subjected to fire, is kept damp until long after the chemical has parted with its water of crystallization. Whilst on the other plan, non-conduction only, the heat steadily progresses onwards, until it reaches the interior, and continues to prey upon the contents for a considerable time after the fire is withdrawn from the exterior.

Although safes are advertised as being made fire-proof by the use of the "most perfect non-conductors of heat," there are no such substances known in science. There are various bad or imperfect conductors of heat, which retard its transmission in various degrees, but the best known non-conductor, asbestos, though an indestructible mineral, is a conductor of caloric.

CHAPTER SEVEN: On the Preservation of Parchment Deeds from Destruction by Steam and

Damage by Water

The preservation of parchment from destruction by steam or damage by water has been partly anticipated in the previous chapter regarding the design of fire-proof safes, and the effect of temperatures above 212 °F.

When parchment is stored within an iron safe that has been made fire-proof on the principle of non-conduction only, such design will fail. When such depository is subjected to intense heat, the paper totally disappears, leaving nothing to indicate its previous existence but an ash almost too minute to be observed.

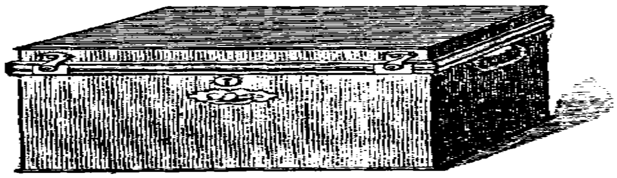
It follows that it is impossible to preserve parchment deeds and documents from damage in any iron-safe, upon whatever principle it may be constructed to resist fire, without some other contrivance when such depositories are subjected to intense heat. The discovery of the result, which is the simple effect of a cause, suggested the necessity of inventing a steam tight box for the express purpose of preserving parchments and other articles of value from the damaging or destructive effects of steam and water.

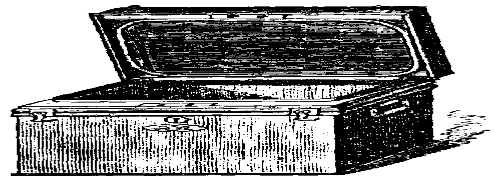
Figures 48-49 represent the box, which is made of planished tin-plate, and in the lid is an open tube which encloses a length of India-rubber cord. The latter, when the box is locked, presses upon a flange or sharp edge fixed to the inside of the top of the lower part of the box, and by hermetically closing it. This effectively makes it air, water, and steam tight.

As the air, oil heating, expands, and would thereby burst the box, a small valve is constructed inside the lock, which latter is placed outside of the India-rubber joint, and thus allows the air to escape through the keyhole without permitting the steam or water to pass into the interior.

In a small box, the act of locking imparts sufficient pressure for the desired purpose. Larger containers require the aid of several clips constructed on the wedge principle, and fastened to the lower part of the box. By drawing over the studs affixed to the lid, this effectively closes it and secures the interior from any injurious external atmospheric influence.

any injurious external atmospheric influence.





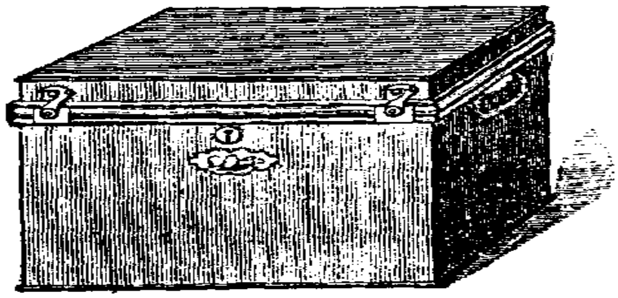


Figure 48. Patent Air, Water, and Steam-tight Box-shut

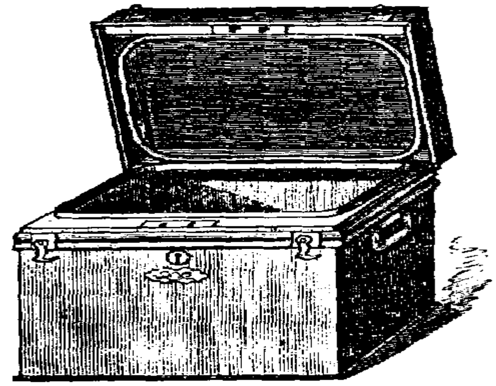


Figure 49. The same open

For bankers who keep "those books of a valuable character which have been filled," and other books and papers not in daily use in an underground closet or damp cellar, these boxes will be found invaluable. Such property must be kept dry, which is not easy in the case where they are confined for years underground. While Clifford's valuable invention for restoring books and papers may do much, it is better to plan to prevent the necessity for its use.

The importance of this branch of the subject cannot be better illustrated than by the debate which took place in the House of Lords on the Church Discipline Bill, on Monday, the 21st of April, in the present year 1856, when the imperfect and deplorable state of the registries in the numerous dioceses throughout England and Ireland was admitted by the various speakers on both sides of the question.

The cost of a central registry office in London for twenty-eight dioceses, to be made air tight, water tight, and fire-proof, was estimated in the bill at 100,000 Pounds Sterling. The importance of preserving these valuable records, however, is far beyond any considerations of pounds, shillings, and pence.

CHAPTER EIGHT: On Fireproof Closets and Strong rooms

Many of the remarks made in reference to iron safes, chests, and

boxes, equally apply to strong rooms and fire-proof closets with iron doors. Because the latter depositories are not moveable but are built with masonry, it may be well to state that these may be made additionally safe from fire by the use of the vaporizing material in the walls forming such closet.

Mr. Granville Sharp says, on this head, at page 312

"Where the property to be secured is so valuable as in banks, it may be desirable to incur some slight inconvenience to place it in a locality which is in itself fire-proof. It is therefore suggested that bankers' safes, especially money safes, should always be *underground.* If this cannot be arranged, then they should have fire-proof floors above and under them, and be so placed that a passage should run round or about them and that no *wooden* fittings or furniture occupies the intermediate space. The safe wall should, of course, be constructed of stone and iron. The next wall to it might be built of hollow bricks, or these hollow bricks filled with some non-conducting material."

I quite agree with these remarks, except, that as underground places are always objectionable and inconvenient, I recommend, in preference, the closet to be on the ground-floor. It should be contiguous to the office or room of business, but built with a **double** wall of bricks or stone.

A space should be left between, of from four to six inches, to be filled with the alum and sawdust, with tubes built in the top of the wall, so as, in case of fire, to convey the steam generated by the heat acting on the chemical composition into the interior of the closet. Such a closet, with properly constructed fire-proof doors, would be quite as secure against fire as the case-hardened door is against thieves.

The doors of fire-proof closets and strong rooms are constructed in the same manner as the doors of safes, and are made either fire-proof to the contrary according to circumstances.

It may be well to remark here, that the majority of the iron doors now in use are most insecure from the circumstance of the locks which secure them being so very large, and the keyhole in proportion.

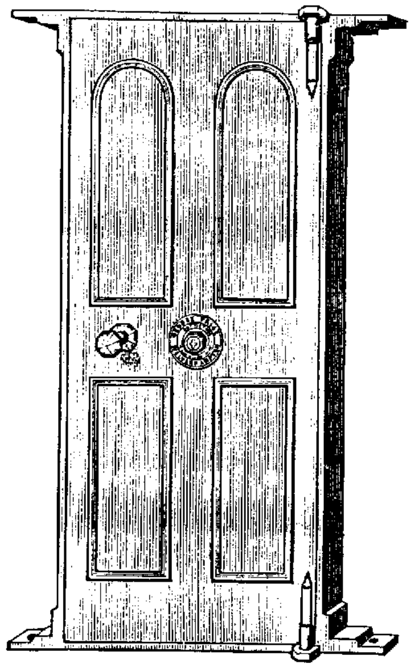
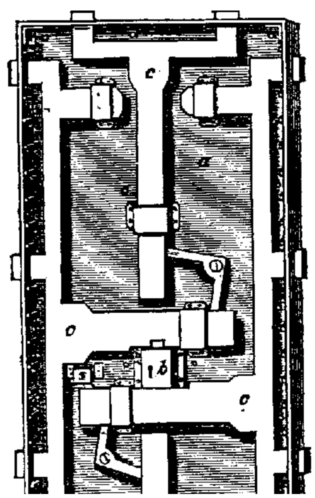


Figure 50. Iron Door and Frame for fire-proof Closet (Size, 6 feet by 2 feet 6 inches)



They can be made with sunk panels to imitate wooden doors, and to any style of architecture. The frame is made of bar-iron, 4″ x 5/8″, and the rabbet in which the holes or recesses are made to receive the bolts of the lock, 3″ x 1/2″. The frames are dovetailed together, and strengthened at each corner with strong plates.

This frame is sufficiently strong for any kind of door and

for any purpose. The width of the door is 28 1/2”, because the risk is very great. The large lock is constructed with four bolts at each side of the door, and two bolts each at the top and bottom. These are thrown with a ‘T” or fist-handle, (figures 31-32,) and secured by a four-inch lock, with a small key.

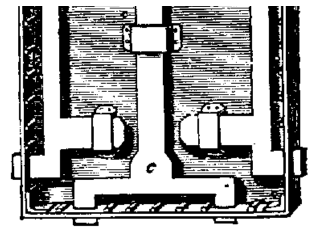


Figure 31. Large Lock for Iron Door, with twelve bolts. a, The lock chamber. b, The small lock. cccc, The large bolts

A plan prevails in Scotland of securing the doors of closets and strong rooms with a lock fastened to the back of the door, about 20” square, with a proportionate key. If this is the only security used, doors with this kind of lock could be opened without difficulty, either by gunpowder or the "jack-in-the-box," as well as by other burglars instruments. I heard one banker say that the lock and keyhole were so large that he could blow the lock off the door with a blunderbuss.

It is usual with some makers to use only a thin iron plate of from 3/16”-1/4” thick for the door, paneled around the edge with bar-iron. Where the closet is not required to be thief proof, this may do; but where security against burglars as well as fire is to be obtained, the plate should ½” thick throughout.

In constructing the large lock, in order to make the bolts move with ease and pleasantness, it is sometimes necessary to fix **anti-friction rollers** under the bolts. When there are bolts at both the top and bottom, as in figure 51, they are not required; the weight of the one assisting in moving backwards or forwards the other.

The strong room of the Wolverhampton and Staffordshire Banking Company, at Wolverhampton, is made of wrought-iron, about six feet cube, and is surrounded with masonry. The interior is fitted with iron shelves. It has both an inner and an outer door of strong wrought iron, which are cornered by a paneled wooden door of the ordinary description. The outer-iron door is secured by a compound lock, requiring three separate keys.

A very general method of securing the doors of closets, by bankers, in addition to the lock, is to have two staples riveted to the back of the door, through which an iron bar, after passing through the upper part of the frame of the door, descends through the staples and drops into another hole in the bottom of the

frame.

This bar is usually in the manager's chamber, which is over the room in which such closet is situated. For doors which do not possess in themselves the requisite security, it is a good contrivance.

Any contrivance, whether applied to safes or the doors of strong rooms, which necessitates more labor in the operation of opening them by other means, other than with their own keys, adds, in the same proportion, to the safety of such depositories against the attack of burglars.

Portable strong rooms are made altogether of wrought iron plates that are constructed in parts that can be fixed in any required place. They are usually made about six feet cube. Such a depository is an iron safe on a large scale.

A great additional security to banking establishments is obtained by using inside iron shutters. These can be made with sunken panels and moldings, and when painted and grained, look as well as those made of wood. The Commercial Bank of Scotland, in Edinburgh, is fitted with such shutters, which appear to be well made and constructed, and to answer the purpose very well.

CHAPTER NINE: The best place for a Fireproof Safe to Occupy

It is a matter of opinion as to the particular place that a safe should occupy within a structure. Some say that it is best to place it on the wooden floor, so that before any damage could happen to the contents, the safe would, by its own weight, be precipitated through the burning, and consequently weakened timbers, to the floor or cellar below.

This, doubtless, would preserve the contents from damage by fire; but unless the safe were sufficiently strong to bear the concussion and the effect of building materials falling upon it, the safe and its contents would be damaged by being crushed. No safes, however strong or well and accurately made, are water tight. The contents, if papers and books, but especially parchments, would be damaged or destroyed by the very agent

employed to extinguish the fire; the water.

Others recommend, as a good plan, the placing of the safe on a stone slab on the floor, or upon a slab let into a recess as a shelf. This would certainly preserve the bottom, but would necessarily retain the safe in its position to be affected more or less by the amount and intensity of the fire contiguous to it.

Another plan is to place the safe on a wooden stand, which is decidedly objectionable; as the less amount of combustible materials about it the better.

The best and most secure plan of all is to build the safe in the wall, or otherwise surround it with masonry. This technique insures that only the part subjected to the influence of the destructive element is the door. In several instances the contents of such safes have been found free from injury, although the **doors were not fire-proof**, i.e. they contained no non-conducting or vaporizing composition at the back of the lock-chamber. (See figure 5).

An instance of this kind occurred at Manchester, when "the counting-house and blowing-room" of Store Street Mill, in the occupation of Messrs. William Jones and Son, "were completely destroyed by fire," on the 15th of May, 1854.

The safe containing their "books, together with cash, notes, policies, etc.," had been built in the "chimney flue" and exposed to intense heat, yet to the astonishment of its owners, had preserved the contents.

Having seen a testimonial from Messrs. Jones and Son to Messrs. Chubb and Son, relating to the above circumstance, and observing the identical safe in the shop-window of the latter firm in Market Street, Manchester, my astonishment was great indeed, when I discovered that the door which had borne the whole force of the flame was not fire-proof, it had no fire-proof composition of any kind in it.

The other parts of the safe, from the paint being only discolored and not burnt, proved that but little heat had been in contact with them. This was so, as all the other surfaces, besides the door, were protected by the masonry forming "the chimney flue." This safe, then, preserved the contents, not from its fire-proof capability, but from the position it occupied in the "chimney flue."

When it is considered that at the great fire at Newcastle-upon-Tyne and Gateshead, in 1854, the contents of almost every fire-proof safe and box were destroyed, the choice of the situation in a building for the fire-proof safe to occupy should have the deepest consideration. It would be advisable to put up with any little inconvenience which should give additional security to the safe, whether against fire or thieves.

The purchase of a fire-proof safe should be looked upon as a kind of insurance, but with this difference: for the payment of *one* premium, although it maybe considerable, *a* perpetual policy is granted, there being no renewal except after the great value of the principle has been proved.

This principle of insurance, instead of being considered by the Fire Insurance Companies of its competing character, meets with their cordial support and recommendation. I once heard the manager of one of the largest fire offices in the Kingdom state that he wished Parliament would make a law which should compel every solicitor, merchant, and shopkeeper to entrust to the custody of a fire-proof safe the whole of their trade books and documents.

"While it is of paramount necessity that bank safes, whether for the deposit of money or of books, should be absolutely protected from the ravages of fire, it is almost as important that the possibility of their being flooded should be equally remote."

"Under the infliction of the extremely unpopular tax upon insurance, people usually feel that they have gone to the extent of their duty by the payment of this impost, together with the premium, leaving the provision of curative appliances to the fire offices."

"Some banks, however, have incurred the expense of fixing 'hydrants,' connected with the charged main, immediately outside their premises; at the same time keeping one or two lengths of hose pipe in constant readiness for immediate service, within five minutes of the discovery of fire."

"This arrangement is extremely valuable; but with regard to books and papers, next to the devastation caused by fire, must be placed the almost destructive influence of water, which, on such occasions, is supplied so copiously that a cellar or underground

safe is forthwith filled."

"To prevent this, it seems desirable that wherever deep drainage is accessible, a communication with the sewer should be provided, the safe door opening at some distance above the floor of the vault. When such an exit cannot be obtained, perhaps it would be desirable that a well or cesspool should be dug, and if necessary a powerful external pump connected with it, by which the water poured upon the building might be drawn off at a convenient distance."

"The pump should be of such character as not to become injured by remaining long unused; otherwise, any defect which might arise from this cause, or from want of care, would probably be discovered only at the moment when everything depended upon its being found in perfect working order."

Such a plan may be carried out by bankers, whose requirements are of an extensive character, and whose means are ample to effect such an arrangement. However, what are the thousands of private gentlemen, merchants, manufacturers, and shopkeepers, to do, the aggregate of whose property in deeds, books, bank notes, bills, and other perishable articles, amounts to so many millions?

There is only one answer. After possessing themselves of a proper safe, and assisting it to preserve such property by every possible means from destruction by fire or abstraction by thieves, they must provide themselves with such a receptacle for placing inside their safe as will effectively preserve such perishable contents from destruction by steam or damage by water. The only invention that has yet been introduced for this purpose is Price's patent air, water, and steam-tight box, as described in Chapter 7.

CHAPTER TEN: On Powder-Proof Locks

Price Gunpowder-proof lock
Tucker and Reeves "Holdfast" lock
Chubb Detector Lock, powder-proof

Since the thieves and burglars have been operating upon the doors of iron-safes by filling the locks or lock-chambers through the keyhole with gunpowder and thereby blowing them open, several modes have been patented and adopted for preventing such depositories being opened by such means.

The original invention of this kind is that of Walter H. Tucker, whose specimen lock was exhibited in the Great Exhibition of 1851, and was patented October 12th, 1852. The security part of this, and all the other principal locks, will be treated in the chapters on the old and modern locks. Mr. Tucker, in his specification, stated:

"My invention consists in so making the frame of the lock that it may be cast when made of metal, or made of wood so as materially to diminish the cost of production without lessening the security or durability of the lock; and this effect by making the frame so generally solid that it may be cast complete, or made of wood."

"I may state, in addition, that the lock is, as a whole, so constructed as to be perfectly secure against attempts to open it by gunpowder or gun-cotton, there being no opening large enough to admit either in such a quantity as to cause damage."

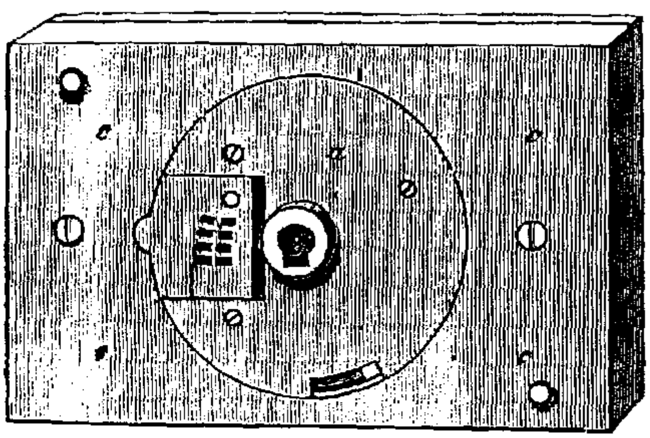


Figure 52. Tucker's gunpowder-proof closed keyhole lock, with the top plate off. 'a' The works of the lock. 'b' the keyhole. 'cccc', the other part of the lock cast solid.

From the above figure, it will be apparent that very little gunpowder could be inserted into this lock, even if it were placed in a horizontal position.

The next patent is Milner's, dated Aril 21st, 1854, and although described earlier, I think it will conduce to a better understanding of the subject to repeat it here.

"This invention is designed for the purpose of protecting locks, of whatever construction they may be, from the destructive effect of gunpowder or other explosive compound or agent, and is more particularly intended to be applied to safes or such strong depositories as are required to be secured from the invasion of burglars or others."

"My improvement in locks consists in filling up all the open space or spaces usually left around the 'tumblers and other working parts of locks, leaving only sufficient space for the turning of the key, the slight lift of the tumblers, and the limited action of the springs; thus substituting for what has commonly been the 'box' of the lock almost a solid block of metal. This 'filling' may be effected either by casting or forming the lock solid with the exception only of exactly the open space required for the working or operative portions of the lock, or it may be made so as to be formed upon the 'cap' of the lock and fitted into the ordinary box of the lock, and thus also leave only the sufficient space acquired for working or opening and closing the lock."

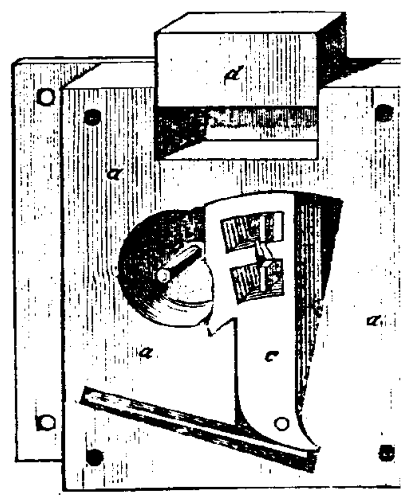


Figure 53. Milner's Patent the "box" solid applied t Protector Lock. aaa, The solid. b, The space required in locking and unlocking. tumbler. d, The bol

"It will be evident, therefore, that the space which has ordinarily formed a receptacle for a large and destructive quantity of gunpowder being, by my invention reduced to the smallest possible capacity and the resistance thus afforded to the effect of explosion, will preserve the lock from destruction by any such means, and will necessarily cause the discharge of the violence through the keyhole."

As stated before, I am unable to discover any difference in principle or construction between this lock of Milner's and that of Tucker's. (See and compare figures 52-53.)

After Mr. Milner had obtained this patent, he got up a trial to test its **powder-proof(449)** capability, which is described as follows in a Liverpool paper of that period:

"Messrs. Milner and Son having applied a new patent powder-proof lock to their safes, recently submitted the contrivance to the test of a trial at the Phoenix Works, Liverpool, in the presence of William Brown, Esq., M.P., several members of the Watch committee, Major Greig, Head Constable of the Borough, and various other gentlemen."

"Mr. Milner, after alluding to the frequency with which safes of different constructions had been of late forcibly opened by the introduction of gunpowder into the lock by means of the keyhole; and having explained that the destructive agent might be introduced in still greater quantity into the chamber which contained the lock by the process of drilling a hole through the front plate of the door, proceeded to exhibit one of the old locks, and also one of the new ones."

"The former consisted of an iron box into which the various wards and levers, popularly known as the 'works', are fastened. The remaining portions of the lock were completely void and capable of containing a considerable quantity of any explosive matter that might be forced into it."

"He explained that into a lock suited to the medium size of a safe, constructed on the old or ordinary principle, about half-a-pound weight of gunpowder might be introduced, while larger locks would of course contain a greater quantity."

"He next showed one of equal power, but of smaller dimensions, in which every morsel of space not occupied by the 'works,' or essential to the working of the parts, was filled up solidly with metal, thus reducing the vacuum in its interior to the smallest possible amount."

"Both of these are what are known as the patented six-lever locks. By the improvements thus effected, the lock did not afford space for more than half a thimbleful of powder. To obviate still further the possibility of applying gunpowder in any way to the opening of the safe, Mr. Milner showed that the chamber in which

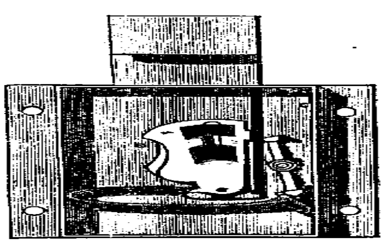
the lock was placed was completely filled with soft spongy timber, which, in the event of being penetrated with a drill, would of itself half fill up."

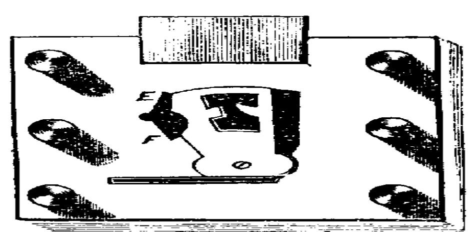
"This would leave the aperture for the reception of any material whatever, exceedingly small. As a still further protection, however, he showed that this timber was protected by a plate of hardened steel, which would resist almost any attempt at boring from the outside."

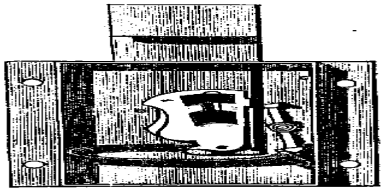
"One of the locks being packed as full of powder as possible, and an explosion produced by means of a fuse, the screws which bolted the outer to the inner door were then unfastened and it was found that the lock had not sustained the slightest injury. All the levers and moveable portions were still in good working order, the only impediment being the dirt caused by the burnt powder."

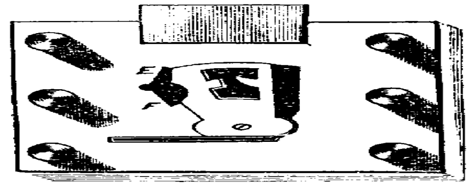
"An experiment was next tried with a lock of the old description, into which about one half pound of gunpowder was introduced. The explosion caused the door of the safe to be driven to a distance of several yards; the lock completely destroyed, and every means of barring access to the interior entirely removed."

The next patent connected with this subject is Milner's second, dated December 20th 1854; but I cannot discover any difference in principle, and, very little in construction between this and his first patent, with one exception. In the first patent "the space which has ordinarily formed a receptacle for a large and destructive quantity of gunpowder being, by this invention "reduced to the smallest possible capacity." is in the second "reduced to a minimum." The following figures, with the explanation illustrating the last patent, are taken from his published list of prices:









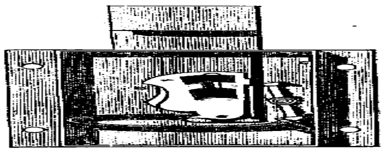


Figure 54. Usual open Detector Six-lever Lock. "Open lock, capable of holding from eight to forty-eight ounces of gunpowder, such as generally used for safes. All locks, excepting Milner's solid lock, (fig.55) are open to the same objection, more or less, and may be easily blown open."

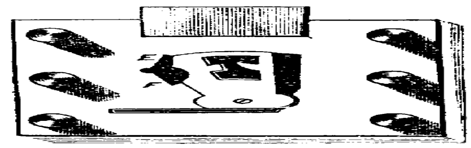


Fig.55. Milner's Patent Solid Powder-p
"Milner's (double) patent solid gunpow
lock. Keyhole and turning space for ke
hold as much powder as may be exploded
times without effect. Put in the key,
at 'F', turn to the right, and take out
To unlock, put in at 'E' and take out a

Mr. Milner states that figure 54 will hold from eight to forty-eight ounces of gunpowder, and he must certainly means this to apply to the locks on the 40,000 safes he had previously manufactured. I have examined many six-lever locks as shown in figure 54, but I cannot get any of them to hold even his minimum quantity. The following table shows the exact quantities each lock will hold, both in a vertical and in a horizontal position.

Description	Vertical	Horizontal
Common Six-lever Lock- 3"	47 grains.	9 gr. 8 gr.
Common Six-lever Lock- 3 1/2"	5 gr. 8 gr.	1 1/2 oz.
Common Six-lever Lock- 4"	12 gr. 6 gr.	2 oz. 5 gr.
Tucker and Reeves' Holdfast- 3"	5 gr.	20 gr.
Tucker and Reeves' Holdfast- 3 1/2"	6 gr.	23 gr.
Tucker and Reeves' Holdfast- 4"	12 gr.	35 gr.
Cotterill's Climax Detector- 3 1/2"	9 gr.	26 gr.
Cotterill's Climax Detector- 4"	9 gr.	26 gr.
Gibbons's Detent, and Price's Gunpowder-proof- 3"	20 gr.	1 gr. 24 gr.
Gibbons's Detent, and Price's Gunpowder-proof- 3 1/2"	20 gr.	1 gr. 24 gr
Gibbons's Detent, and Price's Gunpowder-proof- 4"	25 gr.	2 gr. 13 gr.

It will be noticed that it was an "old lock" that was experimented upon at Liverpool, and which Mr. Milner stated would hold eight ounces of powder. However, **figure 54** represents it as a six-lever lock, which he states will hold from eight to forty-eight ounces! Verily, how is it possible to reconcile such statements. I presume what he meant by an "old lock," is the box of wards, as shown in **figure 4**, and which has a keyhole the size of the one shown in **figure 23.**

To fill such a lock with gunpowder and then blow it open and call it a six-lever lock, is a deliberate and an absolute misstatement.

The locks as previously stated now generally used by safe-makers, are only 3 ½"-4" square. In drawing a comparison between these and Milner's "gunpowder-proof solid lock, I ask is it correct or fair to state that the former "will hold from eight to forty-eight ounces of gun-powder?"

At another test of this lock which took place at Newcastle-upon-Tyne, in December, 1854, during the second explosion, the door-plate parted from the lock and lock-chamber, and was thereby opened. The following account of this trial is taken from the Newcastle Chronicle, of December 22nd, 1854.

"A trial of Milner's New Patent Powder-proof Solid Lock and Safe Door, took place in the Corporation Yard, on Wednesday, in the presence of the Mayor, and about one hundred gentlemen."

"The lock-chamber was taken off and the lock examined, and the chamber replaced. The safe was carefully closed, and the experiment commenced by Mr. Dunne, chief superintendent of police, placing about half ounce of powder in the keyhole, which was plugged, leaving only a small space for the insertion of the match."

"The explosion took place without apparently damaging the safe in any way, but it was found that it had enlarged the cavity of the lock so much that it would now contain about one and one half ounces of powder."

"On a second explosion, the sheet iron front of the door was forced open two or three inches, but the lock still seemed to hold fast. A gentleman, Mr. Middleton, expressed his belief that it could now be forced open by any mechanic, but it required the assistance of four men to effect it, which took a half hour."

"A trial was then made on another safe, having the ordinary lock. Into the keyhole about three ounces of powder were placed. At the first explosion the door was blown off, and the safe thrown over on its side. The result was quite satisfactory as to the capability of these locks, and is highly creditable to Messrs. Milner, and proves incontestably the superiority of theirs to the usual locks."

I may observe, that if the lock in its perfect state would hold only one half ounce of gunpowder, it was simply impossible that the first explosion should have so "enlarged the cavity of the lock" as that the latter should be capable of containing one-and-a-half ounce.

To have inserted this latter quantity in the lock only proves that the first explosion had separated the lock from the door, thereby allowing the gunpowder not only to fill the lock, but to occupy the space between the front of the lock and the back surface of the door-plate. The above account cannot be reconciled in any other way.

The gentleman referred to as Mr. Middleton, whose acquaintance I made some time ago, takes a great interest in all matters relating to fire and thief-proof safes. After relating the above circumstance to me and reading the above account, he declared that instead of taking him half-an-hour to open it after the second explosion, it was only five minutes.

This result confirms an opinion I have always expressed upon these solid locks: their very construction assists the operator in blowing them open. There is nothing in the lock to give way, and consequently, the keyhole being plugged, some other part must suffer from the effects of the explosion.

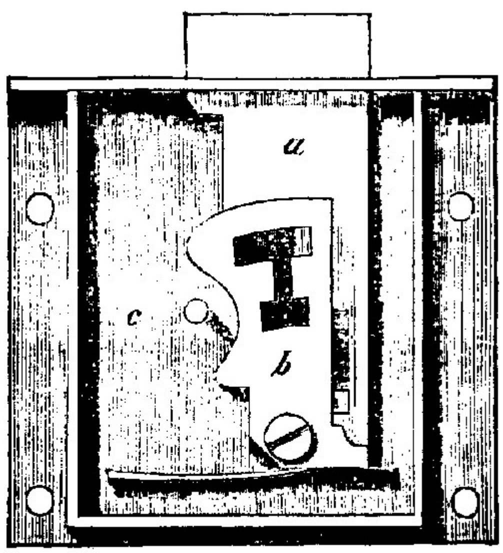


Figure 56. A 3 ½" ordinary six-lever lock, without gunpowder-proof arrangement. a, The bolt. b, The levers. c, The open space

The next is my own, as described earlier, and to assist in making this part of the subject as clear as possible, I insert accurate representations of all ordinary six-lever locks without a detector, and the same lock with the cellular filling, in accordance with the specification of my patent, dated January 31st, 1855. By adopting this simple contrivance, all lever, and most other locks, can be made powder-proof.

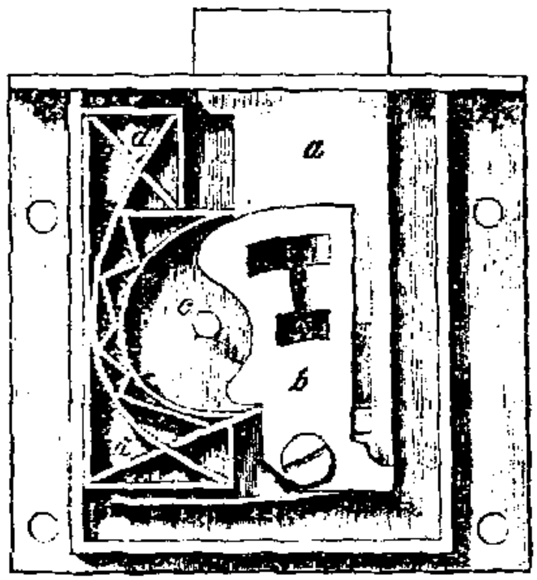


Fig.57. The same Lock, with my arrangement for making it gun-powder proof. a, The bolt. b, The lever. C, The space required for the key in locking and unlocking. Dd, The guard and cellular filling of the vacant space

Figure 56 shows the cavity that can be filled with gunpowder through the keyhole, and **figure 57** shows the guard encircling the

through the keyhole, and **figure 57** shows the guard encircling the space required by the key in locking and unlocking.

It will be at once seen that all the gunpowder that can be forced into the lock through the keyhole is the amount the space will hold. That is, supposing the safe is in a horizontal position, (for if it can be vertical, as most safes are), the gunpowder can only be inserted to the level of the keyhole.

Therefore, there is not the slightest advantage in casting the other parts of the lock solid; to the contrary. The locks, as now made by Chubb, Tucker and Reeves, and Gibbons, have a revolving "barrel and curtain," which, added to the before-mentioned plan, allows only a very small quantity of gunpowder being inserted in the lock.

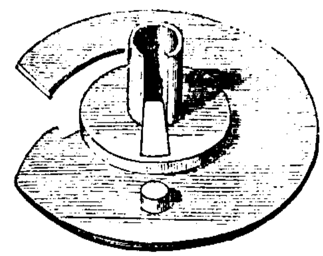


Fig.58. Barrel and curt Tucker and Reeves' Holdf

In addition to these contrivances, in the locks I use, there is a hole made on each side of the "cap" of the lock, as shown in **figure 59**, which causes the force of the gunpowder, when exploded, to lose itself through these apertures.

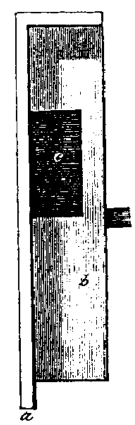


Fig.59-End view of Po Lock. a, The back pl cap. C, The aperture

To make assurance doubly sure, and especially as my statement differs so widely from Mr. Milner's, in May, 1856, I fixed a 3 ½" Gibbons' patent detent till lock, fitted with my patent powder-proof contrivance, on the door of a 26" safe, and charged the lock several times with gunpowder, rammed in as tight as possible to plug the keyhole.

After firing it, the result was that with the exception of the works of the lock being, "furred," both it and the safe door were perfectly uninjured. In each trial, the safe was laid on its back and well shook, so as to get as much powder in as possible.

Chubb's plan is to perforate with numerous holes the back plate of the lock, as shown below.

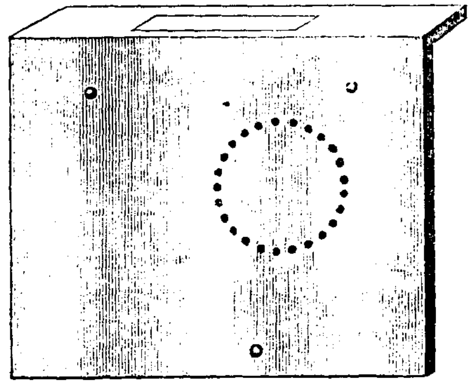


Fig.60. Chubb's Detector Lock, with powder-proof contrivance

Cotterill's Climax Detector Lock is gunpowder-proof in itself. The next powder-proof lock is Tucker and Reeves's Holdfast, which, also, is gunpowder-proof in itself (see **figure 61**).

It will be seen that the key moves inside the levers or slides, the latter being separated by pieces of metal. It is simply impossible to damage this lick, even when it is in a horizontal position, by ramming it with gunpowder, and exploding it.

I have tried to do so with one of them by ramming it with gunpowder, and with the keyhole with a blank key, leaving a minute prime-hole at the end of the bit. Though the charge exploded with the report of a gun, and the lock had been tested several times before in the same way, it proved, on examination, to be uninjured and easily answered to its key. I am quite convinced that both this and the lock shown in **figure 57** may be charged and fired a hundred times in succession without enabling the operator to open the safe.

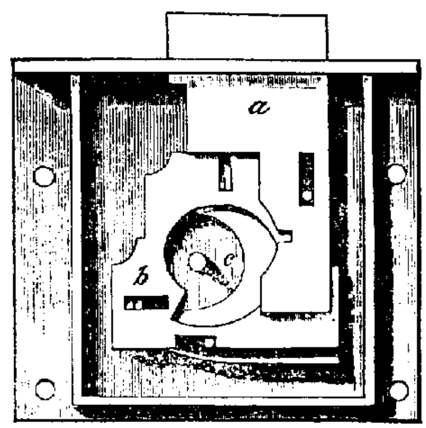


Figure 61. Tucker and Reeve's Holdfast lock, with the barrel and curtain away. a, The bolt. b, The slides or levers. c, The space for the key to lock and unlock

It is but right to state that it is only the "old" locks, as described by Mr. Milner, at Liverpool, which have been blown open with gunpowder.

I am not aware (and I have made numerous inquiries) of a single

instance in which a safe, secured by a modern 3 ½″ or 4″ six-lever lock, has been opened by a thief filling the small lock through the keyhole, with gunpowder.

The box of wards or other locks, by being screwed to the back plate of the lock-case, as shown in **figure 4**, leaves a space of ½″-1″ between the face or cap of the lock and the back surface of the door-plate. This allows gunpowder to be freely poured through the keyhole into the lock-chamber, and most lock-cases will hold from five to thirty pounds' weight of gunpowder, according to the size of the safe-door. However, the small lock is very different than the large lock-chamber, and must not be confounded with it.

By comparing **figure 57** with **figure 4**, an idea may be formed of the difference of internal capacity between the small lock and the lock chamber; the one holding from twenty grains to two grams of gunpowder, the other from five to thirty pounds.

Figure 23 and **figures 62-63** will illustrate the difference in the keys and keyholes of the old safe door locks, the box of wards and the modern ones, a three-and-a-half or four inch till.

Mr. Milner, in his characteristic style, publishes in his circulars, that "the various safes advertised as having powder-proof locks, may all (with the exception of Milner's) be blown open by filling the locks through the keyhole with gunpowder."

I last year invited Mr. Milner to prove the truth or falsehood of

I last year invited Mr. Milner to prove the truth or falsehood of this modest assertion, by operating upon some of my safes with gunpowder; but for weighty reasons best known to himself, he did not accept the invitation.

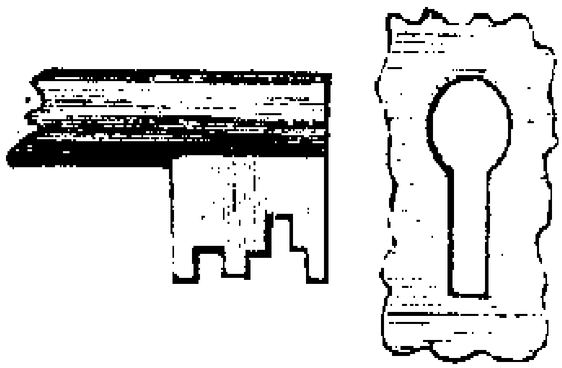


Fig.62. Key and keyhole of Tucker and Reeves' 3 ½"Holdfast Till-lock

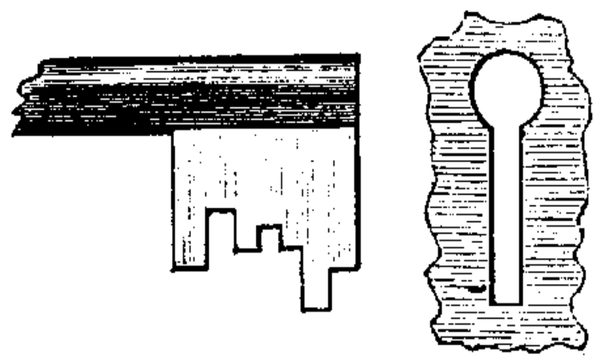


Figure 63. Key and keyhole of Chubb's 4-inch Iron-door Till lock

The liability of a well-made modern safe to be opened by means of gunpowder lies not so much in the small lock, as in the lock chamber into which a considerable quantity can be poured, and not through the keyhole.

In well-constructed safes this is prevented, except by drilling a hole in the door-plate, under the small lock. By adopting my patent case-hardened door and powder-proof lock-chamber, (**figure 28**) even that is effectively prevented.

It is in detached offices and in premises upon which no one resides during the night, or on the Sunday, and which are otherwise so isolated as to be out of the beat of the policemen or passers by, that safes are more especially liable to be opened by gunpowder.

As it must be particularly noticed, most of the safes which can be successfully operated upon by such an agent can be more easily opened, and without half the risk, by other means.

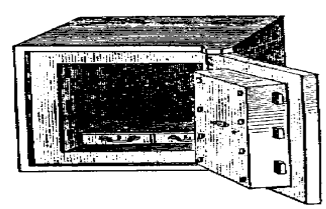
No accomplished thief or "cracksman" would attempt to open a safe by gunpowder in a private house or other inhabited premises, as the report of the explosion would be sufficient to arouse the heaviest sleeper. It must be remembered, also, that as the operator runs the risk of receiving personal injury by the experiment, it obliges him to keep at a respectful distance from the safe until all is over.

Soon after the fire at Newcastle-upon-Tyne, some burglars broke into the premises of Messrs. Leidemann, and by means of gunpowder blew up an iron-safe, but through the report of the explosion attracting the notice of the police, they were unable to secure any portion of the contents.

There has been so much “humbug” practiced with respect to fire and thief-proof safes, that it is necessary to make these remarks to induce those who possess really good ones to place reliance upon their security in this respect, although they may not have a specially constructed powder-proof lock.

A burglar would never run the risk of using gunpowder when, with most safes, he could effect his object by the chisel or drill. In detached offices he might use any means without fear of causing alarm, and in that case gunpowder would doubtless be the readiest, consequently, for such situations the safe lock should not only be powder-proof, but, above all, the door should be drill-proof, the safe itself of sufficient strength to resist the greatest violence, and, where practicable, it should be well secured in its position, or firmly built in the wall of the building.

CHAPTER ELEVEN: On the Comparative Prices of Wrought-Iron Fire-Resisting and Thief-Proof Safes



The majority of the lists of prices published by the different safe makers are quite unintelligible to the uninitiated and the general public. In some lists, the prices are given without naming the thickness of the iron-plates forming the

body and door; in others the price is given without drawers and partitions. The sizes in no two lists are exactly the same; neither do they state (with one exception) whether the plates are dove-tailed or riveted to angle-iron or both.

I conceived that the only way to get at the correct comparative prices of the various makers was to send to each a specification in accordance with the size and description of my “first-class safe," both with single and double doors. I therefore caused a copy of the following specifications to be sent to each of the respective makers, whose estimates are listed as:

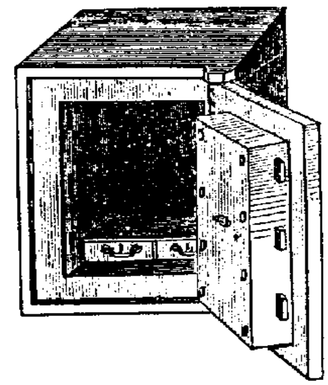


Figure 64. Price’s patent “f single-door safe. No. in 1 Size: 30 inches high, 23 in and 23 inches deep. 18 Pour if with patent case-hardene powder-proof lock-chamber, Sterling

No. I.- Specification for a single-door wrought iron fire-resisting and thief-proof Safe. Outer plates ¼” thick, to be both dove-tailed and riveted to strong angle-iron inside. The door to be 5/8” thick. The chambers for the fire-proof composition to be 3” thick. The knob to throw the bolts; to be secured by a patent unpickable and powder-proof lock. To be fitted with two drawers. Size: outside measure, 30” high, 23” wide, and 23” deep.

POUNDS	SHILLINGS	DENIERS
JOHN TANN, LATE E. TAN AND SONS 17	**0**	**0**
GEORGE PRICE 18	**0**	**0**
W. MARR AND SON 20	**0**	**0**
SAMUEL WHITFIELD 22	**0**	**0**
JOHN LEADBEATER AND CO. 23	**0**	**0**
CHUBB AND SON 23	**10**	**0**
THOMAS MILNER AND SON 24	**0**	**8**

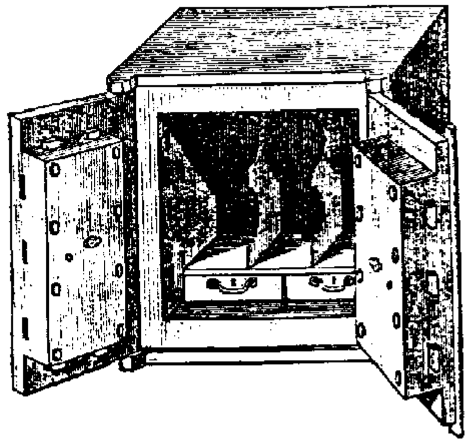


Figure 65. Price’s patent “first-class_ double-door Safe. No. in list, 102D. Size: 36 inches wide, and 24 inches deep. 31 Pounds Sterling. If with patent case-hardened doors, and powder-proof lock-chambers, 35 Pounds Sterling

No. II.-Specification for a double-door wrought-iron fire-resisting and thief-proof safe. Outer plates ¼” thick, to be both dove-tailed and riveted to strong angle-iron inside. The door to be 5/8” thick. The chambers for the fire-proof composition to be 3” thick. The knobs to throw the bolts; to be secured by a patent unpickable and powder-proof lock. To be fitted with two drawers, two partitions, and one shelf. Size: outside measure, 36” high, 36” wide, and 24” deep.

	POUNDS	SHILLINGS	DENIERS
W. MARR AND SON	30	0	0
GEORGE PRICE	31	0	0
JOHN LEADBEATER AND CO.	32	0	0
CHUBB AND SON	36	0	0

JOHN TANN, LATE E. TANN AND SONS 37	0	0
SAMUEL WHITFIELD 40	0	0
THOMAS MILNER AND SON 46	12	0

The estimates for the two safes, added together, give the following result:

	SINGLE DOOR SAFE P. S. D.	DOUBLE DOOR SAFE P. S. D.	FOR THE BOTH P. S. D.
GEORGE PRICE	18 0 0	31 0 0	49 0 0
W. MARR AND SON	20 0 0	30 0 0	50 0 0
JOHN TANN	17 0 0	37 0 0	54 0 0
JOHN LEADBETTER AND CO.	23 0 0	32 0 0	55 0 0
CHUBB AND SON	23 0 0	36 0 0	59 0 0
SAMUEL WHITFIELD	22 0 0	40 0 0	62 0 0
THOMAS MILNER AND SON	24 0 0	46 12 0	70 12 8

These prices include Milner’s double patent powder-proof and door.

After noticing such a disparity of prices for the same article, my readers will naturally inquire how such a difference arises. Since I have been a safe manufacturer, it has been my endeavor to bring the manufacture in my own establishment to a system, and the result is that I can tell to a trifle the cost of every safe that leaves my works.

From the very limited number of safes and chests that can be made annually by a great number of hands, even with the aid of steam machinery, the profit on them is nominally very great, but in some of the before-mentioned estimates it must be excessive.

The weight of the single-door safe (figure 64) is 5 cwt. 3qrs., and the double-door (figure 65) 10 cwt, 1qr., which, allowing at the rate of 121£ Per ton for the iron and fire-proof composition, amounts for the two safes to 9l£ 12s., thus leaving a considerable balance as a margin for cost of labor, wear and tear of machinery and tools, locks, knobs, and other incidental expenses, together with the profit.

The principal item of cost is labor, and therefore it follows that safes can be made cheapest where labor is cheapest. The next item is iron, and the same remark equally applies. Since the rebuilding of my works, with sixty pairs of hands at full work, with the aid of the most approved steam machinery and every contrivance which ingenuity could suggest, I have only been able

to manufacture three hundred and ten safes and chests in a period of six months.

This will give an idea of the number that can be made by those who employ a greater number of hands. The cost of plant and machinery being so great, a fair allowance for interest of money on the outlay must be included in the cost of manufacturing a safe. Beyond this and the other items named, there is no important item of expense, except that of advertising, which, on such a limited and small return, must in some cases amount to something like twenty-five per cent on the cost of the safe.

As the general usefulness of an article is always enhanced by its comparative cheapness so as to bring it within the reach of all classes of society, it should be the object of all manufacturers to do away with all unnecessary and extraneous expenses, which must be paid for by the increased selling price of such article.

It follows that indiscriminate and extravagant expenditure of whatever kind, connected with the manufacture and sale of any article, must be paid for by a proportionate profit, which being paid by the purchaser, becomes a heavy and unnecessary tax upon the public.

We appear to be in such favor with indirect taxation, that it is seldom we inquire what is the proportion of the sum we pay for an article which goes for extraneous and unnecessary expenses; but if the retailer were to tell us that on a 20l£ article, 5l£ went for such expenses, we should be as uneasy and as dissatisfied as we are in paying a direct tax, such as the income and property tax. Yet in too many cases such is the fact.

A manufacturer, no matter of what article, who by purchasing his materials at the cheapest hand, who adopts machinery and economizes labor, who by careful management and being satisfied with a moderate profit, produces such article at a moderate price, deserves the support and encouragement of all liberal-minded men.

CHAPTER TWELVE: On Testimonials

"The upright man is guided by a fixed principle of mind, which determines him to esteem nothing but what is honorable, and

to abhor what is base and unworthy in moral conduct. He seeks no mask to cover him, for he acts no studied part: but he is, in truth, what he appears to be full of truth, candor, and humanity. In all his pursuits, he knows no part but the fair and direct one: and would much rather fail of success, than attain it by reproachful means. In his manners he is simple and unaffected; in all his proceedings open and consistent."

"No calculation of probabilities can insure safety to him who is acting a deceitful part."

"A man of enlarged capacity and extensive views is always upright. Craft is always the supplement of inferior abilities. It characterizes a narrow comprehension and a little mind"

"The man of moderation, as he is temperate in his wishes, so in his pursuits he is regulated by virtue. A good conscience is to him more valuable than any success. He can have patience. He can brook disappointments. He can yield to insurmountable obstacles: and, by gentle and gradual progress, is more likely to succeed in the end than others are by violence ` and impetuosity."

"In his highest enterprise, he wishes not to have the appearance of a meteor, which fires the atmosphere; or of a comet, which astonishes the public by its blazing eccentric course; but rather to resemble those steady luminaries of heaven, which advance in their orbits with a silent and regular motion. He approves himself thereby to the virtuous, the wise, and discerning: and by a temperate and unexceptionable conduct, escapes those dangers which persons of an opposite description are perpetually ready to incur."-*Blair.*

As the value of all testimonials depends altogether upon their accuracy and truthfulness, I must be allowed to express my dissatisfaction with the character of those generally circulated in connection with fire proof safes.

A testimonial, to convey a correct impression to the minds of its readers, should state not only the result to a safe after its exposure to fire, but **all** the attendant circumstances, such as:

- **The position of the safe in the building in which the fire occurred;**
- **How long the fire exerted its influence on the spot where the safe was situate;**

- **Whether it was built in a wall, or otherwise surrounded with masonry, or whether it was in a fire-proof closet;**
- **The room containing the combustible materials on which the fire fed;**
- **In an upper counting-house, or a ground-floor office;**
- **How long the fire had been about the safe before the fire-engine deluged its locality with water.**

If the contents are singed it should say so, and should not attribute such stains to essential oil or pyrolignous acid. If the fire was so slight that, the contents were only "slightly warmed," it should not state that the external heat was intense.

It should also state the exact appearance of the whole of the contents of such safe, when opened. It should not, like some witnesses whose integrity is questionable at a trial in a court of justice, state but part of the truth, withholding essential points of the evidence, but should state "the truth, the whole truth, and nothing but the truth."

There is no necessity for collusion misrepresentations, or the withholding of facts, as all that safe manufacturers can be expected to do is to make such a depository as secure against fire, thieves, and burglars as the laws of nature and science will permit.

Many safe makers declare their safes and chests will do too much more than is possible. The public can only require from inventors such results as are within the bounds of practicability and do not expect to see perpetual motion, or to hear of the actual discovery of the philosopher's stone. Those who offer such gratuitous results must not be surprised to be generally disbelieved, and witness their statements ridiculed and laughed at.

I am compelled to express my surprise and regret that men of the highest character and attainments should append their names to such documents. Such statements, contrary to their makers intentions, are only calculated to mislead the public. They place implicit belief in the truth of the statements therein contained, simply on the strength of such an array of influential and respectable signatures.

Before reading the following testimonials, selected from those published by the safe manufacturers whose names they respectively

bear, it may be well to inquire the meaning of certain words and expressions therein used, as follows:

When deeds are spoken of as having been preserved, it is invariably understood to mean parchment deeds, though in many cases the word "parchment" will be found omitted.

Where the word "seal" or "seals" is mentioned, it must be understood to mean "wax" seals.

"Perfectly uninjured" means that the material remained in its pristine state, after the depository enclosing it had been subjected to intense heat.

"Intense heat," "severe heat", "fierce fire," are synonymous terms, and mean red-heat, i.e. 1000°F.

"The iron was melted," when applied to wrought-iron, is a misnomer, as wrought-iron does not melt; it only fuses, and the lowest heat at which iron will weld being 12,777° F, it follows that such a temperature can only be produced by a blast.

"In immediate contact with the top of the chest" means that the articles touched the iron lining of the interior.

"Not in the slightest degree injured," when applied to wax seals, means that the sealing wax retained its impression; that it did not run or spread upon the surface of the deed.

"Perfect conductor" means that it has no power of transmitting heat.

A simple non-conductor only, when acted upon by fire, evolves no vapor, and is the opposite principle to that of "steam-generation," "evaporation," "vaporising," and "chemical filled" safes. The composition in all of these, on the application of external heat of 1000° F, generates steam.

Steam, unless under artificial pressure, is neither cooler nor hotter than boiling water; 212° F.

All safes, the chambers of which are filled with alum and sawdust, are thereby made fire-resisting on the combined principal of "non-conduction" and "steam-generation."

Many testimonials must be looked upon as the representations of various factories which one sees hung up at the principal railway stations. If the building has ten stories in the picture in order to arrive at the proper height, it will be necessary to take off five; and so with windows, chimney stacks, etc.

"Sir, I beg to inform you, that the patent fire-proof Chest which I purchased from you about eighteen months ago was exposed to the fire which destroyed No. 2, New Square, on Sunday last."

"The safe was full of deeds and papers. A few of the deeds which were in immediate contact with the top of the chest, and which appears to have been exposed to the fiercest heat, are in some degree injured, being shriveled in parts; but, I believe, will not prove to be illegible. All the rest of the documents, being more than nine-tenths of the whole, are quite safe and uninjured. I am sir, Yours faithfully, "JOHN MARTIN". P.S. The safe was exposed to the fire for a period of thirty-four hours."

This testimonial, which is doubtless so far correct as to confirm what I have before stated as to the impossibility of preserving parchment in an iron safe, whether made fire-proof as this was on the principle of non-conduction only, (see Marr's specification) or that of evaporation.

The injury to "a few of the deeds"(parchment) is not attributed to the natural consequences of intense heat acting on such a substance, "for a period of thirty-four hours," but to the accident of these deeds being "in immediate contact with the top of the chest."

As iron is one of the best conductors of heat, it is simply impossible to make a safe so hot that it shall injure deeds at the top, without in the same degree injuring those situated in other parts. It implies that the top plate of the chest was hot, while the others were cool. From some of the deeds being in immediate contact, i.e., touching the inner plate of the top of the chest, the latter must have been pressed full.

I presume the explanation is as follows: the chest, although in the burning premises for thirty-four hours, was subjected to heat but for a very short time. Short as it was, it was sufficient to "shrivel" the few deeds without injuring the other nine-tenths of the contents, which very probably consisted of paper.

"Color Works, 115, Upper East Smithfield, London, June 17th 1852.

Sir, the safe we bought from you, three or four years back was unlocked by us this morning, and all the books and parchments were uninjured. The safe was exposed to the fury of the fire from nine O'clock p.m., to eight o'clock, a.m., during which period not less than forty tons of oil and one hundred barrels of tar were consumed close to the safe. The safe was red-hot. Your Obedient Servants, THOS HUBBUCK & SON.

This Testimonial states that besides "the books" the "parchments were uninjured," although the safe was exposed to "the fury of the fire," and was red-hot for the space of eleven hours, "during which period not less than forty tons of oil and one hundred barrels of tar were consumed close to the safe."

How can this be reconciled with the previous one? In the former the deeds were "in some degree injured;" in this, "all the books and parchments were uninjured." The only solution is that the external heat was insufficient to "shrivel" the parchments.

Mr. Marr, in order to prove the fire-prove capability of his safes, subjected several boxes to an "experimental test."

"To ascertain their security, several of the boxes were thrown into furnaces, and allowed to remain there until they became red-hot; but the boxes and their contents, consisting of parchment and paper, were perfectly uninjured."

"The patentee begs to refer to Messrs. Evans and Co., of Queen Street, Cheapside; and Messrs Gladill, of Clerkenwell Close, in whose furnaces the boxes were thrown when the experiment was made, and which was witnessed by more than forty gentlemen."

The making of the outer plates of several boxes made fire-proof on the principle of non-conduction only, simply red-hot, and then withdrawing them, is no test at all of their fire-proof capability without keeping them red-hot for several hours in succession. In this "experimental test" the parchment is said to have been "perfectly uninjured, which is proof positive of the character of the test.

"24, High Street, Manchester, March 6th, 1854. Gentlemen, we have great pleasure in communicating to you, that the large "patent fire-proof safe" that we purchased from you twelve years ago for our late offices in New High Street, has been the means of preserving our books, cash, notes, etc.

Enclosed therein, on the evening of the 1st of March, our entire premises were destroyed by fire. The safe, after being subject to "fourteen hours intense heat, was unlocked on the morning of the 3rd of March, the locks all answering to their respective keys, and all the damage the contents received (water excepted) was that only some of the books were slightly singed at the edge. You are at liberty to make what use of this communication you may think proper. We are, gentlemen, Yours respectfully, Byland & sons.

If this is true, it is miraculous, as it is physically impossible for a safe made fire-proof with a simple non-conductor, as specified in Chubb's specification, to have preserved the contents from such slight damage, "water excepted," when subjected to "fourteen hours intense heat."

Does it mean that it took "fourteen hours" to ravage the "entire premises?" Where did the "water excepted," that damaged the contents, come from? Not from the fire-proof composition, as it contained no chemical material of a vaporizing nature.

If any fire-engines attended the conflagration, it does not appear that their water lessened the intensity of the heat 'outside' the safe; but it does appear that such water by some means or other got 'inside' the safe, "which was all the damage the contents received," except slightly singing the edges of the books.

"Store Street Mills, Manchester, May 16th, 1854. Gentlemen, we have the satisfaction of informing you that the fire-proof safe we purchased from you about three years ago for our premises in Store Street, (the counting-house and blowing-room of which were completely destroyed by fire last evening,) has secured the entire of our books contained therein, together with cash, notes, policies, etc.

This, to our astonishment, considering the intense heat the safe was exposed to from being built in the chimney flue. You are at liberty to refer parties to us, should any further particulars be required. We are, gentlemen, Yours respectively, Wr. Jones & sons.

In addition to the remarks made in reference to this safe and the fire, I may state that soon after its occurrence I mentioned to the gentlemen who attended the test of my safe in Lever Street,

Manchester, October 17th, 1854, the fact of the door of Chubb's safe, which was the only part subjected to the "intense heat the safe was exposed to from being built in the chimney flue," was "not fire-proof."

The representative of Messrs. Chubb and Son, being present, was appealed, and at once unhesitatingly confirmed the truth of my statement. What, then, is such a testimonial worth in reference to the fire-proof capability of the safe?

It preserved the contents simply from the circumstance of its "being built in the chimney-flue," i.e., every part of it was surrounded with masonry, except the door, which was not fire-proof. This consequently proves that a cast-iron safe, occupying the same position and subjected to the same "intense heat," would undoubtedly have preserved the contents equally well.

Doubtless many who delight in the possession of testimonials will say, "Better this than none at all." Be it so.

"A test of Tann's Patent Safes was made on the 13th of June, 1850, in the Islington Old Market, Liverpool, in the presence of the worshipful mayor, and numbers of gentlemen of the professional and commercial classes of Liverpool."

"The chest contained papers, a 50 Pound bank note, a 5 pound bank note, a silver watch, and a 'parchment' deed with four seals attached. After having been exposed to a severe fire consisting of forty cwt. of coal and other combustibles for three hours, the chest was removed and opened, when the whole of the contents were found perfect; the watch indicating the exact time."

"At the suggestion of several parties on the ground, the chest was subjected to a second ordeal for an hour, and with the same satisfactory result; a gold watch, deposited by a gentleman (a casual visitor), and several other articles of value were restored to the their respective owners as perfect as before the test."

"The parchment deed with the four seals was quite perfect, the impression on the wax being as perfect as when first deposited in the chest. An offer was then made by the representatives of the patentees to subject the chest to a further test, but the majority were of opinion that it was unnecessary, and that the chest had been subjected to a much more

severe heat than ever it could possibly meet with in any accidental fire. The foregoing facts are certified by the signatures of upwards of seventy witnesses."

The principle upon which these safes are constructed and rendered fire-resisting is based upon filling the spaces between the outer and inner surface with a chemical preparation (the discovery of the patentees). The basis of this composition is chemical salts, and thus it remains unaffected until the safe is exposed to a high temperature.

The chemical 'merely fuses' when the heat is increased to a degree at which most substances (except the metals) become decomposed. The 'water of crystallization' having been driven off, affords a great amount of vapor which is effectively condensed in the interior of the safe.

This keeps it at such a temperature that it cannot, even in the most powerful fire, be increased 'beyond that at which fusion takes place, until decomposition. This is an operation that would require a much longer continuance of heat than the destruction of the most substantial residential property would require.

This fact has been established beyond all doubt by the result of many experiments, attested by persons of the highest respectability, and in every trial to which the Reliance Safe has been subjected. Whether accidental or for the purpose of testing its qualities, it has proved to be perfectly secure against the action of fire.

The simple principle of steam-generation is here described in mystical and ambiguous language. Why not have stated simply that the "chemical salts" when merely fusing at a high temperature, 1000°, and becoming decomposed, part with the water of crystallization in the shape of steam or vapor, and that the temperature of the latter is 212°F, and that this temperature cannot, "in the most powerful fire, be increased" so long as the generation of steam can be kept up.

It must be observed that the annexed testimonial states that although "the chest had been subjected to a much more severe heat than it could possibly meet with in any accidental fire," yet, that "the parchment deed with the four seals was quite perfect, the impression on the wax being as perfect as when deposited in the chest."

"An extraordinary test of E. Tann and Sons' Patent Reliance Safes took place at Glasgow, on the 17th of October, 1850, in the presence of the superintendent of police, and a large number of the bankers, merchants, and tradesmen of that city. The safe was placed in the midst of 48 cwt. of coals and several wagons of wood, and was exposed to the action of the fire for three hours and a half. The result was quite satisfactory, as the testimonials underneath will testify."

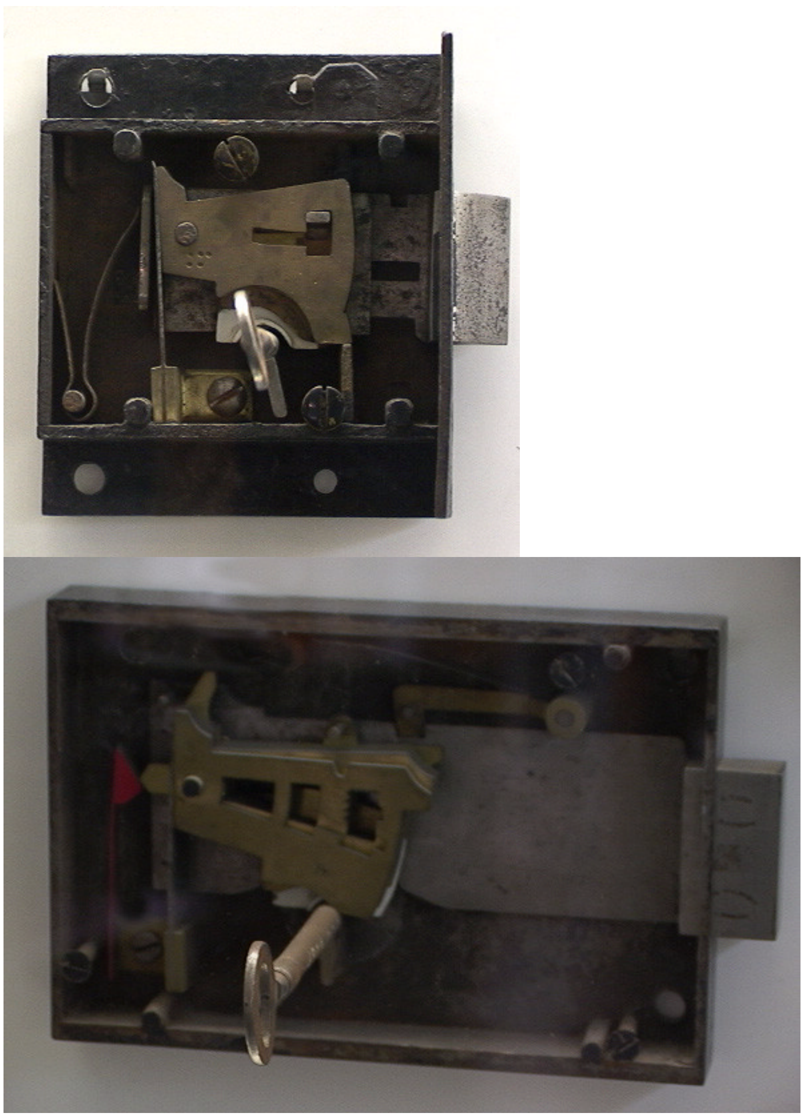


Figure GFP+1201 Tann's Reliance lever lock, circa 1843.

"Glasgow, October 15, 1850. Being present at the commencement of the advertised public test of the fire-resisting

qualities of E. Tann and Sons' (of the Hackney Road, London) Patent Reliance chemical filled safes, we certify that this document, with several books, bank notes, etc., among them parchment deeds with seals, and a watch was deposited in one of the safes immediately before being placed in the fire."

"We certify that the prefixed, and all other documents, watch, bank note, etc., placed in E. Tann and Sons' Patent Reliance Safe, prior to its being deposited in a testing fire, consisting of forty-eight cwt. of coals and several wagons of wood to prove its fire-resisting qualities, were, after a severe test of three hours and a half, found perfect as when lodged. (signed) James Smart, Superintendent of Police."

In order to perfectly understand the principle of vaporization, and the latter and following testimonials, I think it best to copy T. Milner and Sons' own explanation from their pamphlet, pages 8, 9.

"With reference to the superiority of this method of maintaining low temperature in the heart of a strong fire by vaporization, prolonged in chemical non-conductors, in other words, by substituting boiling for burning, it may be observed that from every pint of fluid discharged from the materials of the safe or box by heat into the interior, nearly two thousand pints of steam are evolved and condensed in the contents, rendering the whole mass damp and humid as a newspaper from the press."

By this means, 1000° of heat is neutralized and rendered latent and harmless, one-half of which temperature would destroy the contents of the best safe or box that can be put together of dry materials.

While the papers are made difficult of ignition, the whole process being conducive throughout to their preservation for a much longer period than that during which a box or safe would be in contact with fire in the successive conflagration of the parts of a building.

No greater heat than 212° will pass through this medium into the interior, a temperature perfectly harmless to books, papers, parchment, or even bank-notes.

The cause of the exhaustion of the moisture being so protracted, is its being sheathed and protected from rapid vaporization in

the absorbent non-conductor. In long continued heat, the nonconductor discharges its pyroligneous acid, which, combining with the alkali, forms a carbonaceous crust or pyrolignate of potass, the worst conductor of heat known.

From within this shelter, the papers or books slowly give out against the large volume of steam that has been passed into and condensed in them, reacting most favorably in keeping down their own temperature, that of the box or safe, and the surrounding, fire.

The tea-kettle, boiling at 212° in immediate contact with red-hot fire, into which a handful of bank-notes or gunpowder may be placed with safety, simply and aptly illustrates this principle. Another beautiful and forcible illustration of its extraordinary preserving capabilities may be shown in a very simple manner, by folding a piece of common writing paper into the form of a tea-cup, having a wire circle inside, and another outside, round the top, tied together with small binding wire, and two half-circles of wire crossing each other under the bottom, merely to keep the form.

If this paper boiler be filled with water, and put over a red-hot place on the fire where there is no smoke, it will boil away without even discoloring the paper. With great care, the boiler may be a bank-note; and with perfect safety, notes may be doubled up, and boiled in the water, with only paper betwixt them and red-heat, and afterwards dried.

As the inside of a loaf of bread in an oven is preserved for hours from being more than boiled, under circumstances wherein it would be reduced to a blackened, charred mass were it not for its own self-contained moisture. The most combustible materials are kept from injury in a similar but more perfect manner within these boxes, when surrounded with burning coal.

The same heat that would serve to make an iron safe red-hot in twenty-minutes will not bring the interior Milner's boxes, of one foot inside measurement (which dimensions are necessary for the full advantage of the resistance and reaction of this principle) to the boiling point, 212°, which cools down rapidly the moment the fire subsides around; whereas the red-hot iron safe remains an immovable burning prison for its dry contents, consuming them for hours after the fire has left them.

In short, the Milner's safe and the iron safe, standing near each

other in Messrs. Walker's fire, may be aptly compared to an oven and boiler in vigorous operation. In which of the two would you deposit a bundle of deeds, bank-notes, or gunpowder, with a view of preserving them from being burnt?

Within each of these depositories, a sentinel engine may be supposed always attendant and self-acting, ready not only to extinguish, but prevent fire, with its pipes charged and laid into the most valuable property which a public, professional, or mercantile office or private dwelling contains property uninsurable, and yet often exceeding in value all that is deemed needful to insure, the fire itself, in its first approaches, letting loose, and arousing, in concentrated operation within the box, its only efficient antagonist.

T.M. and S. have now briefly to allude to the insecure state of the monetary and documentary property of the country, from the custom-house, excise, and public offices, with their fire-proof (?) iron safes, strong rooms with iron doors, surrounded by piles of desks, cupboards, office furniture, and floors sufficient to make the safes and doors red-hot ten times over, burning them out with red-hot safety.

The banks and extensive professional offices, consisting of rooms, stories upon stories, whole piles of massive buildings full of wooden chests, drawers, secretaries, deed boxes, and iron safes and closets, little better, the whole property in which an hour’s strong fire would sweep into destruction.

Lastly, to the immense amount and value in commercial books and documents, without any more efficient protection than the worthless depositories which are sold as 'fire-proof,' without any rational claim to the quality of resisting fire.

It is as absurd so to denominate these gewgaw-looking things, like gilt bird-cages, as if fire had any respect for these things, as it would be to nail the old horseshoe over the door to keep out the fire-witch, instead of keeping her effectively out by giving the water-witch (the only fire-tamer!) scientific and permanent possession.

"Earnestly soliciting consideration of these remarks, T.M. and Son proceed to give the following testimonials:

"PUBLIC TESTING OF MILNER’S PATENT FIRE-RESISTING SAFES.”

"The triumph of science was completely shown by the result of the trials of Milner's Safe that took place in Messrs. Ransome and Sims's Old Foundry premises in this town, on Wednesday last, at eleven O'clock, to witness which a large influential body of gentlemen were present.

Two large fires were made in furnaces of bricks with flues all through, in one of which was placed a common iron Safe, filled with loose papers, and one of Milner's fire-resisting safes, also filled with books, papers, silver watch, gold, silver, and steel chains, with the half of a 100 Pound note.

The whole were inspected by the great body of gentlemen present, and locked down by Mr. S.H. Cowell, the Mayor. Fifteen minutes after being so placed, the cast-iron box burst from the great heat conveyed to each, while the patentees' chest firmly stood the test for two-and-a-half hours.

When it was opened, everything was taken out in such a perfect and uninjured state as to surprise and astonish all present. In a second furnace of similar construction was deposited Milner's Double Banker's Safe. After being filled by Mr. D. Wendon, the representative of T. Milner and Son, assisted by S. H. Cowell, Esq., and W.D. Sims, Esq. with the following articles, namely, the half of a 100 Pound note, several copies of various publications, including a beautifully illustrated edition of "Uncle Tom's Cabin," a casket of jewelry with gold and silver watches belonging to Mr. Read, jeweler of this town; a gold watch belonging to Mr. Dorling, a silver watch belonging to Mr. D. Wendon, a silver watch belonging to Mr. Baker, and others, the property of gentlemen present, with which was also a box containing several metals, to try the heat within, consisting of bitumen, iron, lead, zinc, by a scientific gentleman present.

This safe was allowed to remain five hours, during which time every exertion was made to increase the heat, the fire being superintended by four of Messrs. Ransome's men, and 1½ tons of coal, 50 cwt. of firewood, four large and three small hogsheads, several faggots, etc., were consumed.

At the time of opening the safe, the most intense anxiety prevailed; the company, including a great number of ladies for the town and neighborhood being very great. Every accommodation was afforded to give all parties a fair opportunity of seeing, a ring being roped round for the occasion.

Exactly at 4:45 P.M., the Mayor, with the gentlemen superintending, entered the ring and the safe was opened. On presenting its contents, the greatest delight and satisfaction they were evinced; each watch was correct to the time, being compared with the dial at the Old Foundry, no variation had taken place.

Every manuscript, book, paper, etc., was quite as perfect as when placed therein; the 100 Pound note was delivered to the Mayor, who exhibited it round, with all the other deposits, to the great assemblage, who at once expressed their entire satisfaction at the result of the experiments, and proceeded to sign testimonials recording the same.

We before briefly alluded to the common iron safe, which was also exhibited at the same time with the two patent safes from Milner's, and certainly presented a powerful contrast, the papers all being burnt to a calcined ash.

A slight discoloration appeared on the corners of one or two papers taken from the No. 1 Safe, which Mr. Wendon was glad to see, as it gave him an opportunity of explaining the same, being the essential oil form the non-conductor. This proved that however discolored, no injury is derived from the same.

At the close of these experiments, Mr. Wendon made a short address to the body of persons present, thanking the Mayor for his kind attendance and impartial attention; to which his worship replied, expressing his extreme satisfaction at the whole proceedings and heartily wishing so good an invention its deserved support."

A furnace of bricks, with flues all through, is a capital contrivance for conducting and driving the heat away from a safe, when under such circumstances it is subjected to fire.

When a half-note is deposited it is an evidence of doubt as to the capability of a safe to preserve it from destruction. All the newly published works, like "Uncle Tom's Cabin," are invariably bound in cloth, which, as previously stated, is not in the least injured by the steam; it being identical with calico, and is a vegetable production.

Bitumen or asphaltum melts at the temperature of boiling water, and therefore the remarks made relative to sealing was equally applicable to this mineral. Why is not the result to this and

the iron, lead, and zinc stated? Cast-iron begins to melt at 17,977° F. Lead melts at 594°, and zinc at 700°.

Instead of these, in order to prove the temperature of the interior during the fire, such articles should have been placed within that have a melting temperature that is lower than 212°. No parchment is named as having been in this safe.

The half-note during the operation appears to have grown into a whole one; all risk of its loss now being at an end.

This is a very clever idea of Mr. Wendon's, which shows his want of knowledge as to the properties of wood and essential oil. What is the difference between the stain of essential oil and a veritable **singe**? What is the distinctive name of this essential oil? Naphtha is distilled from wood by its total destruction. Essential or volatile oils require a temperature to raise them to a state of vapor, of 212°, which is in this case said to have been produced, and "discolored the covers of one or two papers." Yet it does not appear that the bitumen which melts at the same temperature (212°) did so.

London and Birmingham Railway Office. Easton Square, April 8th, 1844.

Sirs, I am instructed to send the enclosed report of the results of the public experiment on your Fire-proof Boxes and Safes at the Camden station of this Company, which was authorized by the Directors to be made under the immediate superintendence of their own officers, and to congratulate you on the complete success of the very severe trials by which you have allowed your admirable invention to be tested. I am, Sir, your obedient servant, R. Creed, Secretary.

"London and Birmingham Railway, Camden Station, April 8th, 1844. Mr. Bruyeres having requested me to superintend in person the trial of Messrs. Milner's Boxes and safes at this station, on Thursday last, I beg to report as follows:

"Early in the morning about one ton of coals and the same quantity of wood were piled upon a foundation of brick. Within the fire was placed a safe of double 2½" chambers, containing books and papers. The fire was lighted at half-past eight, and quickly burnt up. At the same time a placard describing the case as representing Milner's double-chambered Bankers' Safe was fixed in the ground. Double 2 ½" chambers shows that the chemical

composition is 5” thick."

“At nine O'clock a similar safe was placed in a similar fire, several gentlemen having previously placed inside some books, on which they had written their names, and Mr. Milner a ten pound note. A placard was again hoisted, Milner’s Double Chambered Safe, each chamber 1½". The fire burnt up to a great heat. The composition in this safe was 3” thick."

“A Deed Box was placed in another fire at 11:00 A.M., which had also been filled in the presence of a number of gentlemen. A brisk wind having blown steadily all day, the fires had from the commencement soon burned into an active heat, and this was especially intensely hot. A placard was again fixed near the fire, “Milner’s Portable Deed Box, 1¼”. The composition in this box was 2 ½" thick."

By this means the number of persons assembled having considerably increased, the cases were shortly after one O'clock removed and examined.

“First, the Bankers’ Safe, although taken out of a bed of red heat, the inner chamber and contents were, after five hours trial, quite cool and perfect as when put in. Next the double 1½” chambered safe was taken out and opened; its contents were found perfect like the first. The papers, including the ten Pound note, were only slightly warmed."

"The Portable Deed Box was then examined; when taken from the fire, parts of it were at a white heat on the outside, but the books and papers were all thoroughly steamed and preserved; some were slightly discolored at the edges near the cover, by the non-conductor, but all in a very good and sound state."

"The Bankers' Safe was again placed in a strong fire, and with two short intervals of a few minutes for examination, kept there until eight o”clock, when it was finally removed quite red-hot outside, but the inner chamber and contents perfectly fresh, and unaltered."

The severity of the test may be considered as far exceeding that of any ordinary fire. The perfect state in which the papers were found, after a trial of so many hours, should satisfy the most skeptical of the protective properties of the invention under the most trying circumstances. (signed) H. Wyatt.

This fire was lighted at 8:30 A.M., and the Bankers' safe was withdrawn at 1:00 P.M., consequently it was subjected to the heat arising from "one ton of coals and the same quantity of wood" for four-and-a-half hours. The *steam* in this safe was "quite cool." The second safe was in "a similar fire" for "four hours," and the "Portable Deed Box" for two hours.

All the three safes were made on the same principle, viz. that of steam-generation, and yet in the safe with the 3" composition, the contents are only "slightly warmed," while in the box with the 2½" composition, the contents are "thoroughly steamed." Steam is here represented as being of three degrees of temperature, on "quite cool", another "slightly warm," and the third its true degree, that of boiling water.

I cannot reconcile the plate of a safe becoming red-hot, which plate encloses a neutralizing vapor. Messrs. Milner illustrate this principle by "the tea kettle boiling at 212° , in immediate contact with fire, into which a handful of bank notes or gunpowder may be placed with safety," which, they say, "aptly illustrates this principle."

Also: "Another beautiful and forcible illustration of its extraordinary preserving capabilities may be shown in a very simple manner by folding a piece of common writing paper into the form of a tea-cup, having a wire circle inside and another outside round the top, tied together with small binding wire, and two half-circles of wire crossing each other under the bottom, merely to keep the form.

If this paper boiler be filled with water and put over a red-hot place on the fire where there is no smoke, it will boil away without even discoloring the paper. With great care the boiler may be a bank note; and with perfect safety, notes may be doubled up and boiled in the water with only paper betwixt them and red-heat, and afterwards dried."

Messrs. Milner blow hot and cold in the same breath. The paper or bank-note boiler does not get red-hot, neither does it burn; and yet, according to this testimonial, the red-hot boiler <u>does</u> get red-hot. What can anyone understand from these palpable contradictions?

The contents of these safes are said to have been preserved by steam at the temperature of boiling water, and yet the interior did not arrive at that degree of heat. The principle is

illustrated by a kettle boiling on a fire, and yet the outer plates of these safes, the kettles or boilers become quite red-hot outside, whilst "the severity of the test" of the Bankers' safe "may be considered as far exceeding that of an ordinary fire."

"Liverpool, May 24th, 1841.

"We, the undersigned, having this day witnessed the testing of one of Milners' fire-resisting boxes, by its having been placed in a large fire consisting of wood and upwards of six hundred-weight of coals, for the space of two hours and twenty minutes, do hereby express our conviction that the fire-resisting boxes manufactured by them are a perfect security in all cases of ordinary fire.

The box was filled with commercial and other books, papers, parchments, and deeds, (one of which, of the 16th Henry VIII. had five large thick-seals appended to it,) and, within an inch of the cover, several Bank of England notes; and previously to being closed, were submitted to the examination of J. S. Leigh, Esq., R. Frodsham, Esq., L. Graham, Esq., and others present.

The whole contents, on the box being taken out of the fire and opened in our presence, were found to be in a perfect state of preservation, the seals attached to the deed above mentioned not being in the slightest degree injured. This certificate is written on the deed of the 16th Henry VIII. Above mentioned, which was submitted to the test." (Here follow eight signatures.)

In all these testimonials, the amount of combustibles used for the fire, the time the boxes or safes were subjected to the heat, the articles enclosed, and their appearance when the safe or box was opened, should be particularly noticed.

Manchester, Jan. 20th, 1842.

"We, the undersigned, having witnessed the testing of one of Milners' new patent fire-resistant boxes, by its being exposed to the action of an open fire of wood and seven hundredweight of coals, for the space of one hour and a half, do hereby express our conviction that their new patent boxes afford a perfect security in all cases of ordinary fires."

"The box was filled with miscellaneous papers, an old ledger, and the deed on which this certificate was written, with

the seal attached. On opening the same, after it had been taken out of the fire, its contents were found to be preserved, and even the seal attached to the above deed was not in the slightest degree injured." (Here follow eight signatures.)

In the fire beside this box, the contents of a fire-proof box of another make were consumed." It appears an old ledger was put in this safe, which most likely was bound either in leather or forril. This, with the other contents, "and even the seal" of wax, were "not in the slightest degree injured."

Durham, 25th January, 1841.

"We, the undersigned, having this day witnessed the testing of one of Milners' Patent Fire-resisting Boxes, by its having been exposed to the action of an open fire of wood and coals for the space of an hour, do hereby express our conviction that the fire-resisting Boxes manufactured by them are a perfect security in all cases of ordinary fire. The parchment upon which this certificate is written formed part of an indenture which was in the box during the whole time of its being exposed to the fire." *(Here follow fourteen signatures.)*

The remarks previously made will apply to this and all the following testimonials, as all the latter state the same thing, viz., that the parchment and wax seals were in every case preserved uninjured, although the saving medium was a vapor of the temperature of boiling water, 212 °.

As the same element will always produce the same effects, I shall here copy from Milner's pamphlet another testimonial, and afterwards repeat the account of the test of one of my safes at Manchester, which, as before stated, was made fire-proof on the same principle and by the same means as those which were tested by Messrs. Milner in various parts of the kingdom.

"Gentlemen: A quantity of [parchment] deeds we had deposited in a common tin box at the Albion Bank, about a month since, were entirely spoiled, by water having gained access to the strong room; whilst, at the same time, and in the same situation, there were two or three of your fireresisting boxes also in the water; the papers in which were quite safe and dry.

I am, gentlemen, Yours respectfully," JAMES WENSLEY,

In the latter case it must be distinctly noticed that the

parchments were “entirely spoiled" by water" at the temperature of the atmosphere.

TESTING OF PRICES FIRE-PROOF SAFES.

An experiment was made on Thursday last, with the view of testing the fire-resisting qualities of a book safe, manufactured by Mr. George Price, of Wolverhampton. The trial took place in a yard near the Wesleyan Chapel, Lever Street.

The safe was a No. 8, being 28″ high, 22″ wide, and 22″ deep. The chambers are filled with a steam-generating composition, the moisture from which, on the safe being heated, is forced within, in the form of vapor, a principle which has been found to answer by other makers.

The door was fitted with one of 'Tucker and Reeves' patent safeguard locks," the two inner drawers being secured by Chubb's patent detector lock. Printed circulars were placed in the drawers, and six or seven volumes of books, chiefly ‘Slater's Directories,’ were arranged between the partitions above. There were also loose papers, blotting paper, a wood shaving, and, in addition to these, an account book containing the signatures of parties present, who were witnesses to the various articles being inserted.

Between the leaves of the account-book was inserted a five Pound note. A gold watch was also wrapped up in paper, and placed inside. The door was then locked and the key given to Mr. Councilor Warburton. The safe was raised in the center of the yard, upon two rows of bricks, (five courses) so as to allow the fire to act underneath it. Shavings, wood, and coal were then thrown around it, the wood being arranged conically so as to enclose the top of it, on which coal was also placed.

At a quarter to one O'clock the combustibles were lighted, and in a few minutes the safe was wholly enveloped in flame, which rose about two yards over the top, the heat compelling the spectators to retreat from its scorching influence. Mr. Alderman Heywood, Councillors Thackray, Thompson, Armitage, Worthington, and Howard, with agents of fire insurance Offices, and other gentlemen taking an interest in the matter, were present.

The fire was kept up burning until a quarter-past three o’clock, two and a half hours from the commencement, and was then withdrawn. Being extremely hot, it required to be soused with

water until four o’clock before it was sufficiently cooled to be opened.

It appeared to unlock with little difficulty, although the door was slightly warped by the contracting influence of the water. The brass handle seemed to have been partially melted, and broke on being pulled.

When the door was open, the contents presented the following appearance: The vapor, supposed to be at a temperature of 212° F., had dissolved the glue on the backs of the volumes, and thus loosened the leather. The wood shaving was a little darker, the edges of a few of the circulars were slightly discolored but most of them were not tinged, and the books, with the exception of being damped, presented no appearance of being near a fire.

The papers in the drawers, opened half-an-hour later, were also safe. The watch was going, and indicated four O'clock, but on being taken out, the sudden transition from heat to cold seemed to paralyze its energies, for it held its hands over its face, as if for protection, and refused to move.

The bank note, with the book enclosing it, were unsullied. The five members of the city council, named above, with a number of other gentlemen, placed their signatures to a document testifying their opinion of the fairness of the test, and stating the contents of the safe to have come out unscathed from the fiery ordeal.

We may remark that, so far as an artificial fire can be made to resemble that of a building, the test was a fair one. The conical mode in which the wood was made to surround the safe, threw the heat directly upon it, and from the length of time this was continued, the outer case must have been red-hot.

Indeed, the warping of the sides and door, and discoloration of the iron were sufficient indication of this. We understand that Mr. Price rests his claim to a share of public support on two points. The first is that he uses no solder, his objection to it being that it melts at a comparatively low temperatures, and then tends to allow the escape of what should be confined vapor. The second consideration is one of price, which will, no doubt, have its full weight with the public. (Manchester Examiner and Times)

It will be noticed that the size of the safe is here given, the time it was subjected to intense heat, the way in which it was

cooled before it could be opened, and the appearance of the whole of the articles after such a severe trial.

In addition to the facts already named, it may be well to state, that even after the cooling of the safe, the contents could not be handled. The watch which had been wrapped in a single sheet of paper was handed from one to another like a "hot potato," thus proving that the heat of the interior was that of boiling water, 212°.

Although the steam had "loosened the leather" of the books, it was apparent that whilst those in leather had their backs denuded of the cover, those bound in cloth were quite perfect. Another point to be noticed is that although the watch indicated the correct time on its withdrawal from the safe, yet to say it was uninjured would be to tell an untruth and deceive others; for, in consequence of the steam having entered the interior of the watch, the whole of the steel parts were oxidized the next day, and had to be replaced by new ones. This injury was the effect of the vapor, not the degree of heat, which is another reason why all such delicate articles should be first enclosed in a steam-tight box. It must also be particularly noticed that the watches in all the other tests came out perfectly uninjured.

By comparing this notice with those testimonials which precede and follow it, one of two alternatives is arrived at, viz., that either this or the others state the truth.

Hull, July 9th, 1841.

"We, the undersigned, having witnessed the testing of one of Milners' Fire-resisting Boxes, the same being submitted to a great heat from a fire in the Railway Bonding Yard, consisting of wood, coals, and coke, for one hour and fifteen minutes, do hereby express our conviction that they are a security in all cases of ordinary fire. The box was filled with books and parchments, part of which was the piece on which this certificate is written." (Here follow ten signatures.)

Nottingham, September 8th, 1841.

"We, the undersigned, having this day witnessed the testing of one of Milner's Patent Fire-resisting Boxes, the same being submitted to a great heat from a large fire of wood and coals, allowed by kind permission of Messrs. Bell and Corven, at their Iron Foundry, Beck Works, for one hour and twenty minutes, do

hereby express our conviction that they are a perfect security in all cases of ordinary fire. The parchment on which this certificate is written, with seal attached, was presented by John Buttery, Esq., Solicitor, and was in the box, with other papers and books, during the whole time of the above test." (Here follow six signatures)

Leicester, October 15th, 1841.

"We, the undersigned, having this day witnessed the testing of two of Milner's new patented safety boxes, in the Cricket Ground of this place, do hereby express our conviction that they are a great security in all cases of ordinary fires. The boxes were filled with papers, books, parchments, deeds, etc., and subjected to an intense heat, from a strong fire of wood and five hundred-weight of coal for one hour and fifteen minutes. The parchment on which this is written, containing the seal, was in the box the whole time of the test. ("Here follow nine signatures.)

Edinburgh, April 20th, 1842.

"We, the undersigned, having this day witnessed the testing of one of Milner and Son's Patent Fire-resisting Boxes, and its having been exposed to the action of an open fire of wood and coals for upwards of an hour, do hereby express our conviction that the Fire-resisting Boxes manufactured by them are a perfect Security in cases of ordinary fire."

"A considerable part of the Patent Box, previous to being taken out, was red-hot. A Box manufactured in Edinburgh, in imitation of Messrs. Milners', was tested at the same time, but not having arrived on the ground until the Patent Box had been nearly half-an-hour in the fire, it consequently did not undergo so severe a test. Both boxes were filled with account books, parchments, and miscellaneous papers and, on being taken out and opened in our presence, the papers in Milner's Patent Box were found to be in a complete state of preservation, while those in the spurious imitation box were nearly burnt to ashes. The parchment upon which this testimonial is written formed part of the contents of the box made by Messrs. Milner and Son." (Here follow eight signatures).

Glasgow, May 5th, 1842.

"We, the undersigned, having this day witnessed the testing

of one of Messr. Milner and Son's newly patented Fire-resisting Portable Safes, in the yard of Messrs. John M. Rowan and Co., Atlas Foundry, do hereby express our satisfaction and approbation that these Safes are calculated to preserve books, papers, and other property, in all cases of ordinary fire."

"The box was filled with books, papers, parchment, etc., and though it was exposed to the action of a coal and wood fire for an hour (thereby becoming red-hot), the contents were taken out in a perfect state of preservation. The parchment on which this testimonial is written formed part of the contents of the safe." (Here follow six signatures.)

Grantham, July 12th, 1843.

"Mr. D. Wendon, representative of Messrs. Thomas Milner and Son, new Patent Fire-resisting Box and Safe Manufacturers, of Liverpool, having announced by circular his intention of submitting some of these boxes to a public trial, we the undersigned beg to testify our approval of the principle, and satisfaction of their security in all cases of ordinary fire."

"At ten O'clock a.m. a fire was made in Mr. Green's yard adjoining the Duke of Rutland's premises, consisting of seven cwt. of coals, sugar hogsheads, a quantity of wood and shavings, and a barrel without its ends placed over the same, forming a chimney, and causing a very strong draft."

"At this period a round safe, in which was placed papers, parchments, and a small packet of gunpowder, also a deed box, nearly filled with books, papers, three parchment deeds, a watch, and pamphlets (upon which several gentlemen previously wrote their names) was placed in the fire, after being examined by the gentlemen present, and locked down by R. H. Johnstone, Esq., Mayor."

"At half-past twelve O'clock they were drawn from their bed of heat and opened, when the contents of the circular safe were as perfect as when put therein, the powder being quite cool and dry. The papers, etc. in the box were also preserved, and the watch marking off the time as though it had not been deposited. The circular on which the certificate is written formed part of the contents in the box during the whole time of the above test." (Here follow 21 signatures.)"

"In this test the "powder" is said to have been "quite cool"

in a temperature of 212°, and "dry" though it had been preserved by absorbing and condensing vapor evolved "by the chemical non-conductors," in the proportion of "nearly two thousand pints of steam" to "every pint of fluid discharged from the materials of the safe."

MILNER'S FIRE-RESISTING BOXES

A very interesting demonstration of the capabilities of these Boxes to resist heat took place in the City of Peterborough, at one O'clock on Tuesday last, in a spacious yard belonging to Mr. William Crisp, of Cumber-gate.

Perhaps nothing at the present time has so great a claim to public attention as this invention, warranting, as it does, in the common occurrence of casual fires, to preserve their contents uninjured. Certain, also, it is, that many opinions arising from the supposed impossibility of the thing will start in opposition.

In order, therefore, to remove such, and establish a confidence in the excellence of this patent, Mr. Thomas Milner, one of the patentees, and Mr. D. Wendon, representative of the firm, on their journey to Huntingdon, etc., waited for the purpose of publicly testing one, from the stock of Mr. J. Sawyer, their agent at Peterborough.

To witness the testing, a very large body of gentry and respectable tradesmen assembled. A Box was filled with papers and books; a parchment deed, dated 1657, with two very thick seals attached, belonging to John Broughton, Esq., Solicitor; and a five Pound Bank of England note, placed in by the patentee, and a very curious gold watch by Mr. Wendon, all of which were closely examined by the gentlemen above named, and locked down by P.J. Jenkins. Esq., Solicitor, who kept possession of the keys during the whole period.

At half-past one it was placed in a fire made for the occasion, consisting of a large quantity of coals, wood, shavings, barrels, crates, etc., superintended by Mr. Battersby, the foreman of the Gas Works. At twenty minutes to three it was removed and opened, when every thing deposited was as perfect as when put in.

The watch was set by Mr. Jenkins prior to being locked up, and when taken out was still going, not having varied scarcely a minute. Every person present was now satisfied that sufficient evidence had been shown fully to establish the principle; but on

a request being made for a second trial to ascertain how much more heat it would stand, the box and contents were given up to the parties, who placed it on the top of the fire, which was then at as strong a heat as could be made, every person exerting himself to put the fire on the box.

It was allowed thus to continue, until a general opinion that all was destroyed began to circulate, when it was again removed, and to the surprise, astonishment, and gratification of all, everything remained still uninjured, not even a discoloration or the slightest scorch, being perceptible. The gentlemen then signed the following testimonial:

"We testify our conviction that Milner's new Patent Fire-resisting Boxes are a perfect security in all cases of ordinary fires, and that the principle upon which they are manufactured is the best and most scientific ever brought before the public." (Here follow twenty signatures.)

Glasgow, May 7th, 1849.

"Gentlemen, we beg to inform you of the occurrence of one of the largest fires that has taken place here for many years. We send you, however, the Glasgow Herald, of this date which will give particulars, from which you will perceive that there have been a great many buildings burned down, a sugar refinery, a church, and several manufactories, including the extensive premises of Messrs. Charles Boyd and Son, soap and candle manufacturers."

"They had one of your No. 3 Safes, with drawers, got from us about five years ago; and the writer, upon calling upon them this morning, was perfectly astonished at the sight it presented."

"First of all, the brass knob, as well as the brass-work around the knob, was completely melted off, and the sides of the safe had blistered out nearly a couple of inches. The heat to which this safe has been exposed must have been tremendous."

"After enduring the fire above, it fell from the counting-house to the cellar beneath, and there it was exposed for hours to the most intense heat from the flaming oil and tallow. All the books and papers with which it was filled, and also notes to a considerable amount, wee perfectly saved. The large ledger, which must have been touching the door, was slightly discolored at the back-only; the binding, and no other

book was in the slightest degree damaged."

"On account of the absence of the principal this morning, the certificate of this splendid test of the complete and perfect resistance which your invaluable safes present against the ravages of fire will be obtained this evening."

“Thomas Milner and Son, with deepest feeling of gratification, lay before their friends, the public, the above extract from their Agent’s letter, reporting the strongest testimony they have received to the usefulness of their safes, and have equal pleasure in adding the promised certificate of the owners.”

This Testimonial is unquestionably of a very different character to the whole of those of Messrs. Milner and Son which have preceded it. But instead of admitting the liability to damage or destruction of the leather binding of books under such circumstances, the writer, perhaps in ignorance of the fact, to account for “only the binding” of “the large ledger” being “slightly discolored at the back,” jumps to the conclusion that it “must have been touching the door.”

“All the (other) books and papers with which it (the safe) was filled, and also notes to a considerable amount, were perfectly saved,” the whole of which, I presume, were in mid-air, like “Mahomet’s coffin.”

“As this safe was most severely tested,” how did it happen that none of the “books and papers” were stained by “the essential oil from the “non-conductor” which at the test at Ipswhich, in as severe a fire, “discolored one or two papers,” which Mr. Wendon was so glad to see, as it gave him an opportunity of explaining the cause.

I suppose that as this safe was “in long-continued heat, the non-conductor” discharged its pyrolignous acid, which combined “with the alkali,” and formed “a carbonaceous crust, or pyroliquate of potass,” and thus showed that it had a greater affinity for the “alkali” than for the “books and papers.”

It must be particularly noticed that this “ledger” was bound in either leather or parchment, as all “large ledgers” are invariably bound in one or the other. If the cause assigned for the discoloration of the binding is the correct one, it simply proves that the back-plate of the door must have been red-hot,

and consequently would have discolored the other papers and books in a similar manner. If the plate was red-hot, then it cannot be reconciled with the apt illustration of a kettle boiling on the fire.

Clyde-street, Anderston, Glasgow, May 7th 1849.

Gentlemen: At the calamitous fire yesterday morning, by which our premises and stock of oil, tallow, etc., were totally destroyed, our books were preserved in the Milner's Fire-proof Safe purchased from you. We have great pleasure in thus bearing testimony to the great efficiency of these safes. This safe was most severely tested; the brass knob and brass work about the lock were melted off. "Charles Boyd & son."

While commenting upon these testimonials, the amount of evidence against my hypothesis, viz., that it is a physical impossibility to preserve parchment, leather, and sealing was uninjured in a temperature of 212°.

The only means by which paper and books, bank notes, plate an specie can be preserved from destruction in an iron safe, when the latter is subjected to the influence of fire, appeared so overwhelming, that I began to doubt whether my senses had deceived me.

I immediately had a saucepan of boiling water brought to me, in which I placed two pieces of parchment, on one of which was a wax seal. The result was that the parchment immediately diminished in size one-half, and the wax seal ran and spread upon the decreased surface. In twenty minutes after the water had commenced boiling upon the fire, the parchment had lost two-thirds of its original dimensions, and the sealing wax remained in a liquid state, having lost all appearance of the impression it bore when first placed in the water.

This simple, effective, and interesting experiment can be tried by anyone with a vessel of boiling water, a piece of parchment, and a wax seal, and by folding a piece of paper and putting it in also, it will satisfactorily prove that the vaporizing principle has no injurious effect upon that material, although so destructive to the others.

For the purpose of procuring all the additional information on this very important subject, I wrote to Mr. Thomas Myers, of Gretton, near Uppingham, who carries on an extensive business in

the preparation of parchment skins, for his opinion as to the possibility of preserving parchment by vapor at the temperature of boiling water. He states in reply, that "Parchment will not stand either fire or water."

Conclusions

From the tenor of most of the before-mentioned testimonials, it will be gathered that leather, parchment, and sealing wax were preserved uninjured in a temperature of 212° F., in the various safes that were severally tested in different parts of the United Kingdom.

It will also be noticed that in my tests and experiments the contrary result has happened, although these safes were made fire-proof on precisely the same principle, Milner's patent, 1840.

It will be noticed further, that in one testimonial the parchments were "entirely spoiled" by simply water at the temperature of the atmosphere. Mr. Myers, from his practical knowledge of the substance of parchment and how it is affected by different temperatures, states, that it "will not stand either fire or water;" and, therefore, if the latter evidence is true, and I challenge its refutation, then the whole of the testimonials referred to, mis-state the real facts, and consequently lead the public to believe that such depositories will preserve these substances from injury when subjected to intense hear, at the same time that the contrary will invariably be the result, it being in accordance with a physical law of nature.

Admitting this to be so, then it follows that the appearance of these substances, when the safe is opened, is an infallible test of the severity and duration of the trial, for if they come out uninjured, it is a clear proof that little or no vapor has been generated, the fire having little power or intensity, and therefore that such tests are no tests at all, and that the notices and testimonials having reference thereto are deceptive, and therefore unworthy of credit.

BOOK TWO: On Locks and Keys

CHAPTER THIRTEEN: Early History

As, doubtless, thieving has been practiced in every age, it is only right to assume, that fastenings to the doors of apartments of some kind, by whatever name known, were employed from the earliest period of the world's history; but so little is known about them, that all is mere conjecture as to their construction.

Very little information can be gathered from, the works hitherto published, either in this or in any other country, relating to the early examples of the *manufacture Of* locks and keys, or to their *particular construction,* and there is the same dearth of information as to the lock-trade Of England in general, and that Of Wolverhampton in particular.

Mr. Tomlinson, in his "**Rudimentary Treatise on the Construction of Locks**," says, in the chapter "**On Locks and Lock Literature**" "The manufacture of locks, and a consideration of the mechanical principles involved in their construction and security, have never yet been treated with any degree of fullness in an English work."

This is so, as, although several locks invented in this country have been very minutely described and illustrated by engravings in the various foreign treatises on this subject, yet it is as Mr. Tomlinson says, "both in England and in America, men are more disposed to do the work than to describe it when done. In the 'Encyclopaedia Britannica,' in 'Hebert's Engineers and Mechanics Encyclopaedia,' in the 'Encyclopaedia Metropolitana,' in the 'Penny Cyclopaedia,' and in other similar works, locks are described as well as can be expected within the limits assigned to the articles.

Mr. Bramah's essay on locks, and on his own lock in particular, is one of the few English pamphlets devoted expressly to this subject. An excerpt from the proceedings of the Institute of Civil Engineers, in 1850, gives an interesting paper on locks by Mr. Chubb; and shorter reports of papers and lectures have been published in various ways. Perhaps the best account of locks which we have, considering the limited space within which great deal of information is given in a very clear style, is that contained in Mr. Tomlinson's 'Cyclopaedia of Useful Arts'.

The latter work, unfortunately, is only so far better than the others in respect to the description of locks, inasmuch as it gives a longer account of Chubb's than is contained in any of the former, and an account of the American locks introduced subsequently; otherwise, it is almost the same as the article on "locks" in the “Penny Cyclopaedia," which gives the most lucid description of the locks in general use up to the period when it was written, "within the limits assigned," of any work we have met with.

No one can question the *antiquity* of locks and keys, as there is abundant testimony to the circumstance of fastenings of this kind having been used for many centuries previous to the Christian era.

In Solomon's Song, chap. v., verse 5, this passage occurs: “I rose up to open to my beloved, and my hands dropped with myrrh, and my fingers with sweet-smelling myrrh, *upon the handles of the lock."* In Nehemiah, chap. iii., verse 3, is the following: "But the fish-gate did the sons of Hassenaah build, who also laid the beams thereof, and Set up the *doors* thereof, and the *locks* thereof, and the *bars* thereof." And these words are repeated in the 6th, 13th, 14th, and 15th verses.

It will be observed that in the previous quotations no key is mentioned; but in the following the key is mentioned in connection with the lock. In Judges, chap. iii., verses 23-25, “Ehud went forth through the porch, and shut the doors of the parlour upon him, and locked them. When he was gone out his servants came; and when they saw that, behold the doors of the parlour were locked, they said surely he covereth his feet in his summer chamber. An they tarried till they were ashamed; and behold he opened not the doors of the parlour; therefore they took a *key* and opened them.”

It may be well to notice in connection with these passages, that the word *“misgar”* translated “smith”, is rendered by Buxtorf “locksmith " in the following passage- Jeremiah, chap. xxiv., verse 1:

“The Lord showed me, and behold two baskets of figs were set before the temple of the Lord; after that Nebuchadrezzar, King of Babylon, had carried away captive Jeconiah, the son of Jehoiakim, King of Judah, and the princes of Judah, with the carpenters, and *smiths,* from Jerusalem, and had brought them to Babylon."

The most ancient lock ever discovered, is that described by Mr. Bonomi, as having secured the gate of an apartment in one of the palaces of Khorsabad. He says-

"At the end of the chamber, just behind the first bulls, was formerly a strong gate, of one leaf, which was fastened by a large *wooden lock,* like those still used in the East, of which the key is as much as a man can conveniently carry, and by a bar which moved into a square hole in the wall. It is to a key of this description that the prophet probably alludes, 'And the key of the house of David will I lay upon his shoulder;' and it is remarkable that the word for key in this passage of Scripture, ***muftah,*** is the same in use all over the East at the present time."



Figure 67. Egyptian Key



Figure 68. A Merchant of Cairo carrying the ke magazine

"The key of an ordinary street door is commonly thirteen or fourteen inches long; and the key of the gate of a public building, or of a street, or quarter of a town, is two feet and more in length. We have annexed a drawing of a key (figure 67) and the mode of carrying it (figure 68), alluded to in Isaiah. The iron pegs at one end of the piece of wood correspond to so many holes in the wooden bar or bolt of the lock, which when the door or gate is shut, cannot be opened till the key has been

inserted, and the impediment to the drawing back of the bolt removed by raising up so many iron pins that fall down into holes in the bar or bolt corresponding to the peg in the key."

The above discovery, and also the figure of one being sculptured among the basso-relievos of the Great Temple of Karnac, prove it to have been in use in Egypt for above four thousand years, during which period it does not appear to have underdone any sensible change. It was first described by Eton in his "Survey of the Turkish Empire," published in 1798 but it was not generally known in Western Europe, until the French invasion of Egypt, at the beginning of the present century, when a further account of it was given by M. Denon, in his great work on that country.

From a letter which appeared in the "Journal of Design and Manufactures," for July, 1850, p. 160, signed "W.C. Trevelyan," it appears that this pin-lock been found elsewhere than in the East; he says, "It is remarkable that the locks which have been in use in the Faroe Islands, probably for centuries, are identical in their construction with the Egyptian. They are, lock and key, in all their parts made of *wood;* of which material, if I mistake not, they have also been found in Egyptian Catacombs, and so identical with the Faroese in structure and appearance, that it would not be easy to distinguish one from the other."

It is said also, that a lock similar in character has been in use in Cornwall from time immemorial, which might have been introduced there by the Phoenicians.

Mr. Chubb says, in his paper on the construction of locks and keys, read before the Institution of Civil Engineers, April 9th, 1850:

"It is evident, however, that in the East, another lock and key, of a different description, were in ordinary use for fastening large doors and gates. There is nothing recorded as to the construction of the lock; but it can be inferred from the description given of the key, which is stated to have been in the form of a large sickle. Aratus, in order to give his readers an idea of the form of the constellation Cassiopeia, compares it to a key; and Huetius states that the constellation answers to such a description, -the stars to the north composing the curved part, and those to the south the handle."

"There is some curious information on this subject in

Parkhurst's Hebrew Lexicon. 'In the early ages,' he observes, 'they made use of certain crooked keys, having an ivory or wooden handle. These keys were placed in the holes of doors, and by turning them one way or the other, the bolt was moved forward or backward, in order to open or shut the door. This is evident from the testimony of Homer, where he says (Odyssey, xxi.) that Penelope wanting to open a wardrobe, took a brass key, very crooked, hafted with ivory, on which Eustathius remarks that this kind of key was very ancient, and differed from the keys having several wards which have been invented since, but that those ancient keys were still in use in his time."

"The poet Ariston, in the Antholgia, book vii, gives a key the epithet, *i. e., one that is much bent.* These crooked keys were in the shape of a sickle, according to Eustathius, but such keys not being easily carried in the hand, on account of their inconvenient form, they were carried on the shoulder, as we see our reapers carry on their shoulders, at this day, their sickles, joined and tied together. Callimachus, in his Hymn to Ceres, says that the Goddess, having assumed the form of Nicippe, her priestess carried a key, that is, *superhumeralem,* 'fit to be borne on the shoulder.'"

"It is most probable that the crooked keys' here spoken of were used to fasten and unfasten a simple horizontal wooden bar, moving into and out of a staple on the door-post, the key being inserted in a hole in the door, at some distance below the bar, and then turned to the right or left by its handle."

Very little information can be gathered from any published works relative to the locks used by the ancient Greeks and Romans. Most of the door fastenings of the former people cannot lay claim to the title of a lock.

Mr. Donaldson, in his work on ancient doorways, says, "the fastenings to the doors consisted of bolts, bars, and locks (Pessuli, Obiec Serae). Commentators are uncertain as to the time when keys were first used. Eustathius in his notes on the **x**th book of the Odyssey attributes the invention to the Lacedemonians: Pliny, vii. C. 56, on the other hand, gives the credit of the discovery to certain Theodorus of Samos. At all events, the use does not appear to be so remote as the Homeric Ages, for in the eighth book of the Odyssey, Ulysses is represented securing the rich and costly robes, vases, gold, and other valuable presents of Alcinous and his queen by a cord of rope fastened in a knot "closed with Circaean art.

The knot of Ulysses became a proverb to express an insolvable difficulty,; and a proof of the esteem in which the ancients held the art, so necessary in the absence of locks, maybe adduced from the Gordian Knot, famous in antiquity. And in fact Homer describes the treasures and other valuable objects as being kept in the citadel, secured merely by a cord intricately knotted. This, of course, was soon found to be a very insufficient protection, and therefore a wooden bar was adopted inside the doors of houses, to which it was attached by an iron latch, fastened or removed by a key adapted to it; this key was easily applied from within, but in order to get at it from without, a large hole was made in the door, allowing the introduction of the hand, so as to reach the latch, and apply the key.

The lock called the Lacedemonian, much celebrated by ancient writers, was invented subsequently; it was especially fitted for the inner chamber of houses, the bar fastenings continuing to be employed for closing the outer doors of dwellings and the entrance gates to cities. The Lacedemonian Lock did not require a hole to be made in the door, for it consisted of a bolt placed on that side of the entrance door which opened, and on the inside of a chamber door.

When a person, who was outside, wished to enter it, it was necessary for him to insert the key in the little hole, and so raise the bolt; and in time this species of fastening was improved by the insertion of the bolt in all iron frame or rim, permanently attached to the door by a chain, and fastening the door by the insertion of the hasp, through the eye of which was forced the bolt inside the lock by applying the key. Hence Varro lib vi de LL.- 'Nec satis reserare ab sera dictum, id est aperire. Hinc etiam Serae, quibus remotis fores pandunter. As also Nonius in Patibulum-‘Sera sua sponte delapsa cecidit, reclusaeque subito fores admiserunt intrantem.'

Thus it appears that the locks of the ancients were not of the same constructions as ours, not being inserted or morticed into the doors, nor even attached except by a chain, and being in fact mere padlocks.

Lipsius, in his comments on the second book of Tacitus, is the first to allude to the ancient usages respecting keys, some of which he states to have had a ring the size of the little finger, for the purpose of being worn and engraved so as to answer the purpose of a seal. Garlaeus, in his Dactyliotheca, gives in his

forty-second subject an example of a key with a ring attached to put on the filter; the ring has an onyx engraved with the helm of a vessel between two ears of corn, in allusion probably to the occupation of the wearer, who may have been engaged in the importation of corn from the provinces: the wards of this key, given by the learned Antwerpian are precisely similar to those of the present day; and numbers 205 to 209 inclusive are other keys with rings. There are several specimens of keys among the bronzes of the British Museum.

"The bolts (pessuli) were generally two to each door, as Plautus 'Ostium ambobus occlude pessulis; Aulularia;' for which reason the ancient writers generally use this word in the plural number. The reader will have observed that frequent reference has been made to passages taken from the Odyssey which abounds in allusions to the domestic habits of the Greeks, it being a picture of the domestic manners of the ancients, as the Iliad is of their public life and usages."

We shall here insert a passage forming part of the last paragraph to the second book of the Odyssey. Telemachus, after an angry debate with the suitors of Penelope, has retired to his chamber, attended by his old faithful servant, 'the sage Eurycleia.'

"Whilst to his couch himself the prince addressed,
The duteous nurse received the purple vest:
The purple vest with decent care disposed,
The silver ring she pulled, the door reclosed;
The bolt, obedient to the silken cord,
To the strong staple's inmost depth restored,
Secured the valves."

When the gate was opened among the Romans, the folds (**VALVAE QUOD INTUS REVOLVANTUR**) bent inwards, unless it was granted to any one by a special law to open his door outwards; as to P. Valerius Poplicola, and his brother, who had twice conquered the Sabines ***(UT DOMUS EORUM FORES EXTRA APERIRENTUR),*** Plin. xxxvi. 15, after the manner of the Athenians, whose doors opened to the street ***(IN PUBLICUM***); and when any one Went out, always made a noise, by striking the door on the inside, to give warning to those without to keep at a distance. Hence CREPUIT FORIS, *concrepuit a Glycerio ostium,* the door of Glycerium hath creaked, i.e. is about to be opened; Ter. And. Iv. 1. 59. Hec. Iv 1.6. Plaut. Amph. I.2.34. This the Greeks called "vooelv Ovpav; and knocking from without kottelv, pulsare vel putare.

“The door, when shut, was secured by bars (obices, claustra, repagula, vectes), iron bolts,(pessuli) chains, Juv. Iii.304, locks (serae), and keys (claves). Hence abdere pessulum foribus, to bolt the door, Ter. Iieaut. Ii.3,37, occludere ostium pessulis, with tow bolts, one below, and another above; Plaut. Aul., I,2,25, uncinum immittere, to fix the bolt with a hook; obserare fores, vel ostium, to lock the door, Ter. Eun iv. 6,25, seram ponere, Juvenal, vi. 34, apposita janua fulta sera, locked, Ovid, Art. A. ii. 244, reserare, to open, to unlock, Ovid. Met. x, 384, excutere poste seram, Am. I.6, 24, etc. It appears that the locks of the ancients were not fixed to the panels (impages) of the doors with nails like ours, but were taken off when the door was opened, as our padlocks: hence *et jaceat tacita lapsa catena sera,* Propert. Iv.12,26.”

"That mechanical contrivances for securing doors, which were essentially locks with keys, were in use by the Romans, at a later period, is beyond question, “for the keys found at Herculaneum and Pompeii, and those attached to rings prove that a kind of warded lock must have been well known. There are the remains of a tomb at Pompeii, the door of which is made of a single piece of marble, including the pivots, which were encased in bronze, and turned in sockets of the same metal; it is three feet high, two feet nine inches wide, and four and a quarter inches thick; it is cut in front to resemble panels, and thus approaches nearer in appearance to a modern wooden door; and it was fastened by some kind of lock, traces of which still remain."

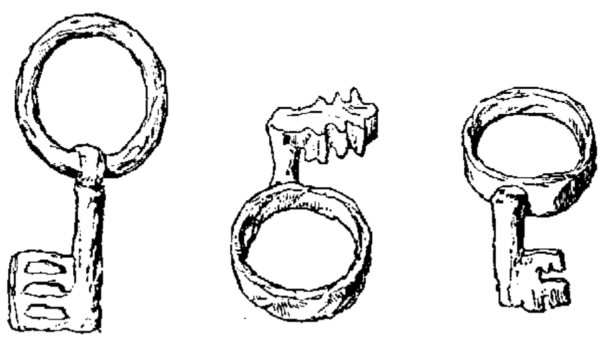


Figure 69. Bronze and Iron Keys from Pompeii and Herculaneum

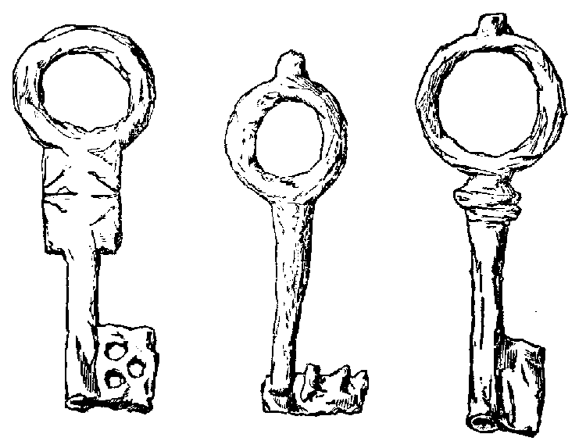


Figure 70. Bronze and Iron Keys from Pompeii and Herculaneum

In 1689, during some excavations in the plain at the foot of Vesuvius, where it was subsequently proved that Pompeii had

flourished, a workman observed the regularity with which successive layers of earth and volcanic matter had been deposited. He compared them to pavements one upon the other; with remains of burnt vegetation, charcoal, and common earth beneath each volcanic deposit. Under one of these dense masses of scoria, dust, and pumice stone, he found large quantities of carbonized *timber, locks, and iron work,* evidently the remains Of the inhabitants, which, together with some *old keys,* and inscriptions giving the name of the locality, satisfied the learned of the day, that they belonged to the ancient city of Pompeii.

In the garden was found a skeleton *with a key* by its bony hand, and near it a bag of coins. This is believed to have been the master of the house, who had probably thought to escape by the garden, and been destroyed either by the vapour, or some fragment of stone. Besides some silver vases lay another skeleton, probably of a slave.

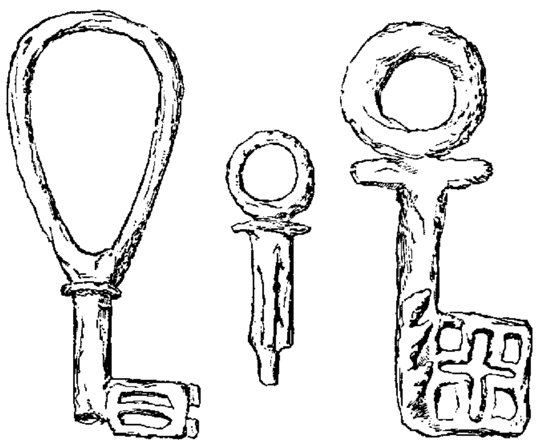


Figure 71. Bronze and Iron Keys from Pompeii and Herculaneum

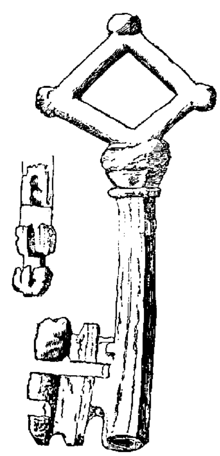


Figure 72. Copper key found

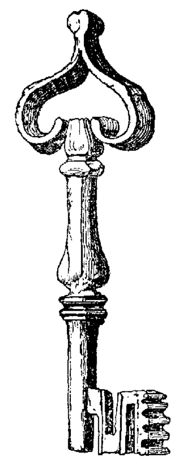


Figure 73. Early Key found at Mec Kent

The examples of Roman keys found in various parts of England and contained in the British Museum fully bear out the previous statement, and these, with the very beautiful specimens of the early English keys in the Museum at Marlborough House, being of such high interest, are well worth, and will amply repay, examination.

We may remark here that this important subject has not had the same attention and research of learned antiquaries which other

branches of science and art have received; and it is in part to this circumstance that so little can be said upon this interesting portion of our work. We may note that between the keys found at Herculaneum and Pompeii (figures 69, 70, and 71) and the Roman keys found in various parts of England (fig.72) there is a distinctive difference, although the whole of them belong to the same description of lock- the warded lock; and in the absence of any locks having been found, by which their particular construction might be ascertained, the shape of the cuts and holes in the "bits" of these ancient keys, prove beyond question, that in locking and unlocking, the key did not perform a complete revolution, and that consequently, they were identical with the spring locks of modern days.

It is remarkable, also, that the early English locks were constructed in a similar manner, as, will be apparent on a close examination of the *locks and keys* at Marlborough House. Several of the latter which were purchased at the Bernal sale are most elaborately and beautifully finished, and are the best specimens of any that have yet come under our observation, and prove that the locks were of the most complex character; and it may be fairly questioned whether they could be excelled either in ingenuity of design, or beauty of workmanship, by any of those, manufactured at the present day.

It was in the sixteenth century, in Germany, Italy, France, and England, that the art of the locksmith was at its highest perfection; and the keys were likewise treated, as M. de la Barte remarks in his interesting Catalogue of the DeBruges Collection,' during the 16th and 17th centuries, 'as absolutely artistic objects.' Nothing could be imagined more graceful than those little figures in the round, those escutcheons and armorial insignia, those ornaments and piercings, with which the end of the key was enriched; that part which is grasped in the hand, and for which we have substituted a common ring."

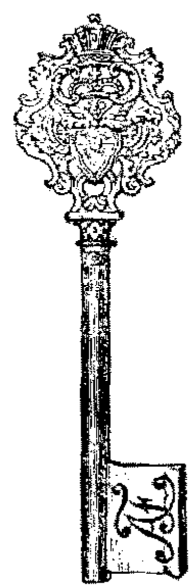


Figure 74. Old English Key

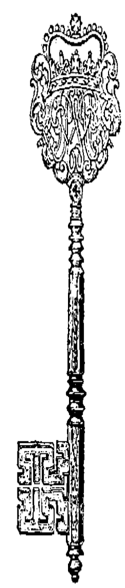


Figure 75. (
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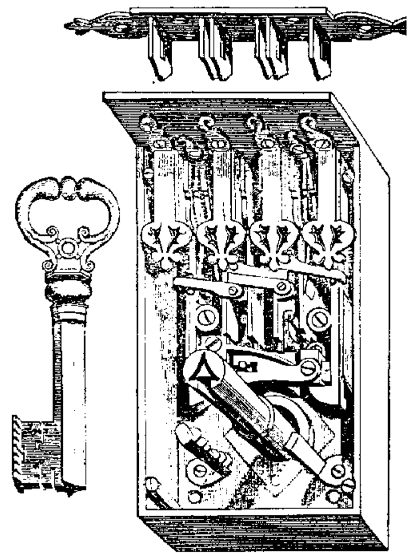


Figure 76. Old Elizabethan Link-plate Chest Lock

The English locks of this period are of such superior excellence in point of workmanship, that too high a value cannot be put upon the specimens now in existence, as they prove the advanced state of the lock manufacture in England three hundred years ago.

The Ornamental locks and keys which have recently been introduced, are mostly copies of those made in the sixteenth century, and as far as design and workmanship go, cannot claim superiority over the former.

Look at Figures 74 and 75, which represent two keys sold at the Bernal Sale. Can anything be more beautiful or artistic? Compare the modern "fancy bow keys" with these, and the superiority of the former will be at once apparent.

The comb-like nose-wards of the Elizabethan Keys are truly wonderful, and the tissue-paper thinness of the other wards are not less amazing. The iron of which these are made must undoubtedly have been of a superior quality.

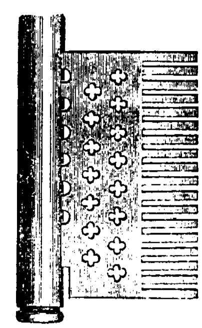


Figure 77. Old Engli
Marlborough House, pu
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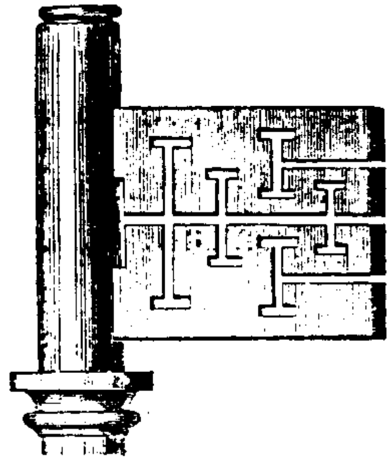


Figure 78. Old English Key found in the ruins of an Abbey

These ancient keys are variously composed of bronze, copper, or iron, and the variety of the locks corresponding thereto must have been as numerous as the modern ones.

The great antiquity of locks and keys being admitted, we shall, in the following chapters, describe and illustrate every principal lock which has been invented, from the wooden pin-lock of the Egyptians, to the most scientific and elaborately finished locks of the present time.

CHAPTER FOURTEEN: On the Old Locks and Keys

Master Index of Locks (chronological by date)

ROWNTREE'S LOCK, Patent dated February 23, 1790.
BIRD'S LOCK, Patent dated October 29, 1790.
FERRYMAN'S LOCK, Patent dated July 19, 1791.
BICKERTON'S SECOND LOCK, invented about 1792.
ODELL's LATCH, Invented about 1792.
MASON'S LATCH, Invented about 1796.
TURNER's LOCK, Invented about 1798.
PEDLEY'S LOCK, Invented about 1798.
BULLOCK's LEVER LOCK-BOLT, Invented about 1800.
ARKWRIGHT'S LOCK, Invented about 1798.
DAVIS'S LOCK, Patent dated April 11, 1799.
NORTON'S LOCK, Invented about 1800.
HOLEMBURG'S LOCK, Patent dated June 24th, 1801.
EAGLE's LOCK, Invented about 1801.
DOODY's LOCK, invented about 1804.
STANSBURY's LOCK, Patent dated May 18th, 1805.
THOMPSON's LOCK, Invented about 1805.
MACE'S LOCK, Invented about 1807.
COX'S LOCK, Invented about 1808.
ROBERTS' LOCK, Invented about 1809.
STUART'S LOCK, Invented about 1810.
TOMPSON'S LOCK, Patent dated December 29th, 1808.
ALPORT's LOCK, Invented about 1812.
DANIELL'S' LOCK, Invented about 1814.
GILES'S LOCK, Invented about 1814.
MITCHELL AND LAWTON'S LOCK, Patent dated March 7, 1815.
SCOTT's LOCK, Invented about 1815.
DEANE'S LOCK, Invented about 1815.
SOMERFORD'S FIRST LOCK, Invented about 1815.
RUXTON's LOCK, Patent dated May 14, 1816.
KEMP'S LOCK. Patent dated May 27, 1816.
SOMERFORD'S SECOND LOCK, Invented about 1816.
BURTON'S LOCK, Invented about 1816.
DUCE'S (SENIOR) LOCK, Invented about 1816.
TOY'S IMPROVEMENTS, Introduced about 1816.
HIGGINSON'S LOCK, Patent dated February 1, 1817.
GOULD'S LOCK, Invented about 1817.
LEES' LOCK, Invented about 1817
BRUETON'S IMPROVEMENTS, Introduced about 1817
CHUBB'S ORIGINAL LOCK, Patent dated February 3, 1818.
DYASS'S LOCK, Invented about 1818.
SMITH'S LOCK, Invented about 1818.
WRIGHT's LOCK, Invented about 1818.
STRUTT's LOCK, Patent dated October 18, 1819.

SPICER'S LOCK, Invented about 1819.
MALLET'S LOCK, Patent dated December 14, 1820.
AINGER'S LOCK, Invented about 1820.
YOUNG'S LOCK, Patent dated May 14th, 1825.
FRIEND'S SECRET LOCK, Invented about 1825.
RUBERRY'S BAG-IRON LOCK, Invented about 1826.
RICHARDS' LOCK, invented about 1827.
MACHIN'S LOCK, invented about 1827.
CHUBB'S COMBINATION LATCH, Patent dated May 7, 1828.
WALTON'S IMPROVEMENTS IN LOCKS, invented from 1828 to 1846.
GOTTLIEB'S LOCK, Patent dated June 21, 1829.
STANLEY's LOCK, invented about 1829.
CARPENTER & YOUNG'S LOCK, Patent dated January 18, 1830.
MORDAN'S LOCK PROTECTOR, invented about 1830.
WALTERS' LOCK, invented about 1830.
AUBIN'S LOCK, invented 1830.
RUTHERFORD's LOCK, Patent dated April 14, 1831.
BARNARD'S LOCK, Patent dated May 23, 1831.
YOUNG'S IMPROVEMENTS, Patent dated July 27, 1831.
PARSONS' BALANCE-LEVER LOCK, Patent dated December 20, 1832.
MACKINNON'S PERMUTATION LOCK, invented about 1835.
Dr. ANDREWS' (America) LOCK, invented about 1835.
MEIGHAN'S ALARUM LOCK, invented about 1836.
MARR'S LOCK, invented about 1836.
THOMPSON'S (SALLY) LOCK, Patent dated November 13th, 1838.
SANDERS' LOCK, Patent dated June 12, 1839.
NETTLEFOLD'S LOCK, invented by John Charles Schwieso, July 20, 1839.
GERISH'S IMPROVEMENTS IN LOCKS AND KEYS, Patented February 27th, 1840.
WILLIAMS' LOCK, Patent dated March 20, 1840.
PIERCE'S LOCK, Patent dated May 2nd, 1840.
WOLVERSON and RAWLETT ' Lock, Patent dated June 13, 1840.
BAILLIE 's LOCK, Patent dated December 23rd, 1840.
BROOKES LOCK, invented about 1840.
FOSTERS LOCK, invented about 1840.
PERRY'S IMPROVEMENT ITT FLUSH-BOLT LOCKS introduced about 1840.
BENTON'S LOCK invented about 1840.
COPE'S PIANOFORTE LOCK, invented about 1840.
HICKIN'S CIRCULAR ESCUTCHEON LOCK, invented about 1840.
WAKEMAN'S IMPROVEMENTS IN LOCKS AND ESCUTCHEONS, introduced about 1840.
DUCE (Junior's) LOCK, invented 1040, Patent dated May 24, 1842.
TILDESLEY and SANDERS LOCK Patent dated March 29 1841.

HANCOCK'S LOCK, Patent dated May 6th, 1841.
STRONG'S LOCK, Patent dated September 28th, 1841.
NEWELL'S (American) LOCK, invented in 1841. English Patent dated April 15th, 1851.
FIELDHOUSE'S IMPROVEMENTS, introduced about 1841.
ROCK'S IMPROVEMENTS, Patent dated Dec. 29th, 1842.
THOMAS'S PRISON LOCK, invented about 1842.
AUBIN'S LATCH-BOLT, invented about 1842.
TANN'S LOCK, Patent dated November 25th, 1843.
PITT'S IMPROVEMENT IN LATCH-BOLTS, introduced about 1844.
PICKIN'S IMPROVEMENTS, introduced about 1844.
CHESTERMAN'S IMPROVEMENT, introduced about 1844.
POOLE'S LOCK, Patent dated December 4th, 1845.
AUBIN'S SLIDE-STUMP LOCK, invented about 1845.
FELLOWES' IMPROVEMENT, introduced about 1845.
COTTERILL'S LOCK, Patent dated March 25th, 1846.
JONES' (American) LOCK, Patented in America about 1846.
DE LA FONS' IMPROVEMENTS, Patent dated July 6th, 1846.
CHUBB'S QUADRUPLE LOCK, Patent dated December 14th, 1846.
AUBIN'S CURTAIN-LEVER LOCK, invented about 1846.
BRIERLEY'S LOCK invented about 1846.
MORRIS'S DIRECTION PADLOCK, invented about 1846.
PLANTE'S Lock, invented about 1846.
TILDESLEY'S PADLOCK, Introduced in 1847
NEWELL'S IMPROVEMENTS, Patent dated September 28th, 1848.
YALE'S (America) LOCK invented about 1848.
WINDLE and BLYTH'S LOCK invented about 1848.
WILKES' LOCK, Patent dated May 8th, 1849.
JONES' LOCK, invented about 1849.
BRADFORD 'S LOCK, Patent dated July 22, 1850.
AUBIN'S BALANCE-DETECTOR LOCK, invented 1850.
AUBIN'S VIBRATING GUARD LOCK, invented 1850.
AUBIN'S COMPOUND LEVER LOCK, invented 1850.
TAYLOR'S LOCK, invented 1850.
BIGFORD'S LOCK, invented about 1850.
TUCKER'S CLOSED KEYHOLE SEPARATING-KEY LOCK, invented 1851.
RESTELL'S LOCKS, invented in 1851.
WOLVERSON'S LOCK, invented about 1851.

In the use of the word “old” at the head of this chapter, it may be proper to remark that we use it only to distinguish the whole of the locks which were in use previous to May, 1851, from the modern locks which have been in use since that period, and which

will be fully described in the chapter on modern locks.

We shall endeavor to describe the various locks mentioned with all possible regard to their chronological order, and also the usual modes of picking each variety as we proceed.

The first lock, of which there is any distinct account or representation, is the Egyptian lock, figure 79. These locks are described generally in Eton's Survey of the Turkish Empire, published towards the end of the last century, as follow: "Nothing can be more clumsy than the door-locks in Turkey; but their mechanism to prevent picking is admirable. It is curious thing to see wooden locks upon iron doors, particularly in Asia, and on their caravansaries and other great buildings, as well as upon house doors.

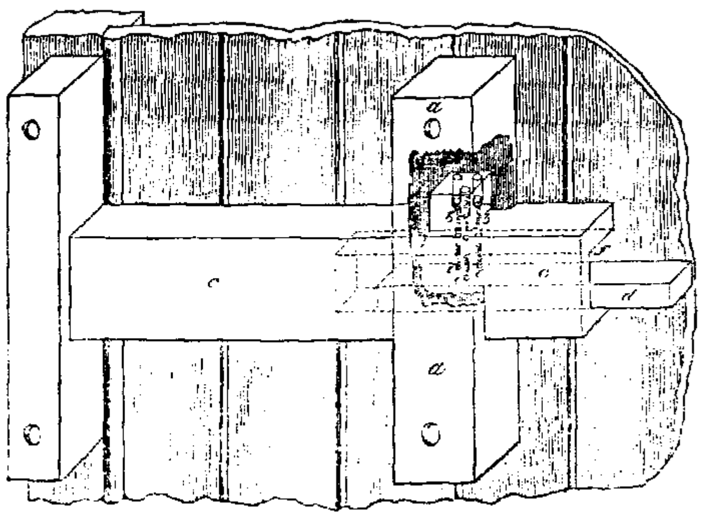


Figure 79. Egyptian Lock, copied from a wooden block recently brought from Alexandria.

The key goes into the back part of the bolt, and is composed of a square stick with five or six iron or wooden pins, about half-an-inch long, towards the end of it, placed at irregular distances. These answer to holes in the upper part of the bolt, which is pierced with a square hole to receive the key.

The key is put in as far as it will go, and then lifted up. The pins, entering the corresponding holes, raise other pins, which dropped into these holes from the part of the lock immediately above. They have heads to prevent them falling lower than is necessary.

The bolt, being thus freed from the upper pins, is drawn back by means of the key. The key is then lowered, and may be drawn out of the bolt to lock it again. The bolt is only pushed in, and the upper pins fall into the holes in the bolt by their own weight.

In respect to the **picking** of this lock, the main difficulty consists in obtaining any false key to correspond with the position of the pins. But this is easily accomplished in a manner analogous to that which is practiced in connection with other kinds of locks.

By laying a small piece of wax on a blank key and pressing it up against the holes, their **impression** would of course be left on the wax, thereby showing the position of the pins which furnish a guide to the fabrication of a false key that would open the lock. There is also little difficulty in picking it by a single instrument.

Although **warded locks** are next in antiquity to the Egyptian, after which followed those with tumblers, it must be particularly noticed that the Egyptian lock, in reality, lays claim to be considered as the type of all tumbler and most other locks.

The most essential part of all locks is the bolt, which can be shot backwards and forwards, locked or unlocked, only by its own key, and the greatest point of security that can be obtained in the construction of locks is that the possibility of effecting this purpose, by other instruments shall depend entirely upon chance.

It has therefore been the object of every inventor and manufacturer of locks that have any pretensions to security, so to construct them, that there shall be no possible means left by which the **particular form of the key(450)** or the requisite position of the security parts can be ascertained, except by having possession of the original or true key, or by an examination of the interior construction and arrangement of each particular lock.

Now although each of the great number of inventors of locks has produced one more or complex in character or new in form, nearly the whole of these innumerable ingenious contrivances for rendering locks unpickable may be classed under one or other of two systems of security.

Some consider that there are three distinct principles of

security exhibited in the numerous variety of locks, viz., the **fixed obstacles**, the **moveable impediments**, and the arrangement of the **letter lock**. Without questioning the propriety of such a classification, we prefer arranging the whole under two heads.

The first consists in inserting within the lock a series of fixed or **stationary obstacles(451)**, called wheels or wards. These are placed in and about the keyhole, or between the keyhole and the bolt, to prevent any other instrument than the proper key from having access to the bolt.

The second mode consists in the insertion of such **impediments to the retraction of the bolt(452)**, which are not fixed or stationary like the wheels or wards, but moveable and of various combinations, and which prevent other instruments than the true key opening the lock. To this class belong all the locks which have been invented, for the first Of Barron's, the patent for which was enrolled October 31st, 1778, downwards to the present year.

As before stated, the Egyptian lock is constructed on the latter principle, a consideration of which does not appear to have suggested itself to any inventor previous to the year 1778.

Barron was the first to improve upon this ancient principle, by affording additional security in the introduction of his double-acting tumblers. Most of the latter class are called either tumbler or lever locks, in contradistinction to the former. These two principles, vis., fixed or stationary wards and moveable wards or tumblers, may be applied separately or in combination.

Previous to the reign of James I, there is little or nothing on record relative to the inventions of our forefathers, as every inventor (no protection as we have under the patent laws) kept the secret of his invention to himself, in order to secure the monopoly of the trade to his own exclusive benefit.

On this account it is a most difficult matter to fix the date or introduction of any particular invention, not only in reference to locks and keys, but to nearly all scientific discoveries of whatever kind, as having taken place in any year, or even in any century. The moment protection was granted to the inventor, records of all the improvements in the arts and sciences which subsequently took place, abound.

Since that period, little difficulty exists for ascertaining the exact date of all meritorious inventions. From the above circumstances, it is not surprising that not a tittle of evidence can be found to prove whether the warded lock was the invention of any person in this kingdom or whether it was introduced from some other country.

The fact of its being of great antiquity is proved from "the representations of warded keys in early missals, and other works," since the commencement of the Christian era, and the keys preserved in the metropolitan and provincial museums. Beyond this, nothing more can be said as to its origin.

Before noticing the warded lock further, we will, for convenience sake, first describe the puzzle or letter lock, which, although not so ancient as the Egyptian, must certainly be considered as one of the oldest locks in use in Europe.

The **puzzle lock(453)** is generally in the form of a padlock, which is opened and closed without the use of a key, and which has certain difficulties thrown in the way of its being opened by any one who is not in the secret of the person who closed it.

It is, in fact, one of the locks in which the doctrine of permutation is made to contribute to the means of security. The key to open it is a mnemonic or mental one, instead of one of steel or iron. Two centuries ago, the puzzle lock attracted far more attention than any other. It has always contained certain parts, the movement of which constitutes the enigma. Some of these very curious and out-of-the-way locks are so formed as to receive the name of dial-locks; but chief among them are ring-locks, a name the meaning of which will be presently understood.

The puzzle or letter-lock of the ring kind, then consists essentially of a spindle, *d*; (figure 80) a barrel c encompassing the spindle; tow end-pieces, aa, to keep the spindle and barrel in their places; and the shackle b, hinged to one of these end-pieces.

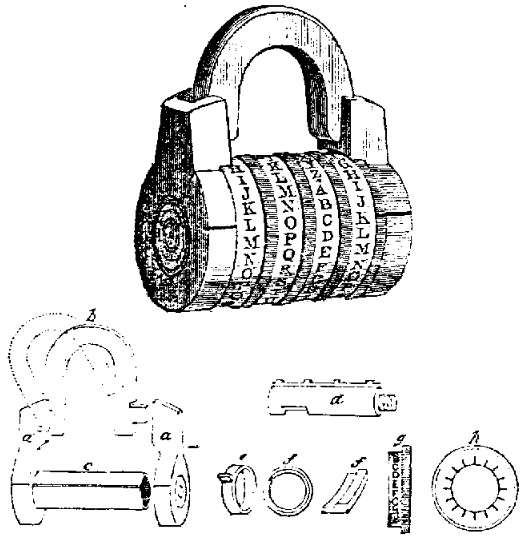


Figure 80. Puzzle or Letter Lock.

To unfasten the lock, one of the end-pieces must be drawn out a little, to allow the shackle or horseshoe to be turned on its hinge. The question arises, therefore, how this end-piece is to be acted upon. This is effected in a very ingenious way; there are four studs or projections in a row on the spindle d, and as the spindle fits pretty closely in the barrel, the former cannot be drawn out of the latter unless there be a groove in the interior of the barrel, as a counterpart to the studs on the exterior of the spindle.

Four rings, *e*, fit on the barrel, upon the interior of each of which there is a groove. Unless all four of these grooves coincide in direction, and lie in the same plane as the groove in the barrel, the studs will not be able to pass, and the spindle cannot be drawn out.

Each ring may easily be made to work around the barrel by means of the fingers, and to maintain any position which may be given to it. There are outer rings, g, one over each of the rings just described, with the letters of the alphabet (or a considerable number of them) inscribed on each. These outer rings, by means of notches on the inside, *h*, govern the movements of the inner rings.

The mechanical design of the lock is as follows; when the padlock is to be locked, the rings are so adjusted that all the grooves shall be in a right line; the spindle is thrust in, the end-piece is fixed on, and the shackle is shut down.

The padlock is now fastened; but a reverse order of proceeding would as easily open it again, and therefore the 'safety' or 'puzzle' principle is brought into requisition. **The outer rings(454)** are moved with the finger, to throw the various interior grooves out of a right line, and thus prevent the withdrawal of the spindle.

As each ring may be turned around through a large or a small arc, and all turned in different degrees, the variations of relative position may be almost infinite. The letters on the outer rings are to assist the owner to remember the particular combination which he had adopted in the act of locking; for no other combination than this will suffice to open the lock.

There may, for instance, be the four letters L O C K in a line, which line is brought to coincide with two notches or marks at the ends of the apparatus. Until all the four outer rings are again brought into such relative position as to place the letters in a line, the lock cannot be opened.

Vanhagen von Ense, in his Memorabilia, furnishes the following information regarding this lock and its inventor, Regnier. Speaking of M. Regnier, who was also the Director du *Musee d'Aruntilerie* in Paris, he says,

"Regnier was a man of some invention, and had taken out a patent for a sort of lock which made some noise at the time; everybody praised his invention, and bought his locks. These consisted of broad steel rings, four, five, or eight deep, upon each of which the alphabet was engraved. These turned around on a cylinder of steel, and only separated where the letters, forming a particular word were in a straight line with one another.

The word was selected from among a thousand, and the choice was the secret of the purchaser. Any one not knowing the word might turn the rings around for years without succeeding in finding the right one. The workmanship was excellent, and Regnier was prouder of this than he was of the invention itself. The latter might be contested.

I had a vague recollection of having seen something of the sort before, but when I ventured to say so, my suspicions were treated with scorn and indignation, and I was not able to prove my assertions; but many years afterwards, when a book, which as a boy I had often diligently read, fell into my hands, Regnier's

lock was suddenly displayed.

The book was called Silvestri a Petrasancta Symbola Heroica, printed at Amsterdam in 1682. There was an explanation at page 254, attached to a picture, with the following words:

Honorius de Bellis, seruloe innexoe orbibus volubilibus ac literatis circuscripst hoc lemma-sorte aut labore."

Honorius de Bellis wrote this inscription, by chance or by labor, around a lock composed of revolving rings graven with letters."

However, neither luck nor labor would have done much towards discovering the secret of opening Regnier's locks, from the variety of their combinations. Their security seemed so great that the courier's dispatch boxes were generally fastened with them."

This interesting extract which was brought forward by Mr. Chubb, in the paper before quoted, shows that the invention cannot be claimed by M. Regnier, as the above and other allusions to this kind of lock occur in authors who flourished two or three centuries ago.

In Beaumont and Fletcher's play of the "Noble Gentleman" the following lines occur:

"A cap case for your linen, and your plate, with a strange lock that opens with A M E N."

In the verses addressed to May, by Carew, in the "Comedy of the Heir," is the following passage:

"As doth a lock that goes with letters; for until every one be known the lock's as fast, as if you had found none."

But it does appear that although M. Regneir was not the original inventor of the letter-lock, he considerably improved it, as in the first example of this lock, supposed to have been invented by Cardan.

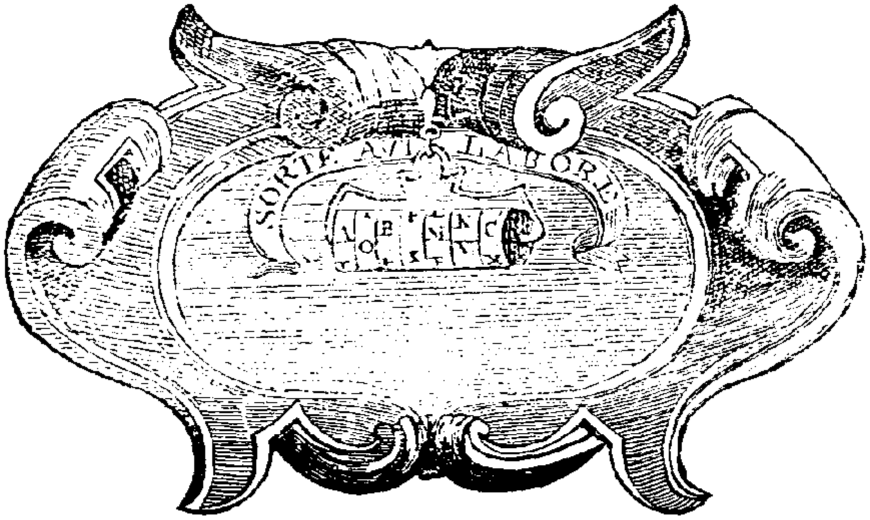


Figure 81. Puzzle-lock of the seventeenth century

Only one particular word or cipher could be used in each lock. **Regnier(455)**, to increase the chances of opening it, doubled all the rings, making each pair concentric, and enabling the user to vary the word at pleasure, by taking off the outer ring and placing what letter fancy chooses over the notch or groove in the inner ring, as contrived in all modern locks of this kind. (figure **80**).

In the work mentioned by Vanhagen, a copy of which is in the British Museum, is a drawing of a puzzle or letter lock (figure 81) which consists of a cylinder or barrel on which seven rings revolve. Letters are inscribed on each of these rings, and the ends of the cylinder are grasped by a kind of shackle.

During the progress of the "lock controversy" the following paragraph relating to this description of lock appeared in the *Observer*:

The French, in their exposition of 1844, availing themselves of the permutation principle, produced some marvels in the art; but the principle has not been adopted in this country.

The Charivari had an amusing quiz upon these locks when they first came out. It said the proprietor of such a lock must have an excellent memory: forget the letters and you are clearly shut out from your own house.

For instance, a gentleman gets to his door with his family, after

a country excursion, at eleven O’clock at night, in the midst of a perfect deluge of rain. He hunts out his alphabetical key, thrusts it into his alphabetical lock, and says A Z B X. The lock remains as firm as ever.

"Plague it!" says the worth citizen, as the blinding rain drives in his eyes. He then recollects that that was his combination for the previous day. He scratches his head to facilitate the movement of his intellectual faculties, and makes a random guess B C L O; but he has no better success.

In addition to his being well wet, his chances of hitting on the right combinations and permutations are but small, seeing that the number is somewhere about 3,553,578. Accordingly, when he comes to the three hundredth he loses all patience, and begins to kick and batter the door; but a patrol of the National Guard passes by, and the disturber of the streets is marched off to the watch-house”.

There is one adaptation of the principle of the letter lock, designed as an “escutcheon lock,” for securely closing the keyholes of locks on the doors of safes and strong rooms. Another modification is the dial lock, but both are too complicated and expensive to be generally used.

The escutcheon has long been a favorite resource with lock makers; various contrivances have from time to time been invented, more or less novel, and of various degrees of merit. But none of them when fixed to the doors of safes or such like depositories, can afford any security against the thief or burglar, from the circumstance of their being usually placed outside the surface of the doors, and consequently they can easily be removed by violence.

One of the first premiums awarded by the Society of Arts, after the commencement of their "Transactions," was to Mr. Marshall for a "secret escutcheon," in 1784, which invention was one of the many attempts which have been made to realize the properties of that “secret apparatus,” suggested by the Marquis of Worcester in his “Century of Inventions,” as follows:

“at page 69. A way how a little triangle-screwed key, not weighing a shilling, shall be capable and strong enough to bolt and unbolt, round abut a great chest, a hundred bolts through fifty staples, two in each, with a direct contrary motion; and as many more from both sides and ends; and at the self-same time,

shall fasten it to the place beyond a man's natural strength to take it away; and in one and the same turn both locketh and openeth it."

"at page 70. A Key with a rose-turning pipe and two roses pierced through endwise the bit thereof, with several handsomely contrived wards, which may likewise do the same effects."

"at page 71. A key perfectly square, with a screw turning within it, and more conceited than any of the rest, and no heavier than the triangle-screwed key, and doth the same effects."

"at page 72. An escutcheon, to be placed before any of these locks, with these properties; first the owner, though a woman, may with her delicate hand vary the ways of causing to open the lock ten millions of times beyond the knowledge of the smith that made it, or of me that invented it."

"Second, if a stranger open it, it setteth an alarum a-going, which the stranger cannot stop from running out; and besides, though none shall be within hearing, yet it catcheth his hand as a trap doth a fox; and though far from maiming him, yet it leaveth such a mark behind it as will discover him if suspected; the escutcheon or lock plainly showing what money he hath taken out of the box to a farthing, and how many times opened since the owner had been at it."

We cannot, of course, tell whether an "escutcheon or lock plainly showing what money" may have been "taken out of the box to a farthing" will ever be invented; but the locksmiths of Wolverhampton, in the sixteenth century, were celebrated for constructing locks that would tell "how many times" a lock had been "opened since the owner had been at it."

The **dial lock(456)** that is suitable for doors is made with one or more dials, each with a series of letters or figures stamped on it, and secured to the door. To each dial is a hand or pointer connected by a spindle to a wheel.

On each wheel inside the lock is a notch or groove which has to be brought to a certain position to allow the bolt to be withdrawn, also a series of **false notches(457)** to add to the difficulty of finding a proper notch.

In order to **change the relative position(458)** of the hand or

pointer to the true notch, a nut on the back of the wheel is loosened, and the pointer set at any figure or letter the parties using the lock may please, and it can be changed as often as they wish.

There is a very general belief that as these locks are susceptible of so many changes, they must necessarily be **secure against any skill or ingenuity(459)** that can be brought against them; but by a little further investigation, it will be apparent that they afford no further security than the Egyptian and the warded locks.

A dial lock was invented some years ago by William Brown, Esq., M.P., and was described in a paper read before the Architectural and Archaeological Society of Liverpool, in 1852. The following is an abridged account of it from a Liverpool paper of that period.

"As your Society are desirous of seeing any improvements or attempts at them, I send you a stock-lock for inspection. The idea for its construction I took from a letter-padlock. I had a lock of this description made by Mr. Pooley twenty-five years ago, which has been in use ever since on Brown, Shipley, and Co.'s safe.

Its **advantages(460)** I conceive to be as follows:

- **it cannot be picked, for there is no keyhole;**
- **it cannot be blown up by gunpowder, for the same reason;**
- **you cannot drill through the door so as to reach the lock, for you are intercepted by a steel plate on which your tools will not act; thus you cannot introduce gunpowder that way to force the lock off;**
- **you cannot bounce off the wheels in the interior with a muffled hammer, for vulcanized India-rubber springs resist this;**
- **you cannot drill the spindles out, as their heads are case-hardened;**
- **you cannot drive them in, for they are countersunk in the door about half-way through.**

"Now let us set the lock to the word "Wood" (any other four letters might be used). When you set the lock, make a private record of them, so that you may not forget them. If parties do not know your letters, nothing but violence, applied by some means or other, can enable them to get into your safe; for the

lock will not open to anything but its talisman. "

Take off all the large wheels and open the lock; you will see that the large wheels have a number of false chambers; if you get the spurs of the bolt into three real chambers and one false, you are as fast as ever, for all four must be right.

Having placed your key and pointer outside the door to point to W on brass-plate No. 1, the small wheel inside obeys the same impulse; then maintain your small wheel steadily on this point, and the large wheel No. 1, will only fit on at the right place, the true opening compartment being opposite the spur of the bolt.

It being necessary at the time you set your lock that it should be open, proceed with Nos. 2 and 3 in the same way; your pointer standing steadily at 0. No. 4 is the same, the pointer being held steadily at D. You should then shoot your lock two or three times, to be sure you have made no mistake.

Every time you shoot your bolts out, **turn your wheels(461)** away from the true chamber, and see when you again turn your pointers to " Wood," that your lock opens freely; it is the proof that you have made no mistake, and you may now venture to lock your safe.

When you unlock the door, and find it necessary to leave it open for a time, you should shoot the bolts as if locked, and turn the wheels, so that no one may find what your real letters are; and again adjust them to their proper places, in order that the bolt may go back and enable you to relock. Once having locked the door and turned the wheels from your real letters, you need not trouble yourself with carrying the key, but leave it in any place beside the lock.

"I believe two wheels would make a perfectly safe lock; three would be quite so. I adopted four to make security doubly sure, as it would be impossible in any given time to work the changes. On **two wheels by chance(462)** the lock might open; you can, however, calculate the chances against this; and also three or four, the false compartment on the outer rim being taken into calculation.

"If this lock is of any value, it should be known; if it has weak points, let them be pointed out, and they may admit of a remedy; for we ought not to be led to believe a lock is safe which is not so."

It be observed that Mr. Brown stated that his lock could not be picked because there was no keyhole; it being in this respect the same as its ally, the ring or letter lock. The same remark has been repeatedly made with respect to all the varieties of these locks.

They are unquestionably difficult to pick by merely turning the rings round and round, in order to hit upon the right combination, but can easily be picked on the **mechanical principle of applying pressure(463)** to the desired parts. It is only necessary to take a small piece of common wire, bend it in the form of the shackle, and put it between the ends of the lock; the spring or tension of the wire forces the ends apart, and causes the studs on the rod to bear against the rings.

On **feeling(464)** the rings, some of them will be found to bind, and by turning those that so bind, the notches or grooves are successively felt and brought into a straight line, and the lock is thereby opened. In a similar manner, the bolt of the dial lock is withdrawn, by feeling the “bind” or faction of the pointers, and the result is the same.

Not long after Mr. Brown made the previous statement, Mr. Hobbs was in Liverpool, and was taken to the office of Messrs. Brown, Shipley, and Co. to inspect the lock referred to. The safe door was closed and locked, and whilst Mr. Hobbs was explaining his views as to the construction of the lock, it immediately sympathized with his manipulation, so that the door was opened in a few minutes.

A puzzle or letter lock, which is really unpickable, was invented in 1855, by Mr. F. H. Wenham, of Effra Vale Lodge, Brixton, which obtained the medal of the Society of Arts in that year. (See the description of this lock in the chapter on modern locks.)

“We think it is probable that most nations have their ‘puzzle locks.’ There are several known by the name of Russian, Chinese, and Hindu puzzle-locks, some of which have the forms of various animals or birds, and they are locked and unlocked by pressing upon or moving some particular portion of their bodies.

The security of these locks, like the ordinary secret escutcheons, depends in most cases upon keeping the part to be pressed or moved, as secret. Some time ago there appeared in the Illustrated London News, the following engraving and description of one of the latter, which was so far secure in proportion to

the amount of reverence felt for the Hindu God it is supposed to represent.

“This curious Lock is in the form of a bird; probably, representing the Hindu god, Garuda, the carrier or bearer of Vishnu, the second of the Hindu Triad, Garuda being to Vishnu what the eagle is to Jupiter."

"Garuda is worshipped by the natives of Madras; and, his living type, a kind of large hawk, is diligently fed by the devotees: the writer has often seen the worshippers with little baskets, filled with flesh which is thrown skillfully, a small piece at a time, into the air, while they shout ‘Hari! Hari!’ a name of Vishnu, and the bird stoops on the wing and takes the prey."

"Garuda is supposed to possess divine intelligence, and is much revered. Many stories are told of his discernment and cunning; and it is, probably on this account that the native artist has made his lock in the form of Garuda, a sufficient guarantee, in his notion, for its acting as a safety or detector, equal, or even superior to the more mechanical and scientific inventions of Bramah or Chubb. We should add, that, in this Indian Lock, the keyhole is on the side, one of the wings of the bird serving as a shifting escutcheon."

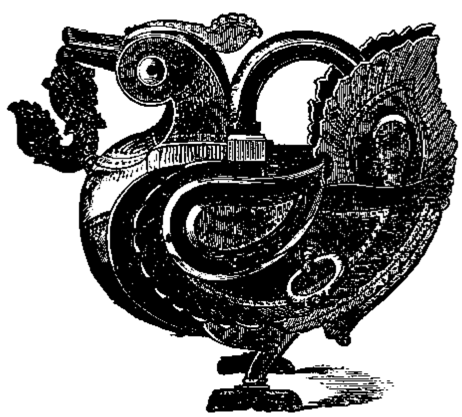


Figure 82. Indian Lock

In ordinary locks the **key(465)** consists of a circular shank with a loop-shaped handle at one end, called the bow, and a piece called the bit projecting from the shaft at a right angle at or near the other end.

The bit-end of the shank is, in the keys of locks which are to be

entered by the key from one side only, made hollow or tubular, hence called the pipe, to fit onto a pin or axis fixed in the lock.

In locks that are to be opened from either side, no pin can be fixed in the lock. In such a case, the shank is made solid and is prolonged beyond the bit, so as to enter and turn as in a socket within the upper part of the keyhole of that plate of the lock which happens to be farthest from the person applying the key.

The projecting bit, after being introduced into the body of the lock by a narrow opening (the keyhole), is turned round within the lock by a rotary motion imparted to the shank, until it comes in contact with a part of the bolt which is so shaped that the bit of the key cannot pass it to complete its revolution without shooting the bolt either backwards or forwards, as the case may be. When thus moved the bolt is retained in its position by a spring, or a tumbler, or by some other means, until it is again moved by the reverse action of the key.

The first and simplest means by which the entrance of a false key may be rendered difficult, is by giving a **peculiar form(466)** to the substance of the bit, and either adapting the form of the keyhole exactly to it, or inserting pieces of metal in the lock in such a way as to prevent the admission of a bit of different shape.

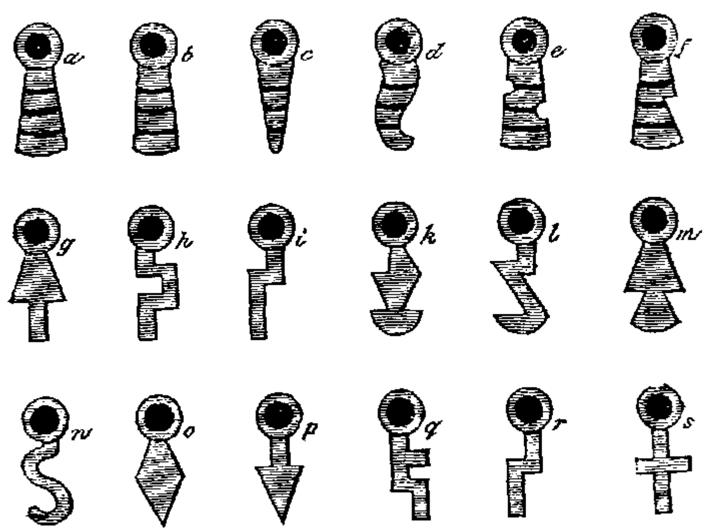


Figure 83. Fancy Bitted Keys

Fig.83 represents numerous forms of bits that are commonly used,

the keys, which are all represented as of the pipe or tubular make, being presented to the eye endways. Of these a b c and d are adapted for keyholes of various corresponding forms, while e and f, though suitable for keyholes of the same general form as the bit a, admit of further security by forming projections upon the sides of the keyholes, and also by forming the keyholes of the peculiar shape of the key bits g to s, the whole of which are cut through the front plate of the lock to fit the notches and grooves cut in the sides of the bit.

The next and principal means of security of the first class before mentioned is the use of pieces of iron or brass of various forms, fixed within the lock in such a way that no key can be turned round within it unless corresponding notches or slits are cut in its projecting bit. Figure 84, which represents a portion of the interior of the lock in isometric projection with the bit-end of the key in its place, will illustrate this. The tinted surface in this cut represents part of the back-plate of a lock with a tubular key turning upon a central pin in the plate.

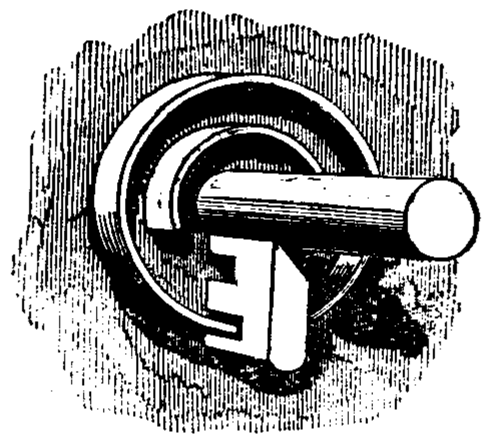


Figure 84. Key Bit and Wards

Attached to this plate are two concentric prominent rings of different degrees of elevation, one of which for the sake of variety is represented as complete or unbroken, while the other is cut away for a small space at the under side.

It is obvious that no key could be put into a lock provided with wards as in the cut, unless a **slit or notch(467)** were made in its bit to correspond with the larger and more prominent of the two rings, the round ward. It is equally evident that, although it might be put into the lock, no key could be turned round without having a notch also to correspond with the smaller and less

prominent circle, the short ward, which, being cut off near the keyhole, could not be discovered by an inspection from the outside of the lock.

In the common kind of locks, the wards seldom form a complete circle, but their effect is the same if they occupy only a small segment of it. They are commonly made of thin sheet iron, riveted to the plates of the lock. Locks with similar wards of copper are made for use in cellars and other places exposed to damp, where iron wards would become rusty.

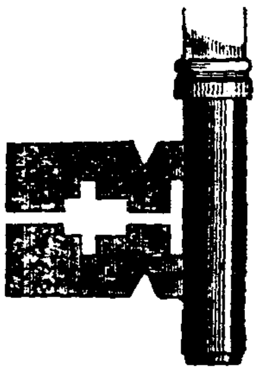


Figure 85. Key to Solid Warded Lock

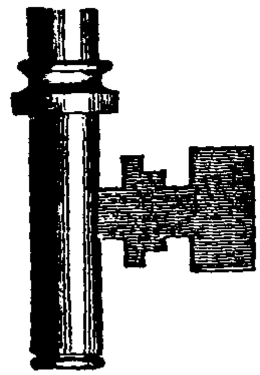


Figure 86. Key to Sash Warded Lock

A thicker kind of ward, known as solid wards, (figures 85-86) formed by casting in brass, and finished in the lathe, is used in many superior locks. Figure 84 represents wards of the simplest possible shape, which require nothing but a simple straight notch in the key to fit them. Many wards, however, are of a more complicated character, such as what are termed L, T, Y, and Z wards, from the resemblance of their sectional form to those letters respectively.

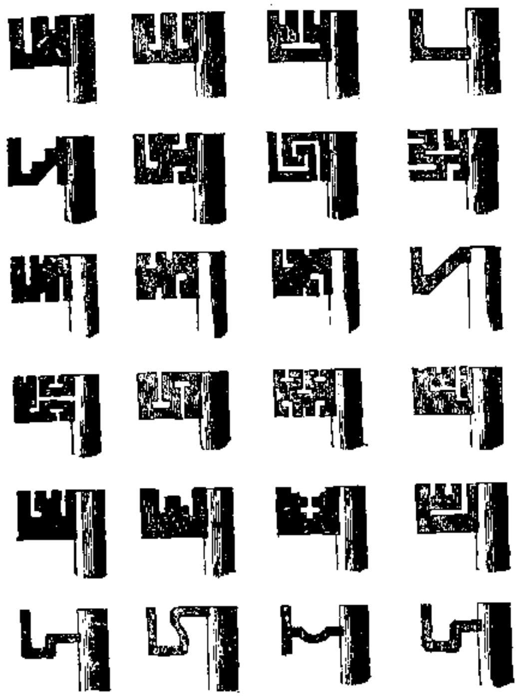


Figure 87. Keys to Warded Locks and ward patterns

There are also nose wards, top and bottom wards, step wards, bridge wards, etc.

By referring to the various forms of key represented in figures 85, 86, 87, and 88, the peculiar advantages and defects of that principle of security which depends upon the use of wards, may be readily comprehended.

The first and greatest defect of the system arises from the circumstance that, in ordinary cases, it is not absolutely necessary that a surreptitious instrument should perfectly thread the mazes of the wards. Thus the form and arrangement of the wards in the three keys numbered 1, 2, and 3 (figure 87) is so different that none of the three could be employed to open the other's lock, the first having two plain or simple wards, the second two L wards, and the third a T ward between two plain wards.

While these afford security against ordinary keys, they afford none whatever against a pick or skeleton key like 4 (figure 87), which would also open any other lock which is guarded merely by wards attached to the back-plate, as in Nos. 17, 18, 19, and 20; the only part essential to the moving of the bolt being the

extremity of the bit, which is retained in the skeleton key with nothing but a slender piece to connect it with the pipe or shank.

The security may be greatly increased by the use of other wards, attached to the opposite plate of the lock, and requiring notches in that part of the bit of the key which is represented by the slender connecting-piece in the skeleton 4. Such is the case in all the keys represented in Nos. 5 to 15 (figure 87) Number 5 represents a key for a solid-warded lock, which might, however, be easily picked by a skeleton key resembling No. 12.

The greater complication of the wards in No. 6 increases the difficulty of picking; while by the adoption of the arrangement shown in No. 7, the difficulty of introducing a false key is made perhaps as great as possible, since no instrument that does not thread all the intricacies of the wards could answer the purpose.

This form, however, requires very accurate workmanship, and unavoidably weakens the key to such an extent that it is in danger of breaking in the lock. All the keys represented in figures 83, 84, and 87, are pipe keys, adapted for such locks as have a fixed pin or axis, and can only be opened from one side.

It is, therefore, of no consequence that the wards attached to the back and front plates of the locks should resemble each other. In ordinary door locks, however, in which the key may have to be inserted from either side, it is essential that the wards attached to the two plates, if such be used, should either be precisely similar, or should bear such a relation to each other that notches may be cut in both sides, or rather in both edges of the bit of the key, to suit both sets of wards, it being a necessary condition that the two sides of the bit, marked a and b in the cut, (figure 88) should be perfectly alike.

In such locks, there is an intermediate plate, or bridge ward, which enters the opening marked c in the following figure, and which carries, on one or both of its sides, the principal wards. In many cases, the bit of a key divided by such an opening may be considered as constituting a double key, of which only one half is used at one time, that half being either a or b, according to the side through which the key is put into the lock.

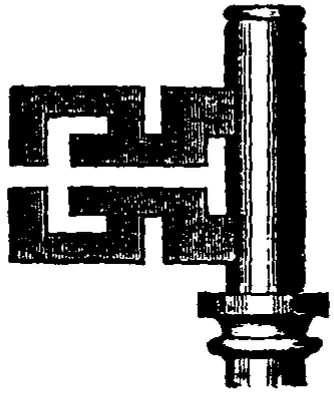


Figure 88 Room-door Key to a lock with bridge ward, etc.

Such is, in some measure, the case in the key from which figure 88 is drawn; although, as it is the key of a tumbler lock, both halves are brought into use at once, whatever may be the direction in which the key is applied, with this difference: that when the key is applied from the outer side of the door, the part marked ***a*** moves the tumbler and ***b*** the bolt, while when the key is put into the lock from the inner side ***a*** moves the bolt and ***b*** the tumbler.

The other illustrations of warded keys are intended to explain the theory of warded master keys, which was early understood by the ingenious locksmiths of Wolverhampton. In figure 87, the wards of the keys Nos.9, 10, and 11 are so far different from each other that neither of those three keys would open the lock designed for either of the other two, but a key formed like No.12 would readily open any of the locks of the other three, or any other of a more extensive series or suit of locks constructed on the same principle.

One defect of the principle of security by wards is that however complicated they may be, an ingenious picker will mostly be able to detect their form and position, by inserting a blank key with the bit covered with wax or tallow, so as to receive an **impression(468)** of the concealed obstructions in the lock.

It is well to observe that it is a very common practice to cut **more notches(469)** in the key than there are wards in the lock, so that the complex appearance of a key is no certain proof of the secure construction of the lock to which it belongs. Indeed some of the commonest locks are manufactured without any wards at all, although the keys are invariably made as if wards were employed.

A system prevails in the manufacture of warded locks of making

quantities in suits, i.e., making so many locks, say ten or twenty, each to differ, but with a master key to pass all of them, and also hundreds of locks for the same key to pass.

These orders are constantly repeated by the various ironmongers to the lock manufacturers or factors, so that in every town there are sure to be a considerable number of locks precisely the same in every respect, and which can be opened by each other's keys.

A set of twenty skeleton keys, similar to figure 89, would probably open nearly all the outer door locks in any city or town in the kingdom; and the keys of the patterns Nos.4, 12, 21, 22, 23, and 24, (figure 87) will open nearly three-fourths of all the common locks which are annually manufactured.

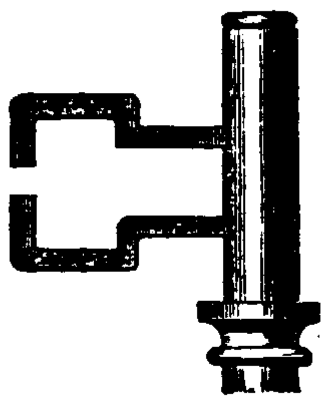


Figure 89. Skeleton Key

There is doubtless an advantage to ironmongers in supplying locks to their customers, which, when the key is lost, can so readily be opened by another key or one of the pick-locks (figure 87). Such a system should be at once abolished, as there can be no real security to those who use such locks whilst it exists.

We cannot better illustrate the consequences of this custom, than by stating a circumstance that occurred some short time ago in London.

A gentleman occupying one of a row of houses, the fronts and internal arrangements of which were exactly the same, went home late one evening, and by accident went to the door of the wrong house; but having inserted his key in the lock and let himself in, the mistake was not discovered until he found himself in his neighbor’s chamber.

Tens of thousands of warded locks are made annually, the whole of which are only duplicates of those which have been made every year for the last century.

We frequently expend from two to three pounds in the purchase of a brace of pistols, or a gun, as a means of preservation from the attack of burglars, when for less than half that amount spent in secure outer fastenings, the citadel might be kept perfectly safe against unwelcome intruders.

Locks, like all other articles in such common use, are considered of little importance by the majority of those who use them, and when from time immemorial we have been in the habit of purchasing a large lock for two or three shillings, it undoubtedly requires a certain amount of courage to give fifteen to thirty shillings for a lock similar in size. Unfortunately, size with many buyers is the only standard of comparison of the merits of various locks.

M.de Reaumur says, “There are no machines more common than locks: they are sufficiently complex to merit the name of machine; but I know of no others, the structure of which is so little understood by those who use them. It is rare to find anyone who knows wherein the goodness of a lock consists, or the **degree of security(470)** that he can attach to it. The outside of a lock is usually all that attracts attention. Doubtless the important uses to which locks are applied would excite curiosity respecting their structure, if curiosity were always excited for worthy objects."

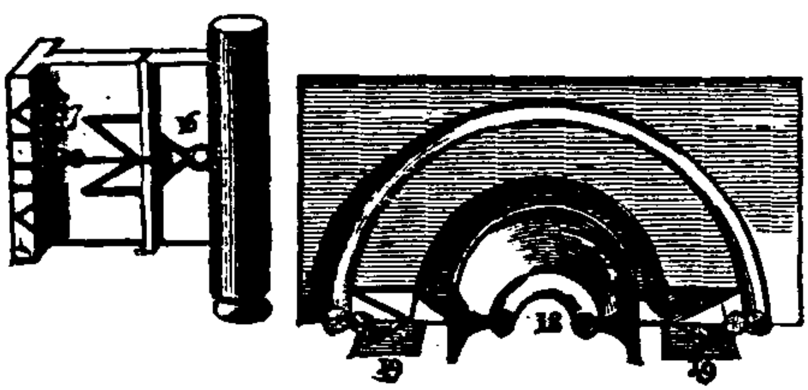


Figure 90. Wards of an Old French Lock

Some of the warded locks of the last century are curious. While the idea prevailed that a complicated ward gave security, there was room for the exercise of ingenuity in varying the shape of

the wards.

Figure 90 is copied from the great French work. It represents the cuts in the key, and also (seen from one perspective) the complicated forms of the pieces of metal which constitute the wards corresponding with those cuts.

The aperture in the key at 16 fits upon the metal surrounding the keyhole at 18; and the M-shaped cuts at 17 fit in like manner upon the similarly-shaped pieces at 19.

Another example of a similar kind is shown in figure 91, where an anchor appears to have been the favorite form. The anchor-cuts in the key are shown at 26; while in the wards the bottom of the anchor is near the keyhole at 28, and the top at 29.

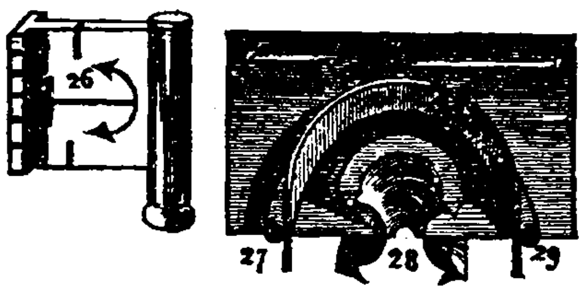


Figure 91. Wards of an Old French Lock

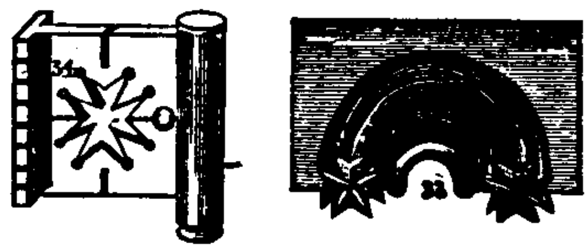
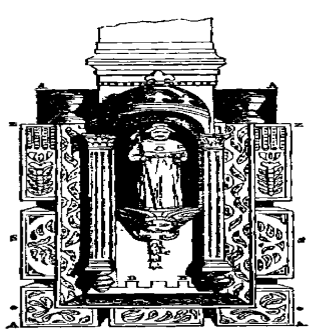


Figure 92. Wards of an Old French Lock

A similar illustration occurs in figure 92, where the star-like cuts at 34 on the key correspond with the star-like wards at 33.

From the fifteenth to the eighteenth centuries, locks were made in France, upon which a vast amount of **care and expense(471)** was bestowed. They were, in an especial degree, decorative appendages as well as fastenings.



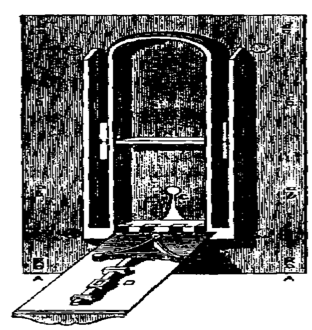




Figure 93. Exterior of an old Secret Lock

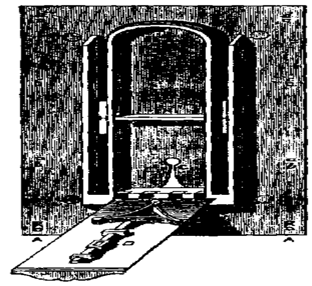


Figure 94. The same with a portion of the of the front let down, shewing the keyhole

chest-locks; they were fixed on the outside of the door or lid, so as to be fully visible. The key had a multitude of perforations which bore no particular relation to the wards of the lock, but which were regarded as tests of the workman's skill. The honorary distinctions awarded to apprentices and aspirants in the art, depended very much on the number and fine execution of these perforated keys.

The locks, considered as fastenings, had slender merit; although usually throwing four bolts, they were not very secure. Figure 93 represents the exterior of a lock made about the year 1730, by Bridou, a celebrated Parisian locksmith.

It was a lock belonging to a coffer or strong chest; all the works being sunk below the level of a carved architectural molding or ornament. There is a secret opening near the part c, forming a portion of the ornamental design. It allows a bolt, shown at D, (figure 94) acted on by the spring E, to be touched by which a doorway opens upon the hinges at BB. AA are a sort of pilasters, which aid in forming a hole for the bolts.

The little ornament at c is drawn down by the hand, opening the secret door and revealing the keyhole G. SS, 00, ZZ, are ornaments fastened on at b, c, d, figure 94, by nuts and screws, intended to display the skill of the workman. The lock itself, access to the keyhole of which is obtained within the secret door, has nothing very remarkable about it.

Figure 95 represents a safe door lock-case with a box of wards as generally used for cast-iron and common wrought-iron safes and chests. It is the kind of lock that enables any ordinary thief so readily to open such depositories, not only by a skeleton key, or other pick-lock, but by gunpowder also. The outer circle of metal which encloses the wards of the lock will of itself hold several ounces of gunpowder, and the lock-case or chamber a will hold some pounds.

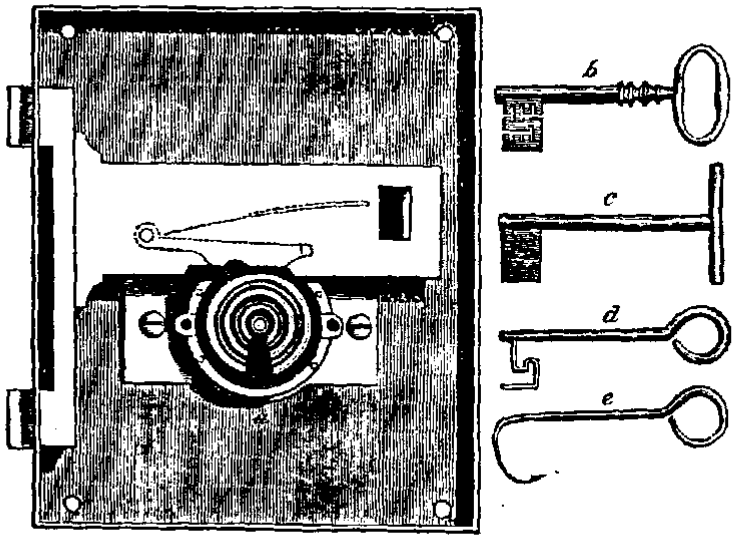


Figure 95 Lock-case, with Box of Wards

The comparative security or chances of opening the warded locks were supposed to depend upon the complexity or simplicity of the form of key required. Consequently, great ingenuity was displayed in arranging and shaping the forms of the wards and the keys corresponding to them.

Such locks can never be secure, because the underlying principle is flawed. The **number of combinations(472)** the lock is capable of, is comparatively so small, so that even in an ordinary dwelling-house, when the key of any particular lock is lost, how often does another on the same ring supply its place equally well.

Although this is so, yet there is millions of pounds worth of convertible property constantly under the care of such a worthless guard. The cuts in the key give it such an appearance of security, that many believe the warded locks to be far more secure than the improved modern locks that have plainer keys.

This is not altogether to be wondered at, when all a purchaser sees of the fastenings of his safe, or other depository, is the **key(473).** The owners of safes, which are secured by such locks, only find out that they are valueless, when they have been robbed of the contents.

The mode of **picking(474)** these locks is as follows: A blank is first made like *c*, (figure 95) generally of tin, the bit of which is smeared over with a composition of bees' wax, oil, and

powdered charcoal.

It is then inserted in the keyhole, and pressed against the wards, and an impression of their shape and position is thereby taken. A skeleton key, or pick-lock *d*, is next formed out of the marked blank, and for every purpose of locking and unlocking, it answers quite as well as the proper key *b*, as it is only necessary to preserve the *end* of the key bit, which comes in contact with, and moves the bolt.

Most of these locks can be picked by an instrument *e*, which is made of steel, and may very properly be called the burglars' skewer. It is passed outside of the outer ward, or wheel, and by a strong grip, will at the same time lift the tumbler and move the bolt. By inclining the door towards the hinges, it is only necessary to lift the tumbler with this instrument; when the bolts will fall down by their own weight and the door is thereby opened. By such assistance it unlocks itself.

Thousands of warded locks are annually made, in which the only security is a single tumbler, so that the only instrument requisite for locking and unlocking, is a skeleton key, like *e*, or just a blank key.

The multiple locks on the foreign coffers belong to this description of lock, and display considerable ingenuity in their construction. We have previously described the general construction of these coffers, and shall here confine our remarks to their locks.

The security consisted doubtless in the number of the bolts, but by far the principal security lay in the size of the key, and the great strength required withdrawing the bolts. In many of the foreign coffers, the lock is covered with a beautifully pierced and chased ornamented plate, as in figure 2, which partially hides the works of the lock.

Figure 96 represents the “strong German coffer” described by Reauniur, who says, ‘Not, withstanding the large size of these locks, and all the apparatus with which they are provided, they correspond but ill with the solidity of the rest of the coffer. If we have given a representation of one, it is chiefly to show how little confidence one could have in such a lock, and what are its defects, in order that we may avoid them."

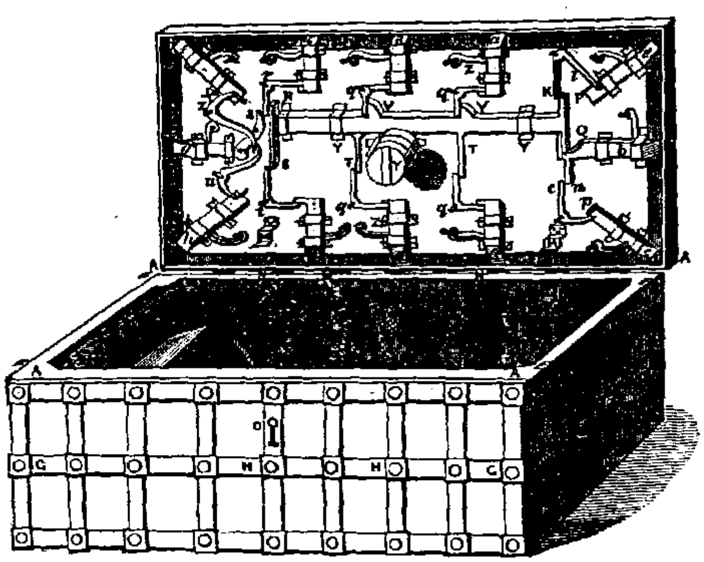


Figure 96. Strong German Coffer

It may be observed that there are, in figure 96, twelve bolts, each of which is connected by a powerful spring, z, to a long bar or lever, which may be properly designated the main bolt. H, f, d, c are the four corner bolts; a d e are the three each at the back and front, and b g one at each end.

There are no staples or bolt-holes in the top of the coffer to receive the bolts, but a projecting inner rim round the top at A A, under which all the bolts shoot. The bolts are usually beveled, so that the coffer locks itself, by closing the lid with a little force.

The keyhole in the front of the chest at D is a **deception(475)** or mask; the real keyhole being in the middle of the lid, concealed by a secret escutcheon, which is secured in its place by a spring. In unlocking, the key moves the main bolt, which simultaneously withdraws the other bolts P, Q, R, S, T, etc., and whilst the key is holding them back, the lid is lifted up and the key taken out. v v are studs which act upon two of the bolts. Y Y are staples confining the main bolt. k, l, c, p, x are small levers which transmit the action to the comer bolts; q, r, s, t, u, are other small levers which render a similar service to the front, back, and end bolts;

L L within the chest are the studs by which the “dogs " m m on the lid assist in securing the back of the chest when locked. As previously remarked, the multiple lock is only the rude lock multiplied by the number of its bolts, which if comprising twenty

can as easily be picked as if it had only one. It is not so much a lock as a series of spring latches, and any instrument sufficiently strong to move the main bolt will easily unlock it.

Besides the key, there is usually an instrument like a turn-screw, which is used for releasing the escutcheon and to put through the bow of the key for a lever. Without the aid of such a lever, the bolts cannot be withdrawn.

These coffers are by no means scarce, as we have frequently met with specimens in various parts of the kingdom, as well as in London, and there are several smaller ones at Marlborough House, in all of which the construction of the multiple lock is the same. There are different opinions as to the country in which these coffers were manufactured; some consider they are from Spain, while others pronounce them to be of German manufacture.

The keys to these multiple locks form a strong contrast to the keys of the locks belonging to similar depositories of modern date. The enormous size of the coffer keys precluded their being carried about the person, except when attached to the girdle. Many of them measure from ten to twelve inches in length.

As before stated, some contrivance is necessary to keep the bolt steadily in the position in which it is left by the key. In locks which depend upon wards for their security, this is usually effected by means of a spring, as illustrated by figure 97, which represents the interior of a small cupboard lock, with the bolt, ab, locked out, and capable of being moved backwards by the action of the key at c in a curved hollow, formed in the lower edge of the bolt.

This hollow or curve is called the "talon." The top of the bolt carries a long elastic piece, formed by nearly separating a stout lamina of metal from the body of the bolt, or as is more frequently done, by fastening a piece of tempered steel into a slot made in the top of the bolt, as shown in figure 97, and giving it an inclination to diverge from the bolt at the end b; and the lower edge of the bolt, behind the curved part acted upon by the key, is indented with two deep notches, *b* and *d*, with a smooth convexity between them.

The opening in the back rim, through which the end *b* of the bolt passes, is so small as to compress the spring with considerable force. If, therefore, the key be so applied as to shoot the bolt forward, the reaction of the spring will cause the notch *b* to

hold firmly on the edge of the rim, from which it cannot be disengaged without raising the bolt, and compressing the spring. This allows the convexity between *b* and *d* to pass over the edge of the rim, after which the notch *d* will hold on the rim in like manner.

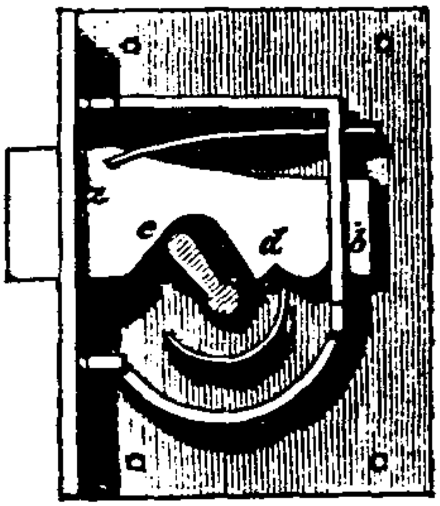


Figure 97. Back-spring Lock

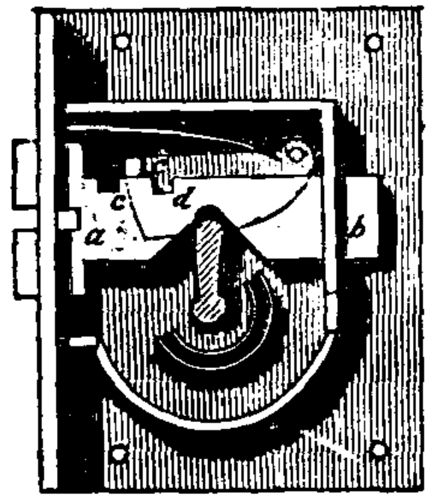


Figure 98. Common Tumbler Lock

The necessary raising of the bolt and compression of the spring is properly effected by the action of the key, but as it may be effected by pressure upon the end of the bolt, the security of locks in which such an arrangement is adopted, which are called back-spring locks, is inferior to that of tumbler locks. This is because of the means of retaining the bolt in its position, as well as from the defects already explained as incident to the use of wards.

We pass naturally from the consideration of the back-spring, as an essential feature in a lock protected by wards alone, to the explanation of one of the simplest modes of applying the second principle of security, that which consists in the use of moveable impediments to the motion of the bolt, and which may be applied, as an additional security, to locks in which the most ingenious arrangements of wards is employed to prevent the access of a false key to the bolt.

Figure 98 represents a lock similar to figure 97, provided with a *common* tumbler. In this figure the bolt *ab,* though shot backwards and forwards in the same manner as that of figure 97, has no spring or notches to catch on the back rim of the lock to

hold it in any required position. It is provided with two notches in its upper edge, at *c* and *d*.

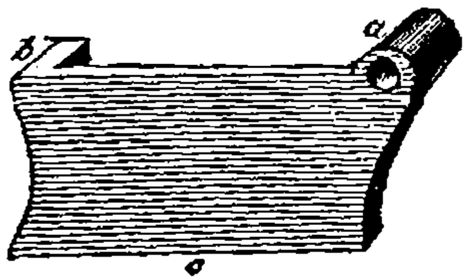


Figure 99 Common Tumbler

Behind the bolt is a piece of metal called the tumbler (figure 99) pivoted to the plate of the lock at F, (figure 98) and continually forced downwards by a spring which presses upon its upper edge. The upper part of the tumbler, which is visible above the bolt, is distinguished in figure 98 by being covered with a light tint, while the shape of the lower part, which is concealed by the bolt, is indicated by dotted lines.

At the angle e (figure 98) the tumbler carries a projecting stud b, (figure 99) which, when the bolt is fully shot, falls into the notch d. This holds it firmly, until, by the application of the key, (the bit of which reaches the lower edge of the tumbler), the tumbler is lifted up to the position shown in figure 98. In this manner, the bolt is released so that the further turning of the key shoots it back when the stud of the tumbler falls into the notch c and again secures the bolt.

It is obvious that so long as the tumbler remains in its proper notch, the bolt cannot be moved backwards or forwards by any pressure upon its ends; and also that the lock cannot be opened by any false key unless its bit be so formed as to reach the tumbler as well as the bolt.

To render this more difficult, the tumbler is often made to fall a little lower than the bolt, so as to be acted upon by a step formed on the bit of the key. Further complication and security may be obtained by the use of two or more tumblers, which may be acted upon by different steps on the key.

The great exactness requisite in the length of the bit forms a strong recommendation of even the commonest tumbler locks; for if the bit be ever so little too short it will not lift the tumbler out of its notch, while if it be but a very little too long, it

will not enter the curved portion of the bolt.

The common tumbler lock, like the back-spring lock, is easily picked, as it is only necessary to lift the tumbler sufficiently high when the bolt is easily set free. An expert mechanic, therefore, finds little difficulty in throwing out the tumbler, and at the same time moving the bolt.

There is nothing on record relative to the date when the tumbler was first invented, neither can we ascertain in what country it was first used. “The invention has been claimed by or for persons subsequently to the year 1767, when the celebrated French treatise (*Art du serrurier*) already referred to was published; and yet this treatise contains numerous examples of simple tumbler locks of ingenious construction, as will presently be shown.”

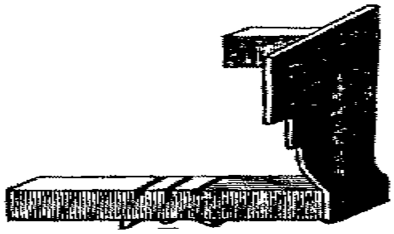
That tumblers were in use in the sixteenth century, in England, is evident from the specimens of that period now in existence. The Elizabethan lock, shown in figure 76, contains a well-constructed tumbler, and also a revolving barrel, the latter a contrivance which is to be found in many of the French locks of a later period. The revolving barrel in combination with the curtain has only recently been adopted.

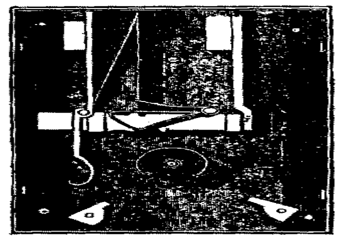
“The great French treatise proves that the locksmiths of France were familiar with tumbler locks a century ago. The plates of that work represent the details of numerous locks, on the upper edge of the bolts of which were notches called *encoches, as* at *o k,* figure 100."

"Into these notches sank a small iron stud or stump called the arret du pene, or bolt stop, shown in figure 101. It was attached to the upper portion of the *guchette* or tumbler, which for the sake of economy of metal is made in the form of a triangular spring in front of the bolt ki."

"Not until the key, by its circular action, had raised this stud out of one or other of the notches, could the bolt move to the right or left. The stud was generally fixed to a spring which forced it down again into the notch as soon as the action

which forced it down again into the notch as soon as the action of the key had ceased."





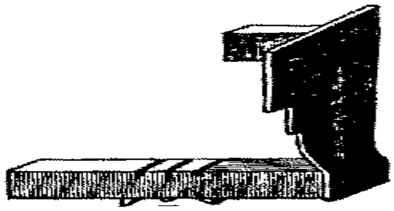


Figure 100. Bolt of old French lock

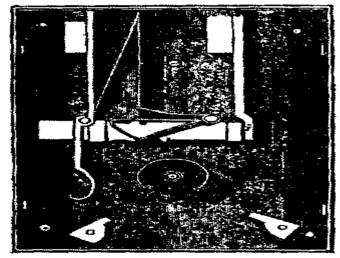


Figure 101. Old French Lock

Sometimes, however, the stud was fixed to the bolt, and the notches were in a separate tumbler or *guchette* (see E E, figure 103). In other instances again, the stump was fixed to the case of the lock and caught into notches in the bolt.

It will be seen, when we come to the treatment of tumbler locks of later date, that there was much in these early locks to point out the way. Figure 101, copied from the French work, represents a lock of the box or casket kind. Two staples, fixed into the cover, fall into two cavities or receptacles at *c d;* and a short bolt in each receptacle catches into each staple, one near *g*, and one near *h*. The small bolt is attached to the upper extremity of the lever *q r s, (*figure 101,) and shown separately in figure 102. By the pressure of a spring *a* (figure 101) upon this lever, the bolt *q* is kept locked in the staple.



Figure 102. Small b old French loc

The vertical portion of this spring presses at its lower end on another spring *P* (figure 102) of singular curvature; and attached to the horizontal part of this second spring is the stud, which falls into a notch in the top of the bolt.

The action of these parts, then, is as follows: when the key is placed upon the key-pin at *z*, and turned round in the direction in which the hands of a watch move, the bit presses against the tail *s* of the lever, moves it upon its center *z* (Figure 101*), v* (figure 102) to the left, and consequently moves the upper part *q* to the right, drawing it out of the receptacle and liberating the staple within *c*.

Thus it will be seen that the lever *q r s,* held in one position by the spring *a*, forms in itself a simple kind of spring

catch-lock, and was, in fact, formerly used as such, without any other appendage except the staple in the lever, into which the catch *q* fitted on shutting down the lid.

So also we may regard the other portion, figure 100, or *k, i, p, h,* (figure 101) as forming a separate lock. The key, after having passed *s*, comes in contact with the triangular spring, which it raises thereby, lifting the stud out of the bolt, and exerting pressure against the barbs of the bolt *n.* Figure 100 shoots the bolt *k,* and also the short bolt *l*, which passes through the staple in the cavity *d,* (figure 101).

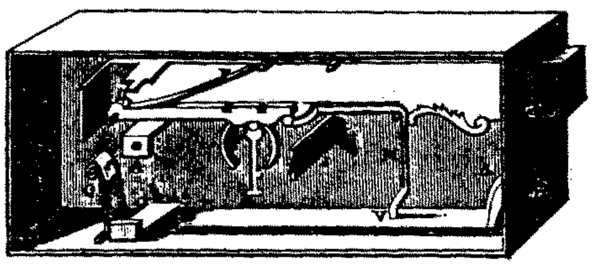


Figure 103. Details of Old French Lock

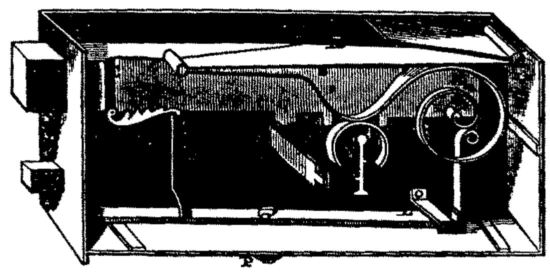
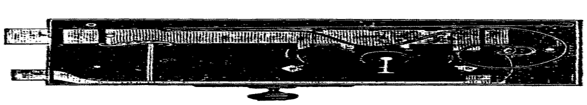
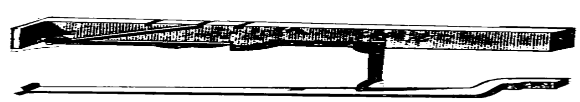


Figure 104. Another view of the same

The lock represented in the four following figures is also from M. de Reaumur's chapter on locks in the work referred to. In this lock the tumbler principle is carried out in a very elaborate manner, for not only is the stump or stud H (figure 105) attached to a very strong spring (best shown at H, figure 104) which holds it with considerable force in one of the three notches of the principal bolt *R S* (figure 106); but there is also a second set of notches *e e* in the *guchette g o* I (figure 103), and a pin attached to one of the plates of the lock fits into one of these notches.

This prevents the bolt from being moved until the *gauchette* is lowered by the revolution of the key; so that in attempting to pick this lock, not only must the spring *H* be raised so as to release the stud from the notches of the great bolt, but the *gauchette* must be lowered to disengage the fixed pin from the notches.





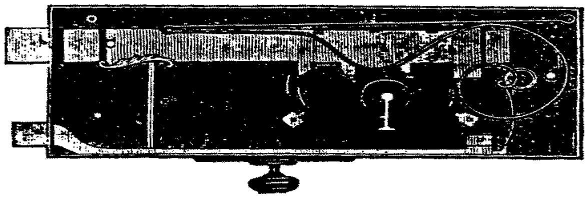


Figure 105. Another view of the same

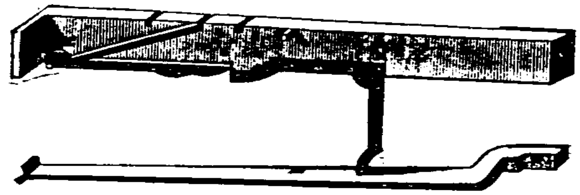


Figure 106. The two bolts detached

There is yet a third source of security. Attached to the large bolt are short projecting pins *F* (figure 103) against which an arm or detent, *G F*, of the *gauchette* projects, thus preventing the bolt from being shot back by any pressure applied to its extremity *S.*

There are a few details relating to this remarkable lock, which may as well be introduced here in order to complete the description. The principal bolt can be shot twice, or be *double-locked*; hence it is furnished with three barbs for the key to act against, and with three notches for the spring-stud.

The lower bolt *I k* can be shot by the horizontal pressure of the button *P* (figures 104-105), which is situated on the inner side of the door to which this lock is attached, so that a person inside the room can secure the door against anyone on the outside who is not furnished with the proper key, for it must be remarked that the small bolt as well as the large one is acted on by the key.

Now supposing the small bolt to be shot or locked, it is kept so by the pressure of the coiled spring *Q* (figures 103-104). But this small bolt is connected with the large one by means of the bent lever *o n m* (figures 103-106) which turns on a pin *N* attached to the main bolt.

Now, when both bolts are either fully shot or unshot, the arm *O N* lies flat against and parallel with the main bolt. When the large bolt is unshot and the small one not moved, the arms *O N, N M,* fall into an inclined position, and the arm *O N* passing a little below the main bolt comes within the range of the web of the key, which in its revolution causes the bent lever to move upon its center *N*, thereby restoring *0 N* to its horizontal position, and at the same time causing the arm *N M* to move from right to left, or in the direction for unshooting the small bolt. The end of this arm thus catches into a mortise *v* (figures 103-106) in the small bolt, and immediately unlocks it.

We have now described the whole of the locks known in England previous to the reign of James the First, and we shall here insert a correct list of all the patents granted for "locks and latches" since that period, to April 1851, and describe those which contain any peculiarity of construction, or any contrivance of sufficient merit to interest our readers.

List of Patents granted for Locks and Latches, from the time of James the First, until April 4, 1851, compiled from an "Alphabetical Index of Patentees and Applicants for Patents of Invention," published by order of the Honorable Commissioners of Patents, under the Act of 15 and 16 Vict., cap. 80, sec. 32.

Chronological Master Patent Index 1774-1851, England

No. of Pat.	Year	Date	Name of Patentee
1071	**1774**	**May 27**	**Black, George.**
1192	**1778**	**May 19**	**Martin, Joshua Lover.**
1200	**1778**	**Oct.31**	**Barron, Robert**
1226	**1779**	**May 28**	**Henry, Solomon**
1430	**1784**	**April 23**	**Bramah, Joseph**
1636	**1788**	**Jan. 15**	**Angell, James**
1692	**1789**	**July 7**	**Cornthwaite, Thomas**
1730	**1790**	**Feb. 23**	**Rowntree, Thomas**
1778	**1790**	**Oct. 29**	**Bird, Moses.**
1819	**1791**	**July 10**	**Ferryman, Robert**
1835	**1791**	**Nov. 3**	**Antes, John.**
2062	**1795**	**Aug. 28**	**Spears, James.**
***2203**	**1707**	**Nov. 18**	**Langton, Daniel.**
2232	**1798**	**May 3**	**Bramah, Joseph.**
2277	**1798**	**Dec. 8**	**Turner, Thomas (London.)**
2306	**1799**	**April 11**	**Davis, George.**
2521	**1801**	**June 21**	**Holemburg, Samuel.**
2851	**1805**	**May 18**	**Stansbury, Abraham Ogier 3188**
1808	**1808**	**Dec. 29**	**Tompson, William.**
3676	**1813**	**March 30**	**Egg, Joseph.**
3891	**1815**	**March 7**	**Mitchell, Wm. and Lawton, John.**
4027	**1816**	**May 14**	**Rumton, Thomas.**
4036	**1816**	**May 27**	**Kemp, Robert.**
4096	**1817**	**Feb. 1**	**Higginson,George Montague.**
***4101**	**1817**	**Feb. 8**	**Clark, William.**
4219	**1818**	**Feb. 3**	**Chubb, Jeremiah.**
4275	**1818**	**June 30**	**Roux, Albert.**
4402	**1819**	**Oct. 18**	**Strutt, Anthony Radford.**

4443 1820 April 11 Jennings,Henry Constantine.
4519 1820 Dec. 14 MaDett, William.
4812 1823 July 10 Fairbanks, Stephen.
4862 1823 Nov. 13 Ward, John.
4972 1821 June 15 Chubb, Charles.
5171 1825 May 14 Young, John.
5656 1828 May 17 Chubb, Charles.
5798 1829 June 1 Gottlieb, Andrew.
5880 1830 Jan. 10 Carpenter, James AND Young, John.
5886 1830 Jan. 20 Arnold, John.
6105 1831 April 14 Rutherford, William.
6116 1831 May 23 Barnard, George.
6143 1831 July 27 Young, John.
6350 1832 Dec. 20 Parsons, Thomas.
6516 1833 Dec. 3 Parsons, Thomas.
6527 1833 Dec. 20 Chubb, Charles, AND Hunter, Ebenezer.
***6532 1833 Dec. 20 Pierson, Josiah Gilbert.**
6674 1834 Sept. 6 Longfield, William.
***6694 1831 Oct. 11 Audley, Lord Baron.**
6792 1835 March 18 Hill, Richard.
6960 1835 Dec. 16 Warrick, John.
7000 1836 Feb. 10 Fenton, Samuel.
7715 1838 June 30 Uzielli, Matthew.
7872 1838 Nov. 13 Thompson, Sally.
7972 1839 Feb. 21 Uzielli, Matthew.
8106 1839 June 12 Sanders, Joseph.
8140 1839 July 3 Cochrane, Alexander.
8163 1839 July 20 Schwieso, John Charles.
8181 1839 August 1 Williams, William Morrett.
8293 1839 Dec. 2 Guest, James, jun.
8402 184O March 20 Williams,William Morrett.
8440 1840 Feb. 27 Gerisli, Francis William.
8489 1840 May 2 Peirce, William.
8543 1840 Junel3 Wolverson, Joseph, AND Rawlett, William.
8747 1840 Dec. 23 Baillie, Benjamin.
8903 1841 March 29 Tildesley, James, AND Sanders, Joseph.
8953 1841 May 6 Hancock, James.
9029 1841 July 14 Berry, Miles.
9104 1841 Sep.28 Strong,Theodore Frederick.
9144 1841 Nov. 9 Smith, Jesse.

9224	1842	Jan. 15	Poole, Moses.
9364	1842	May 24	Duce, Joseph,jun.
9395	1842	June 13	Williams, William Morrett.
*9497	1842	Oct. 20	Statham, James.
9578	1842	Dec. 29	Rock, Joseph, jun.
*9879	1843	Sept. 6	Thomas, William.
9963	1843	Nov. 25	Tann, Edward, Tann, Edward, jun. AND Tann, John.
9965	1843	Nov. 25	Rock, Joseph, jun.
10,032	1844	July 30	Fletcher, William.
10,182	1844	July 14	Pitt, Benjamin.
10,611	1845	April 15	Carter, George.
10,978	1845	Dec.4	Poole, Moses.
11,015	1845	Dec. 22	Smith, Philip.
11,152	1846	March 25	Cotterill, Edwin.
11,283	1846	July 6	De la Fons, John Palmer.
*11,299	1846	July 15	Thomas, William.
11,491	1846	Dec. 14	Chubb, John.
11,523	1847	Jan. 11	Chubb, John, AND Hunter, Ebenezer, sen.
11,659	1847	April 15	Collett, Charles11,
11,869	1847	Sep. 16	Hancock, William
12,274	1848	Sep. 28	Newell, Robert Stirling.
12,604	1849	May 8	Wilkes, Samuel.
13,184	1850	July 22	Bradford, James.
13,595	1851	April 15	Newell, Robert (America).

Master Patent Index, 1774-1851, by Inventor

Inventor	Patent	Date
Angell, James	1636	1788
Antes, John	1835	1791
Arnold, John	5886	1830
Audley, Lord Baron	*6694	1831
Baillie, Benjamin	8747	1840
Tildesley, James	8903	1841
Barnard, George	6116	1831
Barron, Robert	1200	1778
Berry, Miles	9029	1841
Bird, Moses	1778	1790
Black, George	1071	774
Bradford, James	13,184	1850

Bramah, Joseph	**1430**	**1784**
Bramah, Joseph	**2232**	**1798**
Carpenter, James	**5880**	**1830**
Carter, George	**10,611**	**1845**
Chubb, Charles	**4972**	**1821**
Chubb, Charles	**5656**	**1828**
Chubb, Charles	**6527**	**1833**
Chubb, Jeremiah	**4219**	**1818**
Chubb, John	**11,491**	**1846**
Chubb, John	**11,523**	**1847**
Clark, William	***4101**	**1817**
Cochrane, Alexander	**8140**	**1839**
Collett, Charles	**11,659**	**1847**
Cornthwaite, Thomas	**1692**	**1789**
Cotterill, Edwin	**11,152**	**1846**
Davis, George	**2306**	**1799**
De la Fons, John	**11,283**	**1846**
Duce, Joseph	**9364**	**1842**
Egg, Joseph	**3676**	**1813**
Fairbanks, Stephen	**4812**	**1823**
Fenton, Samuel	**7000**	**1836**
Ferryman, Robert	**1819**	**1791**
Fletcher, William	**10,032**	**1844**
Gerisli, Francis	**8440**	**1840**
Gottlieb, Andrew	**5798**	**1829**
Guest, James	**8293**	**1839**
Hancock, James	**8953**	**1841**
Hancock, William	**11,869**	**1847**
Henry, Solomon	**1226**	**1779**
Higginson, George	**4096**	**1817**
Hill, Richard	**6792**	**1835**
Holemburg, Samuel	**2521**	**1801**
Hunter, Ebenezer	**11,523**	**1847**
Hunter, Ebenezer	**6527**	**1833**
Jennings, Henry	**4443**	**1820**
Kemp, Robert	**4036**	**1816**
Langton, Daniel	***2203**	**1707**
Lawton, John	**3891**	**1815**
Longfield, William	**6674**	**1834**
MaDett, William	**4519**	**1820**
Martin, Joshua	**1192**	**1778**
Mitchell, Wm.	**3891**	**1815**
Newell, Robert	**12,274**	**1848**
Newell, Robert (U.S.)	**13,595**	**1851**

Parsons, Thomas	6350	1832
Parsons, Thomas	6516	1833
Peirce, William	8489	1840
Pierson, Josiah Gilbert	*6532	1833
Pitt, Benjamin	10,182	1844
Poole, Moses	9224	1842
Poole, Moses	10,978	1845
Rawlett, William	8543	1840
Rock, Joseph	9578	1842
Rock, Joseph	9965	1843
Roux, Albert	4275	1818
Rowntree, Thomas	1730	1790
Rumton, Thomas.	4027	1816
Rutherford, William	6105	1831
Sanders, Joseph	8106	1839
Sanders, Joseph	8903	1841
Schwieso, John	8163	1839
Smith, Jesse	9144	1841
Smith, Philip	11,015	1845
Spears, James	2062	1795
Stansbury, Abraham	2851	1805
Statham, James	*9497	1842
Strong, Theodore	9104	1841
Strutt, Anthony	4402	1819
Tann, Edward	9963	1843
Tann, Edward	*9879	1843
Tann, John	9963	1843
Thomas, William	*11,299	1846
Thomas, William	*9879	1843
Thompson, Sally	7872	1838
Tompson, William	3188	1808
Turner, Thomas (London)	2277	1798
Uzielli, Matthew	7715	1838
Uzielli, Matthew	7972	1839
Ward, John	4862	1823
Warrick, John	6960	1835
Wilkes, Samuel	12,604	1849
Williams, William	8181	1839
Williams, William	8402	1840
Williams, William	9395	1842
Wolverson, Joseph	8543	1840
Young, John	5171	1825
Young, John	5880	1830
Young, John	6143	1831

***Those marked thus are not for improvements in the construction of locks or latches, but for contrivances in some way connected with them, and for fastenings for doors, windows, shutters, etc.**

The following lock was invented previous to May 1851, though not patented until 1852. It was exhibited at the Great Exhibition of 1851, and consequently it will be described in this chapter.

Besides those named in the preceding list, there are many other locks which are *called* "patent" whereas no patent has ever been taken out for any of them, and we understand it as a very common circumstance for applications to be made at the office of the Commissioners of Patents for information relative to "patents" which never existed.

The following list comprises all the other locks we have heard of, the improvements in which were not *patented*. Many of these will be described as we proceed.

Locks that have not been Patented by Claim to have received a Patent

Ainger's	**Mason's**
Andrews, Dr. (America)	**Mackinnon's**
Arkwright's	**Meighan's**
Aubins, 6 locks	**Mordan's**
Benton's	**Moore's**
Bickerton's	**Nettlefold's**
Brierley's	**Norton's**
Brookes'	**Odell's**
Bryden and Son's	**Parke's**
Burton's	**Peer's**
Bullock's	**Perry's**
Chesterman's	**Picken's**
Cope's	**Prices'**
Danielle's	**Robert's**
Davis's	**Scott's**
Downs'	**Smith's**
Duce's (senior)	**Somerford's**
Duce's (junior) 3 locks	**Spicer's**
Eagle's	**Stanley's**
Edwardes'	**Steele's**
Foster's	**Strong's**
Friend's	**Stuart's**

Having arrived at that portion of our work when plainness of diction and perspicuity of description becomes absolutely necessary for a correct appreciation of the various patented and other locks, and the differences in their construction and their comparative merits, we think it will conduce to an easier understanding of the subject, to first explain and illustrate the several principal parts of which most locks are composed.

Definitions and Component Identification

The "back-plate" is that into which the "drill-pin" which receives the key, and other portions of the works of the lock are riveted.

The "cap" is that part which covers the internal mechanism of the lock. It is usually fastened to the back-plate by two screws. The cap used to be made of iron, hammered and bent to the required size, shape, and riveted to the back-plate. The caps of the very commonest locks of the present day are made and fitted in the latter way.

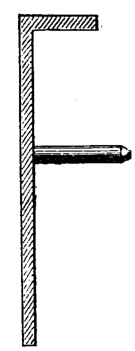
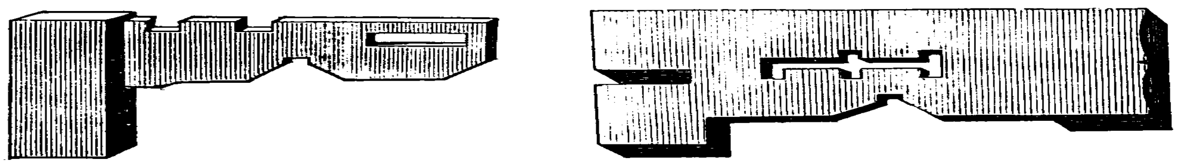


Figure 107. Bac

The **talon** of the bolt, **b**, (figure 109), is that part by which it is moved backwards or forwards by the end of the key-bit being forced against it.

A *common* tumbler bolt has the "racks" or "notches" in its top

A *common* tumbler bolt has the “racks” or “notches” in its top edge, as shown in figure 108.



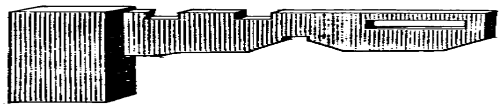


Figure 108. Common Tumbler Bolt

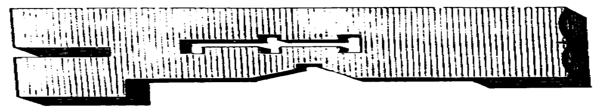


Figure 109. Bolt to a Barron's Lock. a, The gating. b, The talon

The bolt of a Barron's lock has the "gating" in the position shown in figure 109.

The term "double-acting" means that the slot in the bolt or lever has "notches" or "racks" at the top and bottom of each opening, as shown in figures 109 and 111.

The "gating" in the **bolt** is the slot or narrow passage through which the stud or stump of the tumbler moves. The "gating" in the **levers** is the slot or narrow passage through which the stump of the bolt moves. The bolt with the gating belongs particularly to all the locks known as Barron's, and the bolt with the stump to those known as Chubb's or other lever locks.

The "stump" of the bolt is that stud which projects at right angles from the face of the bolt, and which passes in and out of the "slots" through the gating in the levers, or combinations, or other moveable obstructions contained in the lock.

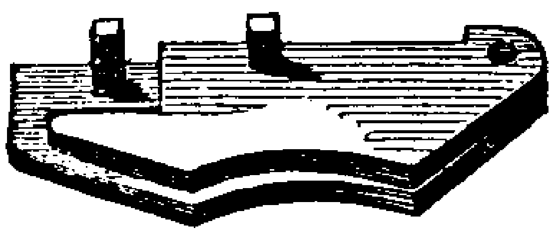


Figure 110. Pair of Barron's Tumblers. A, The Front Tumbler. B, The back Tumbler.

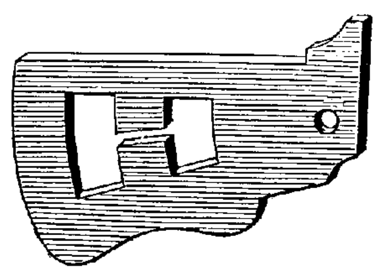


Figure 111. A lever as used for most locks of that kind

Figure 110 represents a pair of Barron's tumblers, the stumps of which move in and out of the slots through the gating in the bolt *a* (figure 109)

All the writers on locks up to the present time have used the terms tumbler and lever synonymously, but as there is a difference between the two, as shown in figures 110-111, we shall, throughout the work, observe the distinction. This distinction is strictly attended to in every workshop in the

district, for as a master locksmith remarked to us when discussing this pint, if he were to send one of his men for a tumbler, he would certainly bring him a *Barron's tumbler;* and if he asked him for a lever, he would give him one *similar to Chubb's.*

We have often heard the word tumbler used to express the different locks having moveable impediments to the passage of the bolt, and in this sense only is it admissible. Unless the distinction is strictly observed between the tumbler and the lever, confusion of ideas must be the result.

BLACK'S LOCK, Patent dated May 27, 1774.

The first patent granted for "locks and latches" was to George Black, May 27, 1774, for "a latch or lock so made as to raise the door over the carpet, and so made as to admit air into the room without opening the door."

Although there is nothing in the construction of Black's lock to add to the security of those which were then in use, yet as it is the first patent in connection with this subject, and as a curiosity, we should have printed the specification at length could we have procured a copy of it in time.

It has been thought by many that Black invented the "double-acting " tumbler, which, they say, Barron improved and patented in 1778, but there is nothing, whatever to support such a supposition.

BARRON's LOCK, Patent dated October 31, 1778.

As shown in the list of patents, it was in the year 1778 that the first great improvement in the art of making locks secure, took place. Mr. Barron, who had directed his attention to what is called the "tumbler " principle, added it to the warded lock.

In his specification, he claims "the gating or racking to allow a stump on the tumbler to pass through the bolt, or an opening in the tumbler to allow a stump on the bolt to pass through." This clearly proves that the invention of the modern, "lever," as well as double-acting tumbler," belongs to Barron.

Besides the above, he employed two or more tumblers, of the construction shown in figure 110, which, although similar to the *common* tumbler before described, are so arranged that they must

be operated upon at different times or altogether, and be moved so as to take the “stumps” completely out of their notches, and release the bolt, so that it can be moved backwards or forwards by the step of the key which acts upon it.

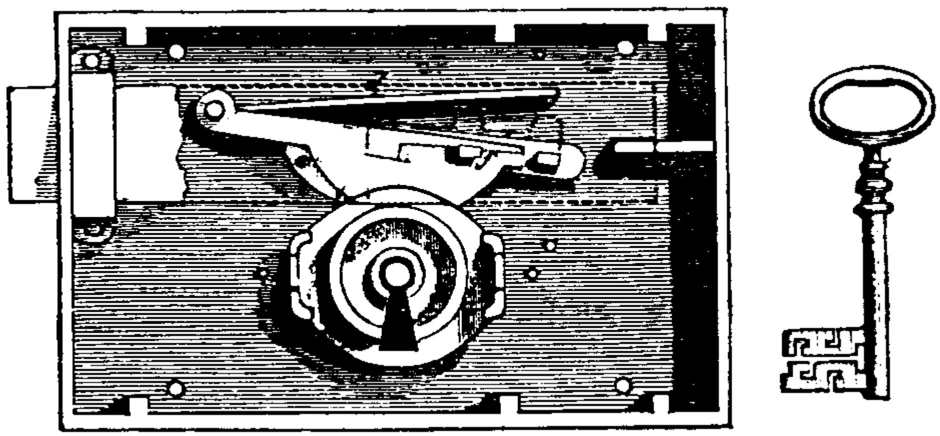


Figure 112. Barron’s Lock

Figure 112 represents Barron’s lock with wards and tumblers: *a* is the bolt; *b* and *c* are the two tumblers which are kept in their position by the spring *d*. The studs or stumps, *e f,* which project from the tumblers, retain the bolt in its locked position.

It is only with its own key *g*, which is cut in “steps" of different lengths to correspond with the varying lifts of the tumblers, that the latter can be raised to the exact height to bring the studs or stumps into a line with the slot in the bolt through which they pass, and thus allow the top step of the key to act on the talon *h*, and unlock it.

In the common tumbler locks, as stated before, it was only necessary to raise the tumbler sufficiently high to open the lock, it could not be raised too high. But in Barron's, there is a limit, for if the tumbler be raised either too low or too high, they either remain in the lower notches or get into the upper notches, and in either case prevent the moving of the bolt.

The tumblers, whether two or more, must be lifted exactly to the same height, at precisely the same time, and in a line with the slot in the bolt. The steps of the key are made to fit the inequalities in the width of the tumblers, so that all shall be raised to the required position at the same instant. Though the

upper and lower notches are applicable to a single tumbler, yet Barron, by using two, considerably increased the amount of security in his locks.

This lock, therefore, contains two important improvements on the common tumbler lock, viz., the double action of the tumblers in the bolt, and using two instead of one tumbler. Although this lock is constructed on precisely the same principle as the Egyptian, it is far superior, as the over-lift of the tumblers is a most important improvement and adds considerably to the security of the lock.

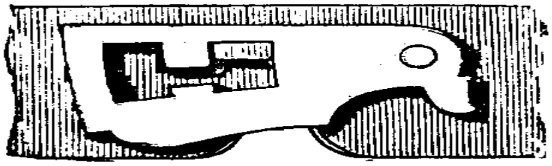
In the simple form of the tumbler represented in figure 99, there is the disadvantage, that, while it effectively prevents the removal of the bolt unless the tumbler be raised high enough, it presents no obstacle to its removal when, by the use of a false key, the tumbler is thrown up beyond the proper degree.

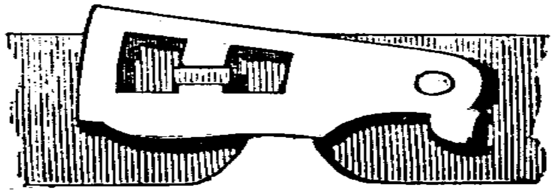
This defect is remedied in Barron's lock and in many more recent contrivances which are based upon it, by the use of from four to twelve *levers,* each of which requires to be raised to a different degree, and any one of which, if lifted too high, will form as effectual a barrier to the motion of the bolt as if it were not lifted at all.

To illustrate this, let *a* (figure 113) represent a lever pivoted at *b*, pressed downwards by the action of a spring, (not shown), at *c*. Underneath, or behind the lever, lies the bolt, a part of which only is shown, where it is distinguished by a dark tint, and at *d*, an opening, the gating and racking, somewhat resembling the letter H, in shape is cut through the lever, to allow a prominent square pin or stud, the stump, which is attached to the bolt, and is shown in the cut by a light tint, to pass through it.

It is obvious that the bolt, secured by such a lever, can only be shot when the lever is raised precisely to such a degree as to bring the horizontal portion of the H-shaped aperture opposite to the stud, so that the stud, which fits it accurately, may slip through it. Figure 114 shows the lever raised to this position, and the bolt half shot. When fully shot, the lever again falls; the stud is secured in that division or notch of the **H-shaped(476)** aperture which lies nearest the end of the lever.

H-shaped(476) aperture which lies nearest the end of the lever.





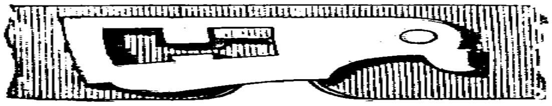


Figure 113. A Lever.

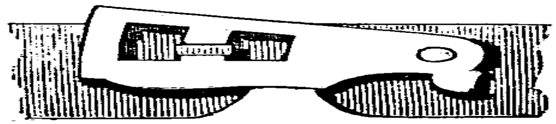


Figure 114. A Lever

An equal security is afforded against any attempt to return it to its first position by any key that does not lift it precisely to the proper height. Many such levers may be placed in one lock, the whole being mounted upon one pivot; and if the horizontal connection portion of the H-shaped aperture be placed at a different elevation in each, each will require to be raised to a different degree to allow the stump of the bolt to pass.

These different degrees of motion are provided for by variations in the curved portion of the lower edge or bellies of the levers, *e*, (figures 111-113) against which the bit of the key acts, and by dividing the end of the bit into a series of steps and notches, each acting upon a single lever. Figure 115 represents the bit of such a key adapted for a lock with either three tumblers or three levers. As may be seen from the cut, the lock to which this key is adapted is guarded by two wards of different forms, and the end of the bit is divided into four portions, of various degrees of projection, of which that marked *a* is employed for moving the bolt, while *b c* and *d* act upon the three tumblers or levers.



Figure 115. Barron's Key

In the event of such a key being lost to a lock with levers, or it being suspected that an impression of it had fallen into wrong hands, the levers of the lock might be taken out and returned on to their common axis in a new order, so as to require a key in which the members *b c* and *d* would stand in a different relation to each other, by which means the old key would be rendered utterly useless.

Barron’s Lock, when well made with three to six tumblers, and a well-constructed series of wards, is extremely difficult to **pick(477)**; for the wards, as previously shown, though useless as preventives to the operation of lifting up a single common tumbler, greatly impede so delicate a proceeding as the elevation of three or more to the precise height required for the passage of the stumps through the grating in the bolt.

A strong recommendation in its favor is its simplicity, and the strength of the various “limbs” which form the internal mechanism. There is also nothing in the construction of a Barron’s lock to render it very liable to get out of order.

The only successful method of picking the tumbler and lever locks is by applying pressure to the bolt through the Keyhole. We shall defer saying more relative thereto, until we discuss this part of the subject in the chapters on the Lock Controversy.

PRICE’S LOCK, invented about 1778.

About the year 1778 a lock was invented by Price, and was the first lock ever constructed with *four double-acting levers.* This lock bears a very close resemblance to those of more recent introduction. We have been furnished with a sketch of one of these locks, which was until lately in the possession of Mr. Aubin, of Wolverhampton, and which has been traced back to the above period.

The peculiarity of this lock was that it locked without the key by pressing a stud or knob, which released a common tumbler in the main bolt; the four levers had plain gatings. The bolt was driven forward, or locked out, by a powerful spring and “follow” resting against the bolt-head. To unlock it, the key was used in the ordinary way.

It may be well to remark here that all the modern spring or self-acting locks are constructed precisely on the same principle as that exhibited in this lock, except, that in the modern locks, the driving spring is placed against the bolt tail instead of the bolt head.

BRAMAH'S LOCK

No lock has been more generally used, the mechanism of which is less understood, than that produced by Bramah. It has continued

to have a most extensive sale from the period of its invention to the present time, and thus we must beg to be excused for giving at such length the following description and particulars relating thereto.

However great the number of new locks which may be introduced, none will interfere much with the almost universal employment of the Bramah lock, from the circumstance of its construction being so peculiarly adapted for all cabinet purpose, and the key of it being so conveniently small.

The majority of locks that are now or ever will be in use, are not required to be secure against the accomplished scientific thief, but only against the prying curiosity of children, servants, and employees. They must protect against petty fraud, and the designs of ordinary thieves; therefore, such locks as Bramah's or Barron's, well made, and there are now a great variety, will always command an extensive sale.

When locks are required to secure property of considerable value, as in banks, the fastenings to the depository should be as perfect and inviolable as possible, as the anticipated booty being so valuable tend to stimulates the ingenuity and enterprise of the highest class of burglars in devising complete and effective measures to accomplish the robbery.

A lock possessing perfect security with simplicity of construction, and which could be sold at a moderate price, is the article which all inventors, since the time of Barron, have been trying to fabricate. Almost every patentee, in his specification, states that he has accomplished this great and important desideratum.

It will be seen, as we proceed, that nearly every inventor, instead of simplifying that which had gone before, has complicated the construction without giving additional security. In the language of the workshop, he has added more "limbs" to the machine without increasing its security or utility, and it will most likely surprise many of our readers to find in the great number of locks that have been introduced, how few there are that can be called original, and how many there are that are "new" only in respect to the altered form or position of the several parts or "limbs" they contain.

We shall not forget the motto "Honour to whom honour is due," and it will be our object to point out to the general reader those

locks in which this copying or repetition exists. It is a fact which will be corroborated by a little inquiry and observation, that in the majority of inventions the so-called improvements are only complications.

The object of all improvements should be to simplify that which has preceded it; in other words, to construct a machine, say a lock, to be composed of only five pieces, which shall offer all the security, strength, and durability of others which comprise ten pieces.

Man's inventive powers seem to be like a lawyer's in a bad cause where there is plenty of money; the object being to complicate rather than simplify it. It would appear that our lawmakers also frequently act upon the same principle.

How different are all the contrivances of Nature, how beautifully simple are all the constructions of her machines. We do not see in her "handiwork" two "limbs" performing that which is better effected by one; and it is a fact that wherever an inventor has taken Nature for his guide, he has triumphantly succeeded in his design, as for instance, the "toggle," or knee-joint, etc.

Although Bramah's lock is constructed on the principle of the Egyptian, it will be seen that the mode of application is, however, very different. It is a compound of both end way pushing and revolving motion, which is also different from the simple rotary movement of Barron's lock.

We here insert, at length, the specification of the patent, published in the *Repertory of Arts*, for 1796.

BRAMAH'S PATENT SPECIFICATIONS, dated April 3rd, 1784

The principle of all locks hitherto known, or in public use, is too well understood to require any particular description here; yet it may not be improper to observe on what ideas their security was always founded, and likewise how far such principle may tend to render them perfect or effectual; by which may be obtained some comparative information necessary to show or explain the advantages and superior utility of this my said invention. The means hitherto adopted for the security of all locks are the inserting or fixing, between the keyhole and the bolt, a greater or a less number of wheels or wards.

Wheels or wards may be crossed or interwoven, in such a manner as

to render the communication between the keyhole and the bolt as irregular and crooked as possible, in order to prevent the said bolt from being moved by any counterfeit application when the key is absent. The bit of which said key is so cut or shaped as to form a complete tally with the said wheels and wards, and is thereby capable of producing the required effect, when applied for the purpose of moving the bolt.

Now the insufficiency of this method of rendering locks a perfect security is as follows, viz., notwithstanding the said wheels and wards may be variously placed and disposed, yet they cannot by any means become sufficient to answer the intended purpose, owing to their being always left fixed in the lock.

Their form and disposition can be easily obtained by impression; so that notwithstanding they may prevent the use or effect of pick-locks, yet the making a perfect or skeleton key is always extremely practicable.

And further, the **variations(478)** capable of being made in the disposition of the said wheels or wards, and the form of the key's bit, are not sufficient to produce the required number of locks, without having great quantities exactly alike, and their keys capable of opening each other reciprocally; from which they become a very imperfect security, as any ill-disposed person may, by furnishing himself with a number of old keys, be enabled to open almost all the common locks in the Kingdom, with as little difficulty as if he had in his possession the key belonging to each lock.

To remedy these objections, by discovering some principle or method whereby the success of pick-locks, false-keys, and all other counterfeit means of opening locks may be infallibly prevented, and has been the ultimate design of my said invention.

Such may be effected in manner following, vis.; instead of introducing (for the security of the bolt and other moveable parts of the lock) a number of wards and wheels, I have found out and invented much more simple and effectual means of rendering the said bolt and other parts entirely immovable, without the absolute application of the real key.

By those said means, the effects of pick-locks, the practicability of obtaining the form of the key, and the having a number of the said keys alike, are entirely avoided by having a greater or less number of moveable parts, such as levers,

sliders, etc.

These are adapted and placed in the lock, so as to require each of them a separate and distinct change in their situation and position, before the bolt, and other parts of the lock on which its safety depends, can be set at liberty or moved.

These said levers, sliders, or other movables, by the assistance of an elastic, gravitating, or other power, have the property of maintaining, or restoring, their given position or situation, after it may have been destroyed by any forcible application for that purpose.

From this said property, the said levers, sliders, or other movables, are rendered capable of receiving (as it were) any impression or required change in their position or situation, correspondent to the cause which produces such said change, and are also thereby always restored to their former state, or resting situation, when the said cause is withdrawn.

So that the opening these, my said invented locks, is as difficult as it would be to determine what kind of impression had been made in any fluid, when the cause of such said impression was wholly unknown; or to determine the separate magnitudes of any given number of unequal substances, without being permitted to see them; or to counterfeit the tally of a banker’s cheque, without having either part in possession.

The form of these said levers, sliders, or other movables, and also the manner of fixing them in the lock, may be varied without end, without altering or losing any of the intended properties or advantages, as the principal merits and efficacy of my said invention in no way depends thereon.

Rather, it entirely depends upon the said levers, sliders, and other moveable parts being so fixed or disposed as to prevent the bolt, or other parts of the lock on which its safety depends, from being moved, without the said levers, sliders, or other movables first receiving each of them a separate and distinct change in their position or situation, by a key or other contrivance for that purpose.

Such must be pushed or pressed in a progressive direction, without revolution, against some part of each of the said levers, sliders, etc., that occasions them to change their positions, in manner exactly correspondent to the part of the key so applied.

And the said part, being formed with a number of irregular surfaces, equal to the number of levers, sliders, etc., against which it is pushed or pressed, causes them to move at different times, and to different distances from their original situation.

And the said key, by having a stop, or some mark whereby to limit or determine the length of its push against the said levers, sliders, etc., puts a period to each of their motions, notwithstanding they are at liberty to move farther, but are prevented by the resistance of a spring, gravity, or other poser, always endeavoring to restore them to their original situation.

So that the motion of each lever, etc., separately, depends on the height or depth of that surface of the key against which it falls. So that perfect tally is formed, similar to any impression made in a soft body by the forcible application of any harder one. Said hard body represents the essential part of the key, and may be of any determinate shape, formed by rule or by accident; and the moving the bolt or other parts of the lock whereby it may be opened, entirely depends on the positive motion of the said levers, sliders, etc., as any one of them would, by being pushed the least degree too much or too little, entirely prevent the bolt, etc., from being moved or set at liberty.

And, as the whole of the said levers, sliders, etc. are restored to their resting situation when the key is withdrawn, by the properties or powers above-mentioned, the said tally or impression is then totally destroyed, and consequently the opening of the lock is then left wholly dependent on chance, whilst the said key is absent, as there is no rule whatever, nor imagination founded on certainty, that may in the least degree tend to assist in discovering the required position or situation of each or any of the said levers, sliders, or other movables whereby the form of the key, or the part of the said key necessary to the opening of the lock, might be ascertained.

Now, admitting that no lock on this said principle can be picked, or the form of the key obtained, their farther security then depends on the number of different keys that may be made without having any two of them alike, which number I trust will appear indeterminate from the following demonstration.

Let us suppose the **number of levers(479)**, sliders, or other movables by which the lock is kept shut, to consist of twelve, all of which must receive a different and distinct change in their position or situation by the application of the key, and

each of them likewise capable of receiving more or less than its due, either of which would be sufficient to prevent the intended effect.

It remains, therefore, to estimate the number of differs which may thus be attempted, viz., let the denominations of those levers, etc., be represented by twelve arithmetical progressions, we find that the ultimate number of changes that may be made in their place or situation is 479,001,600, and by adding one more to that number of levers, etc., they would then be capable of receiving a number of changes equal to 6,227,020,800, and so on progressively, by the addition of others in like manner, to infinity.

From this it appears that one lock, consisting of thirteen of the said levers, sliders, or together moveable parts, may (by changing their places only, without any difference in motion or size) be made to require the said immense number of keys, by which said lock could only be opened under all its variations.

Wherefore it likewise appears that the said number of locks may be made, consisting of the same parts, without the smallest difference whatsoever, and, by varying the places of such said parts, would require each of them a separate key, and not one out of the whole number above-mentioned be capable of opening any lock, except that particular lock to which it belongs.

Now it must be observed, that the number of different locks, above stated, is produced by thirteen movables, (to wit,) levers, sliders, etc., which having all a distinct difference in their required motions, determines their denominations or names, without any relation being had to the separate value or positive motion of each, which said motion may be given at discretion, so that it plainly appears that the number producible from a like number of levers, etc., is far from terminating here, as their motions, and the difference in proportion one to another, may be varied without end, and are to be added to the former.

It is therefore very obvious from this demonstration, that a much less number of the said levers, sliders, or other movables, will be found sufficient to produce any required number of the said locks, without having any of their keys to pass each other. These said levers, sliders, or other movables above-mentioned, may be adapted and applied to all sorts of discretionary fastening whatever, such as bolts, bars, turnbuckles, etc. The figures or drawings hereunder written, or hereunto annexed,

together with the demonstration or description therewith given, will more fully show the true nature and intent of this my said invention.

“Before I refer to the drawings, I think it proper to observe, that the art of constructing locks wholly depends on some method or means, so adapted or contrived as to be rendered capable of admitting or preventing, at discretion, the motion of some fastening, such as bolt, bar, or other moveable part, which may be made of iron, brass, wood, or other materials sufficient for the purpose."

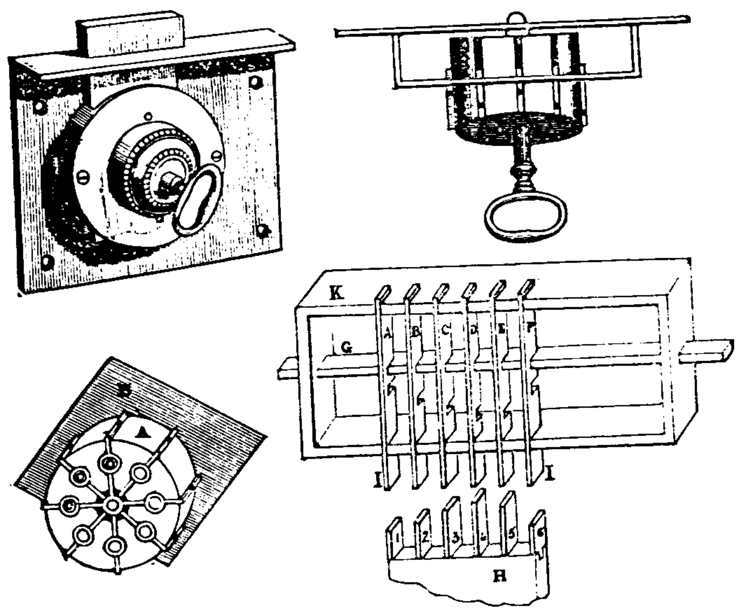


Figure 116. Bramah's Lock

Figure 116 represents the exterior of a Bramah until lock, with three diagrams to illustrate the principle of the sliders. *G* represents a sliding bar, or bolt, in the frame *X*, that contains within the cut in its edge six notches of any proper depth.

In these notches are placed six sliders, or small bars, *A B C D E F*, that are sunk into the bottom of each notch, so that the motion of the bar or bolt *G* is thereby totally prevented until these sliders are moved some way or other to give it liberty. This must be done from their ends at *I I*, as no other part of them is meant to be exposed for the purpose of moving them; which ends at *I I* always have an equal projection when the bar *G* is set fast.

Now we will suppose each of these sliders capable of being pushed upwards towards *A B*, etc. to any determined distance, and when each of them has exactly received its due motion, the bar *G* is set at liberty, so as to slide backwards and forwards as required.

Now in order to determine the separate and distinct motion that shall be given to each, we will suppose the part *H* to be made; which part serves to represent a key, and the ends *1 2 3 4 5 6* are cut of different lengths, either by rule, or by chance, so that when pushed against the ends of the sliders at *I I*, they will cause each of them to be moved up at different times, and to different distances from *I I*, in a form exactly correspondent to the ends of the part *H*.

When they have thus received their correspondent position, and their ends *I I* form a complete tally with the part *H*, by making a notch in each slider at *1 2 3*, etc., in a line with the bar *c*, the said bar will then have liberty to be moved backwards and forwards without obstruction; and, when brought into its original situation, and the part *H* withdrawn, the sliders *A B C*, etc. will then fall down into their notches, and fasten it as usual.

Their ends at *I I* will be restored perfectly even, as before, and not the least trace be left of the position required in them to set the bar *G* at liberty; it depends, therefore, entirely on chance when the part *H*, or key, is absent.

A is a frame or barrel that moves the bolt by its turning, in which barrel or frame are fixed eight, or any other given number of sliders. *B* is a thin plate fixed in the lock, through which the barrel or frame *A* passes, and is prevented from turning for the purpose of moving the bolt, by the projecting parts of the sliders that move in the fixed plate *B, un*til the notches in each of them are, by the application of the correspondent part of the key, pushed into contact, or in a line with the plate *A*.

At the end of each slider, in the cylindrical parts *c c c*, etc., is fixed a spiral spring, which always restores them after the key is withdrawn, similar to *A B C*, etc., by their own gravity."

c (figure 117) represents a spiral spring, which is lodged in each of the cells *c c c*, etc., in the barrel *A,* (figure 116). The other half of the barrel is filled with a slider that rests on the spring. *b* is the nib which is projected through the

interior groove into the space which forms the center or keyhole on which the key is pressed.

The office of these sliders exactly corresponds with that of the levers in the diagram *K*, (figure 116) "When lodged in their respective cells, they are upheld, like the levers, by the elastic power of the springs on which they rest, until a pressure superior to that power is applied; and are again restored to their stations by the reaction of the springs, when the weight which depressed them is withdrawn."

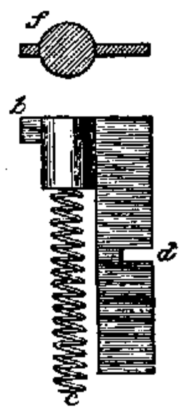


Figure 117. Bramah's first slider slider b, the nib. c, The spiral spring d, The notch. f, Top section.

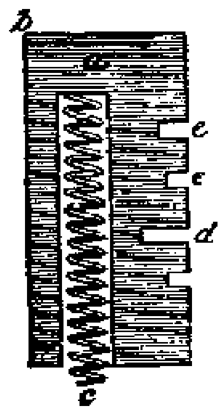


Figure 118. Bramah's with spiral spring, and False notches, as introduced in the year 1817. b, the point on which the key presses. C, The spiral spring. d, The principal notch or Main gating. eee, The False notches.

It will be well to notice particularly that Bramah's first locks were constructed with a spiral spring to each slider, as shown in figures 116-117, as we shall have to refer to this point hereafter. We have had lent to us for examination an example of these early locks, a large padlock. It is a beautiful piece of workmanship and proves the great mechanical skill of its inventor, and from its expensiveness must have been used to secure some depository of great importance.

It has eight sliders of the pattern figure 118, with a spiral spring, c, to each, and a slide escutcheon before the keyhole. At the top of the nozzle is a chamber for holding sealing wax to prevent the raising of the slide.

We have omitted several of the diagrams annexed to the foregoing specification, for the purpose of substituting others contained

in another version of the same specification, which forms a continuation of "A Dissertation on the Construction of Locks, containing, FIRST-Reasons and Observations, demonstrating all locks which depend on fixed wards, to be erroneous in principle, and defective in point of security.

SECONDLY-"A Specification of a lock constructed on a new and in infallible principle, which, possessing all the properties essential to security, will prevent the ruinous consequences of HOUSE ROBBERIES, and be a certain protection against thieves of all descriptions: by Joseph Bramah," which was published soon after the date of the first patent.

A second edition of this interesting, and now very scarce pamphlet, was published in the year 1815. We shall quote at some length from both editions, and shall conclude our description with numerous diagrams of the details of the lock as it is at the present time constructed, and with such additional explanations as may appear necessary.

At the time Mr. Bramah wrote the "Dissertation," house-breaking had risen to a most fearful height in London, which caused the public to examine into the nature of the fastenings to their doors, and to their money depositories.

The warded lock was the kind almost universally employed, Barron's being at that period but little known. That Mr. Bramah thoroughly understood the principle and the defects and insecurity of the warded locks is evident from his writings.

It would appear, from the following pages, that although he appreciated the ingenuity of Mr. Barron in the construction of his double-acting tumbler lock, yet that he considered it insecure, from the circumstance of the tumblers having a uniform motion, and there being presented with a face which tallies exactly with the key.

"But if the variations of locks in which the bolt is guarded only by fixed wards could be multiplied to infinity, they would afford no security against the efforts of an ingenious locksmith. For though an artful and judicious arrangement of the wards, or other impediments, may render the passage to the bolt so intricate and perplexed as to exclude every instrument but its proper key, a skilful workman having access to the entrance will be at no loss to **fabricate(480)** a key which shall tally perfectly with the wards, as if the lock had been open to his inspection.

This operation may not only be performed to the highest degree of certainty and exactness, but is conducted likewise with the utmost ease. For the block or bit, which is intended to receive the impression of the wards, being fitted to the keyhole, and the shank of the key bored to a sufficient depth to receive the pipe, nothing remains but to color the bit with a preparation, which, by a gentle pressure against the introductory ward, may receive its impression, and thus furnish a certain direction for the application of the file.

The block or bit being thus prepared with a tally to the first ward, gains admission to the second, and a repetition of the means by which the first impression was obtained, enables the workman to proceed, until by the dexterous use of his file he has effected a free passage to the bolt.

In this operation he is directed by an infallible guide; for, the pipe being a fixed center on which the key revolves without any variation, and the wards being fixed likewise, their position must be accurately described on the surface of the bit which is prepared to receive their impression. The key therefore may be formed and perfectly fitted to the lock, without any extraordinary degree of genius, or mechanical skill. It is from hence evident, that endless variations in the disposition of fixed wards are not alone sufficient for the purpose of perfect security.

I do not mean to subtract from the merit of such inventions, nor to dispute their utility and importance. Every approach towards perfection in the art of lock-making may be productive of much good, and is at least deserving of commendation and encouragement; for if no higher benefit were to result from it, but the rendering that difficult or impossible to many, which is until practicable and easy to *a few,* it furnishes a material security against those from whom the greatest mischief and dangers are to be apprehended.

“The first claimant to merit in this branch of mechanics is Mr. Barron, whose lock is undoubtedly, and beyond all comparison, more excellent and more secure than any lock that ever was in use before his invention was made known. An observation or two upon Mr. Barron's lock will however illustrate what I have said on the subject of fixed wards, and prepare my readers to comprehend more readily the principle on which my own lock is constructed."

It appears from the object of improvement which employed Mr. Barron's attention in the construction of this lock, that he was aware, and as sensible as I am of the impossibility of guarding the avenues to the bolt so effectively by fixed wards as to prevent all access to it. Leaving the entrance and passage to the common protection of wards and outworks, his ingenuity has been wholly applied to the interior fortification of the bolt, by a new and judicious application of additional tumblers.

These are a kind of grapple, by which the bolt is confined as well in its active as its passive station, and rendered immovable, until set at liberty by the key. One of these instruments is commonly introduced into all locks that are of any use or value; it is lodged behind the bolt, and is governed by a spring which acts upon the tumbler, as the tumbler acts upon the bolt.

The application, therefore, of any force to the tumbler, which is superior to the force of the spring, will cause it to quit its hold, and set the bolt at liberty. And in this operation no skill or nicety is required to ascertain the degree of force to be applied; for it matters not how far the tumbler is lifted above the point at which it ceases to control the bolt.

In Mr. Barron’s lock the case is otherwise. He has not only improved upon the practiced method of applying the tumbler, but has given it an office which is perfectly new, and of more importance to its security than any impediment, which art can oppose to the introduction of a false key.

Instead of leaving his tumblers liable to be forced to an indefinite distance from the point at which they cease to control the bolt, he has confined their action within a circumscribed space, cut in the center of the bolt, of a dimension barely sufficient to the purpose they are intended to answer.

This space or groove is, in form, an oblong square, and is not only furnished with niches on the underside, into which the hooks of the tumblers are forced by the spring as in other locks, but is provided likewise with correspondent niches on the upper side, into which the hooks are driven, if any greater force be applied to the tumblers than is required to disengage them from the bolt.

Hence it becomes absolutely necessary in the fabrication of a false key that the pressure of the extreme point of its bit on the tumblers be proportioned with the greatest degree of

exactness to the point of height to which they must be raised, to release the bolt. Otherwise the power which disengages the hooks on the one side will fix them on the other, and until leave the bolt immovable.

This improvement, which does great credit to Mr. Barron's mechanical skill and invention, being as useful and important in effect as it is new and curious in principle, must be admitted by every competent and impartial judge to be a very valuable acquisition to the art of lockmaking. But greatly as the art is indebted to the ingenuity of Mr. Barron, he has not yet attained that point of excellence in the construction of his lock which is essential to perfect security.

His improvement has greatly increased the difficulty, but not precluded the possibility of opening his lock by a key made and obtained as above described. An impression of the tumblers may be taken by the same method, and the key be thence made to *act* upon them as accurately as it may be made to tally with the w*ards.* Nor will the practicability *of* obtaining such a key be prevented, however complicated the principle or construction of the lock may be, whilst the disposition of its parts may be ascertained, and their impression correctly taken from without.

I apprehend the use of additional tumblers to have been applied by Mr. Barron as a remedy for this imperfection because a less object would not have been worthy the exercise of his great talents and ability; and because (if such were his intentions) he did not overrate the effect which the cause was capable of producing.

He seems evidently to have conceived the **principle(481)**, but has certainly failed in the execution. For, by giving a uniform motion to the tumblers, and presenting them with a face which tallies exactly with the key, they until partake in a very great degree of the nature Of fixed wards, and the security of his lock is thereby rendered in a proportional degree defective.

To make these remarks more intelligible, I must ask my readers to suppose the key, with which the workman is making his way to the bolt (by the process above described) to have passed the wards, and to be in contact with the most prominent of the tumblers. The impression, which the slightest touch will leave on the key, will direct the application of the file, until sufficient space is prepared to give it a free passage.

This being accomplished, the key will of course bear upon the tumbler which is most remote; and being formed by this process to tally with the face, which the tumblers present, will acquire as perfect a command of the lock as if it had been originally made for the purpose. And the key, being thus brought to a bearing on all the tumblers at once, the benefit arising from the increase of their number, if multiplied to fifty, must inevitably be lost; for, having but one motion, they can act only with the effect of one instrument. But nothing is more easy than to remove this objection, and to obtain perfect security from the application of Mr. Barron's principle."

From this last passage it would seem that Mr. Bramah had some idea that Barron's lock was capable of being made perfectly secure by some easy method.

If the tumblers, which project unequally, and form a fixed tally to the key, were made to present a plane surface, it would require a separate and unequal motion to disengage them from the bolt. Consequently, no impression could be obtained from without that would give any idea of their positions with respect to each other, or be of any use even to the most skilful and experienced workman in the formation of a false key.

"The correction of this defect would rescue the principle of Mr. Barron's lock, as far as I am capable of judging, from every imputation of error or imperfection; and, as long as it could be kept unimpaired, would be a perfect security. But the tumblers on which its security depends, being of a slight substance, exposed to perpetual friction as well from the application of the key as from their own proper motion, and their office being such as to render the most trifling loss of metal, fatal to their operation, they would need a further exertion of Mr. Barron's ingenuity to make them durable."

It is evident that at this period Mr. Bramah had not conceived any other **method of picking(482)** locks, than by taking impressions of the fixed obstacles to the passage of the bolt and the fabricating of a skeleton key. The mechanical or tentative method was then unknown.

"The idea of constructing a lock that might resist every application and effort of art, was first suggested to me by the alarming increase of house robberies; which, there is great reason to believe, are as often perpetrated by perfidious servants, or accomplished by their connivance, as by any means

that are used by the common house-breaker. In this view of the evil to be remedied, it was evident that a lock or fastening, which might effectively exclude the one, would be no security against the other; and that no lock would completely answer its intended purpose, unless a free and deliberate access to the keyhole could be rendered as useless to the purpose of obtaining a key by impression, as the pick-lock, and other instruments of mischief, may be rendered (to the purpose of opening, the lock) by the multiplicity. and intricacy of its wards."

The hasty execution of a midnight robbery, in which the servants of a family do not act a part, will not allow sufficient time, (if proper instruments were at hand) to overcome the difficulties which ingenious locksmiths have opposed to foreign invaders. My chief attention, therefore, was applied to contrive a security against the advantage which *a* domestic enemy possesses, in the opportunity of executing his purposes at his leisure.

Practicable as I conceived this to be, I did not venture to attempt it by any means which had hitherto been found ineffectual. I had not the presumption to imagine that I could give perfection to an instrument, which men of much greater knowledge and ability had left defective. I was, therefore, as solicitous to avoid their *excellences,* as to escape their imperfections which are so blended in the best locks, as to make it impossible to adopt the one, without falling into the other.

A very little thought on the subject convinced me that my success would depend on the application of a Principle as dissimilar as possible to that by which other projectors had in vain sought to attain perfection in the art of lock making. As nothing can be more opposite in principle to fixed wards, than a lock which derives its properties from the motion *of* all its parts, I determined that the construction of such a lock should be the subject of my experiment.

In the prosecution of my purpose, various models were constructed, and I had the satisfaction to receive from the least perfect of them the clearest demonstration of the truth and certainty of my principle. The exclusion of wards made it necessary to cut off all communication between the key and the bolt; as the same passage which (in a lock simply constructed) would admit the key might give admission likewise to other instruments.

The office, therefore, which in other locks is performed by the

extreme point of the key, is here assigned to a lever, which cannot approach the bolt until every part of the lock has undergone a change of position. The necessity of this change to the purposes of the lock, and the utter impossibility to effect it otherwise than with the proper key, are the points to be ascertained by a specification of the component parts of the movement, and an explanation of their respective offices.

"Among the various methods of applying the principle of motion, in the construction of locks, which have yet occurred in my practice, I think those described in the subjoined plates are to be preferred for their simplicity."

"The first plate shows the interior face of a lock which was constructed at a very early period of my experiment, and was intended merely as a model to try the efficacy of the principle; but, to my great admiration, it turned out a complete instrument of security, and gave the clearest demonstration that the principle was certain and infallible."

"The lines which cross the face of the lock (figure 119) represent six levers, which are united in a joint, and turn on a common axis. Each lever rests on a separate spring of sufficient strength to sustain its weight, or, if depressed by a superior force, to restore it to its proper position, when that force has been withdrawn."

The curve F represents a frame through which the levers are carried by separate grooves or passages; these grooves are exactly fitted in their width to the thickness of the levers, but are of sufficient length to allow them a free motion in a perpendicular direction, whether lifted by the elastic power of the springs on which they rest, or sunk by the pressure of a superior weight from above.

The part which projects from the opposite side of the joint, inserts its extreme point in the bolt at B, and is a lever of a different form, which acts in subordination to those above described; to this lever, two offices are assigned; the one to keep the bolt in a fixed and immovable position in the absence of the key; the other to give it its proper motion when the key is applied.

The joint or carriage of the levers, and the springs on which the levers bear, are fixed on a circular platform, P, which turns on a center, and in its motion impels the bolt in either direction,

by means of which the lever is projected from the joint before-named.

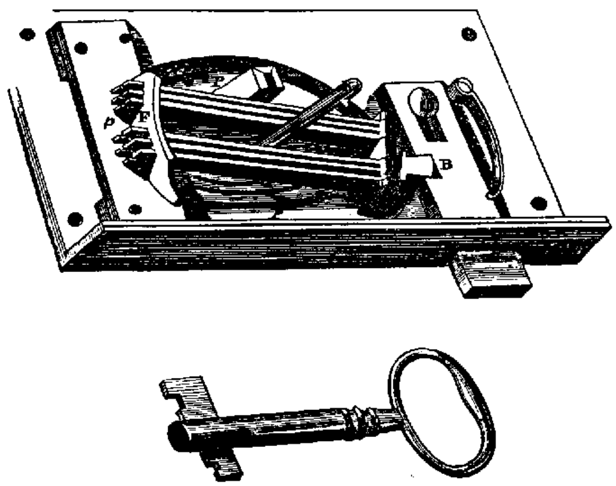


Figure 119. Bramah's First Model

"To give this machine the property of inviolable security, it was necessary to subject its motion to some restraint which the key only could remove. This power is lodged in the part *p*, which is a thin plate, bearing at each extremity on a block, and having, of course, a vacant space beneath, equal in length to the thickness of the blocks on which it rests."

"This plate is applied either to check or to guide the motion of the machine, and these opposite offices are thus performed. On the edge of the plate, which faces the movement, six notches are expressed, into which the points of the levers projecting beyond the frame are received; and whilst they are so confined, the motion of the machine is totally suspended, and the bolt so fixed, as to defy every effort of art or force to move it."

The necessity of the proper key to the purpose of opening this lock, and the impossibility of effecting it by other means, will be clearly seen from the process by which the machine is put in motion. It is to be observed that each lever has a notch expressed on its extreme point; and that those notches are disposed as irregularly as possible.

To give a capacity of motion to the machine these notches must be brought parallel to each other, and by a distinct and unequal pressure upon the levers be formed into a groove, in a direct

line with the edge of the plate *p*, which the notches are exactly fitted to receive. The least motion of the machine, whilst the levers are in this position, will introduce the edge of the plate into the groove; which, controlling the power of the springs, will give liberty to the levers to move in a horizontal direction, as far as the space between the blocks which support the plate *p* will admit, and which is sufficient to give the machine a power of acting on the bolt.

The impossibility of thus bringing the notches expressed on the points of the levers, to fall into a direct line, and to form a groove which shall perfectly tally with the edge of the plate *p* by any other means than the application and impulse of the key, is the principle of security which constitutes the peculiar excellence of the lock.

"The key (figure 119) exhibits six different surfaces on its bit, against which the levers are progressively admitted in the operation of opening the lock; the irregularity of these surfaces describes the distinct and unequal degree of pressure which each level requires to bring them to their proper bearings, for the purpose of putting the machine in motion."

It hence appears that unless the various heights of the surfaces expressed on the bit of the key are exactly proportioned to the several distances to which the levers must be carried to bring their notches into a direct line with each other, they must remain immovable; and, as one stroke of a file is sufficient to cause such disproportion as will prove an insurmountable impediment to their motion, I may safely assert that it is not in art to produce a key, or instrument, by which a lock, constructed on this principle, can be opened.

“It will be a task indeed of great difficulty, even to a skilful workman, to fit a key to this species of lock, though its interior face were open to his inspection; for the levers being raised by the subjacent springs, to an equal height in the frame *F*, present a *plane* surface; and, consequently, convey no direction that can be of any use in forming a tally to the *irregular* surface which they present, when acting in subjection to the proper key."

Unless, therefore, a method be contrived to bring the notches, expressed on the extreme points of the levers, in a direct line with each other, and to retain them in that position until an exact impression of the irregular surface which the levers will

then exhibit can be taken, the workman will in vain attempt to fit a key to the lock; or, by any effort of art, to move the bolt.

When it is considered, that the process will be greatly impeded, and may perhaps be entirely frustrated, by the action of the springs, it must appear that great patience and perseverance, as well as great ingenuity, will be required, to give any chance of succeeding in the attempt. I do not state this circumstance as a point essential, or of any importance to the purpose of the lock, but to prove more clearly what I have before observed upon its principle and properties.

If such difficulties occur to a skilful workman, as to render it almost, if not altogether impracticable to form a key when the lock is open to his inspection and its parts accessible to his hand, it pretty clearly demonstrates the impossibility of accomplishing it, when no part of the movement can be touched or seen.

It will naturally be imagined by the reader that the same difficulties which occur in the formation of a key in the second instance, must have been experienced by the maker of the lock; and that, however insuperable they may be to other workmen, they were easily conquered by him. But the contrary is the case.

No such difficulties occur in forming the original key; nor is any greater ingenuity exercised in the formation of it, than falls to the share of a common workman; for *the key is not fitted to the lock but the lock adapted to the key*; and this is effected by a mean, the most simple and the most easy that can be imagined.

The surfaces expressed on the bit of the key are worked as chance, or fancy, may direct, without any reference to the lock. The key being so completed and applied to the surface Of the levers, gentle pressure will force them to unequal distances from their common station in the frame *F*, and sink their extreme points to unequal depths into the space beneath the plate *p*. Whilst the levers are in this position, the edge of the plate *p* will mark the precise point at which the notch, on each lever, must be expressed.

"The notches being cut by this direction, the irregularity which must appear in their disposition when the levers resume their station in the frame *F*, and the inequality of the recesses

expressed on the bit of the key, will be as a seal and its impression to each other."

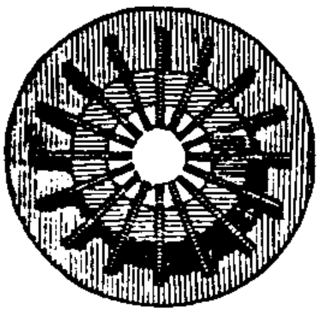


Figure 120. Top face of the Barrel or cylinder

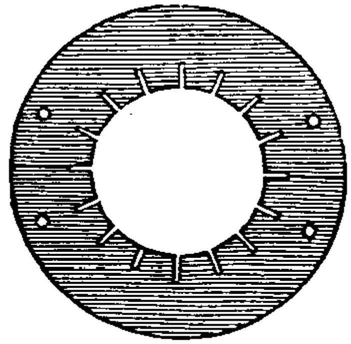


Figure 121. Locking-plate with Plain Notches or gatings

"Figure 120 represents the face of a circular block or barrel of brass, having a cylindrical cavity throughout, and divided from the center into sixteen compartments, separated by grooves passing also quite through, and fitted with as many steel sliders. The upper parts of these sliders project into the cylindrical cavity, and are elevated to be flush with the prominence in the center of the barrel. The notch in one part of this prominence receives the bit or lever on the key, which turns round the barrel in the operation of opening the lock.

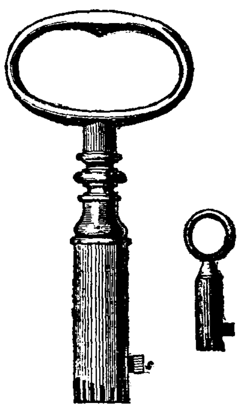


Figure 123.

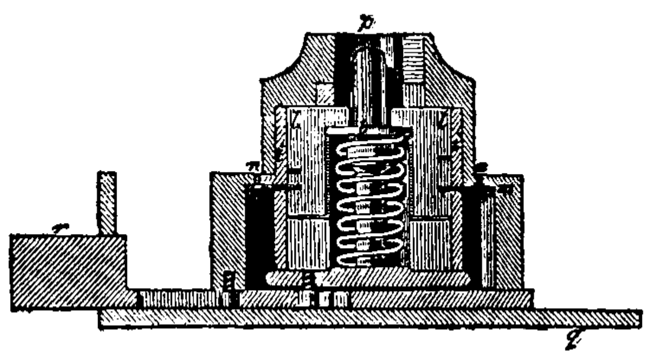


Figure 122. Bramah lock.

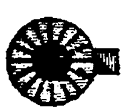
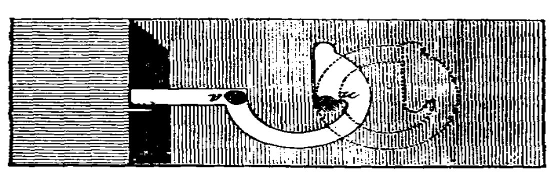


Figure 124.



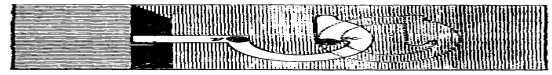


Figure 125.

"Figure 122 is a section of a complete lock; *i i,* is the brass barrel, as figure 120, having a groove cut in the middle of its spherical surface of a depth equal to the notches expressed at different distances on the outer edge of the sliders l l, and into which is fitted a thin plate of iron, shown at figure 121, and divided in halves for that purpose.

This plate is screwed to the cap or covering, m, at n n, with its internal edge to fit the cylindrical cavity, being previously notched thereon to correspond with the projection of the sliders in the groove. P is a pin attached to a brass plate at the interior end of the barrel; the plate is made to confine the parts in their places on that side, and the pin carries a small socket, *b*, on which the overhanging ends of the sliders rest, and which by the action of the spiral spring keeps the sliders buoyant.

The cap or covering plate, *m*, screws down to the external plate of the lock, *q*, limiting the upward pressure of the sliders, and protecting all the operative parts. When the barrel, *i i,* is moved round, the bolt, *r*, is thrown forward by a process which will be hereafter explained."

The description to figure 119 so well explains the action of the lock shown in figure 122, that we shall only here describe the analogous parts represented in the latter figure. The plate *n n,* (figure 122) corresponds to the plate *p*, in figure 119, and which in this lock is called the *lockinq-plate,* into which are cut sixteen notches, as shown in figure 121.

The sliders *l l* project into the cavity of the barrel, and are upheld in their respective grooves by the elastic power of the central spring on which they rest. All these sliders, as before observed, have a notch in the outer edge *d*, (figures 118 and 126) disposed as irregularly as possible, and all admit of pressure beyond the point which brings these notches parallel with the notches in the locking-plate.

By a distinct and equal pressure on the sliders, the notches therein must be formed into a groove in a line with the locking-plate *n n*, (figure 122) which those notches are exactly fitted to receive, before a revolving motion can be given to the

barrel or cylinder. This can only be performed by the key, which is represented in figure 123, and its indented point or extremity corresponding with the depths of the notches is seen at figure 124.

It will be recollected that the upper ends of the sliders overhang, or project into the cylindrical cavity which forms the keyhole; when the key therefore is applied, it must of course encounter these interior projections. Its extremity being notched in exact proportion to the several distances to which the sliders are to be carried, it will, when pressed forward, force the sliders to unequal distances from their bearings, and bring the notches on their exterior projections in a direct line with each other, and parallel with the plate, leaving the barrel at liberty to be carried round by the bit or lever on the key, (see *s*, figure 123) and which fits for that purpose into the notch on the prominence of the barrel, as explained in the description of figure 120, serving at the same time to stop the key at its proper point of pressure.

When the key is withdrawn, the sliders, of course, resume their station by the reaction of the spring, and the barrel returns to its confinement."

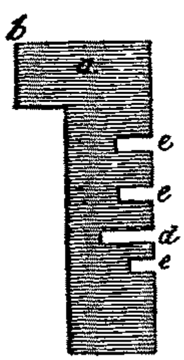


Figure 126. Steel Slider

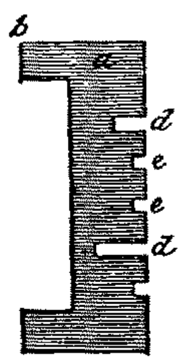


Figure 127. Steel Slider



Figure 128. Section of a Steel Slider

Figure 126 represents one of the sliders l l, (figure 122); b is the nib which projects into the keyhole; d is the notch. Figure 127 is a similar slider for a two-sided lock, and figure 128 shows a section of a slider split in its thickness so that it may move up and down in its groove with a slight friction, and thereby not fall simply by its own weight.

"Figure 129 is a plan of a complete lock, with a part of the cap or covering removed, to show the original mode of applying this

principle of security. The dotted lines on the bolt are the spring and tumbler, situated beneath, and having the same office as in the common lock. The lever *x* which is firmly attached to the barrel, represents the web or bit of an ordinary key, and which being carried round with the barrel, takes hold of the bolt in the notch, which it releases by lifting up the tumbler, and projects or withdraws in its revolution.

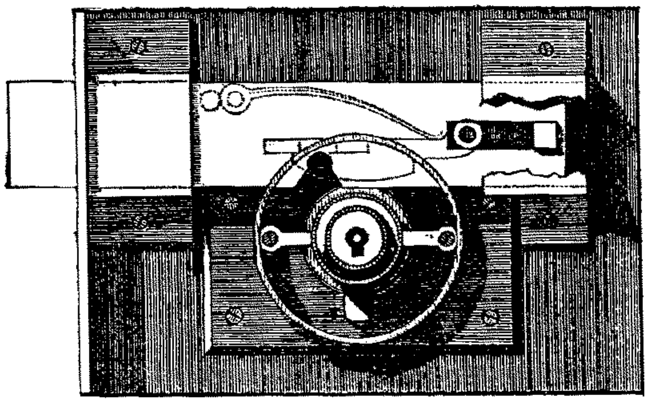


Figure 129. Complete Lock, showing the original mode of construction

As circumstances might by possibility occur, where ingenuity could gain access to the tumbler and release the bolt without attempting the principle of security, locks are now fabricated in the manner shown at figures 122 and 125, a method which can only be accomplished on this principle, and which vies in importance with the original invention.

"Figure 125 is a plan of the bolt of the lock figure 122. The point u is a pin fixed in the bottom of the barrel e e; and which, when the barrel is carried round, moves in the direction of the dotted circle, and, and of course, carries the bolt to and from with it. The pin v is attached to the covering plate, and serves to steady the bolt in its motion. The principle of security is thus made to restrain the bolt without the intervention of any other agent; and the slightest inspection must convince that no power can move the bolt, but that which also puts in motion the barrel.

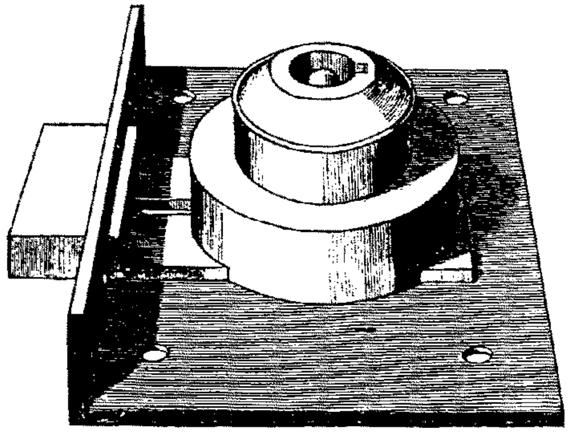


Figure 130. Drawer or Until Lock--complete

It would appear that previous to the publication of the second edition of the "Dissertation," a main central spring had been substituted in the place of the separate spring to each slider. In the words of the writer of the article "Lock" in the *Encyclopaedia Britannica*,

"Such was Bramah's lock as it first came extensively into use, and as it continued for many years, employed for the most important purposes, and by the most distinguished persons. At length an advertisement appeared in the public papers, requesting those who had lost keys of Bramah's locks, not, as had hitherto been done, to break open their doors or drawers, but to apply to the advertiser, who would undertake to save this destructive process by picking; and it appeared that an individual of great dexterity could perform this operation almost with certainty.

The effect of this discovery on the demand for the locks may easily be imagined; but the effect it had in stimulating ingenuity to provide a remedy is one of the best illustrations of the Proverb that necessity is the mother of invention.

Within a few days or weeks, Mr. Russell, who was at that time employed in Mr. Bramah's establishment, devised an alteration which at once, and without any expense, entirely overcame the difficulty, and converted the lock into one of perfect security. This contrivance is the most simple and extraordinary that ever effected so important an object; but before we describe it, we will endeavor to explain what has been called the *tentative* process of lock-picking, and which has been so successfully applied to Bramah's locks.

To do this, we will refer to the diagram (figure 131) in which *a* represents a bolt fitting loosely an outer-case, and tending to move in the direction of the arrow. It is, however, prevented by three studs, which are moveable upwards and downwards by their knobs, 1, 2, and 3; but it would be free to move if these studs were elevated or depressed to correspond with the notches made in the end of the bolt.

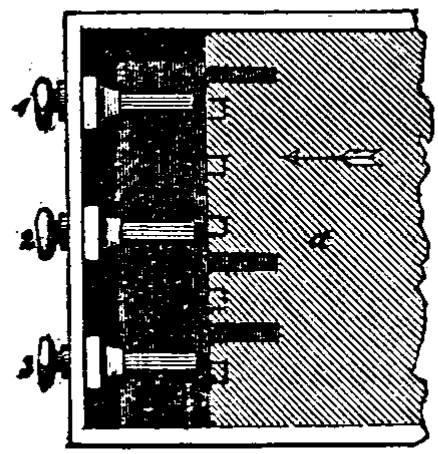


Figure 131. Diagram to explain the false notches

Now, if the case were closed, it would be perfectly easy to place these studs in the requisite position by the following process: Apply a pressure to the bolt, which can be done in any lock, tending to move it for unlocking. This will, of course, be resisted by the studs 1, 2, 3, but not by all equally; it will in fact be resisted by only one of them; the necessary imperfections of all workmanship would prevent more than one at a time from coming into sensible contact with the bolt.

Having therefore applied pressure to the bolt with one hand, with the other the operator would ascertain which of the studs was most bound by the pressure. This would be easily done, and then he would move the stud gently up and down until he felt it catch in the notch to which it belonged. The bolt would move until the next most prominent stud received it, which would be tracked to its notch in the same manner, and so on until all were disposed of.

“By a similar process the picking of Bramah's lock was effected. A tendency to revolve was given with some force to the barrel; then by means of a pair of small forceps, the several sliders were tried, and it was ascertained which was most detained by the pressure against the locking-plate. That which offered most

resistance was gradually depressed until its notch was felt to hang itself upon the locking-plate, and so on until the whole were depressed in succession, exactly as they would have been depressed simultaneously by the key.

Returning to figure 131, it will be easily understood that if, in addition to the three principal notches, a number of **shallower notches(483)**, as indicated by dots, be made equal in depth to any possible inequality in the projection of the studs, the process we have described is entirely prevented, because it will be perfectly impossible for the picker to tell whether he has brought the stud to one of the deep notches or to one of the shallow or false notches, and he will of consequence be entirely baffled.

This was the happy suggestion to which we have alluded. This will explain the two or three shallow or false notches which now appear in the edges of Bramah sliders, (see *e e e*, figures 118, 126, and 127) and which require corresponding false notches, or rather false widening in the notches of the locking-plate."

The Bramah lock has thus far been described in the words of its inventor. Its importance will induce us, at the expense of being considered too prosy, to illustrate and explain one of these locks, as at the present time constructed, and we shall do so as briefly as possible.

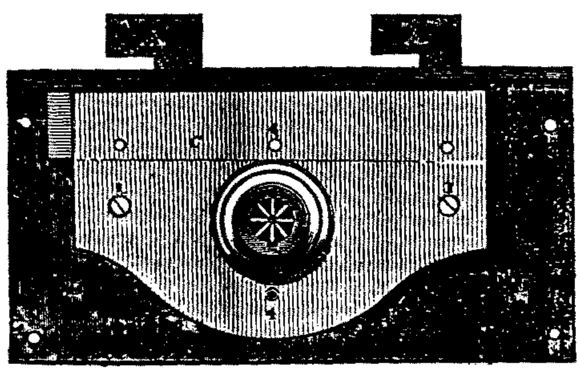


Figure 132. Exterior of a Bramah Box or Desk Lock

Figure 132 represents the exterior of a box or desk lock, a variety for which the Bramah principle is peculiarly adapted. The neat appearance of the nozzle, the small keyhole, and the corresponding small key, are properties not to be overlooked.

A A shows those portions which rise from the bolt through the

holes in the fore-end or selvage of the plate B B of the lock, upon which the bolt has a backward and forward motion. c is the cap, which is secured to the back-plate by two screws at 1 1. The cylindrical projection or barrel, D, contains the whole of the security parts of the lock. The pins, 4 4, are employed for securing the locking-plate f f (figure 133) firmly in its position between the cap c and the back-plate B B.

Figure 133 shows several of the internal limbs of the lock separately. *E* is the cylinder or barrel, with the hole in its center for the key, and into which the steel sliders *a a a a* (figure 134) project from the grooves cut inside the cylinder.

As mentioned before, the sliders are split open about half-way up, and since the year 1817, besides the principal notch or main gating, there two or three false notches cut in addition as before shown in figures 126 and 127, and at 3 3, (figure 134).

F is the circular plate of metal into which the drill-pin is riveted; the former being secured to the bottom of the barrel by two screws. c is the stud which works in that portion of the bolt d, (figure 135) by which it is moved backwards and forwards. 6 is the central spring coiled loosely round the drill-pin; the pressure of the spring forces up the collar 7, on which the upper part or nibs of the sliders 8 (figure 134) rest.

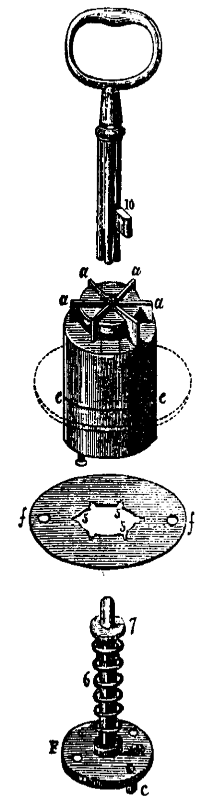


Figure 133. Detai interior of a Br

The locking-plate f f has six notches at 5 5 5, which, in consequence of the false notches in the sliders, are made wider or more open for the purpose of increasing the difficulty of opening the lock by any other instrument than its own key. By comparing this figure with figure 121, the difference between the former and the locking-plate as first used will be understood.



Figure 134. Stee

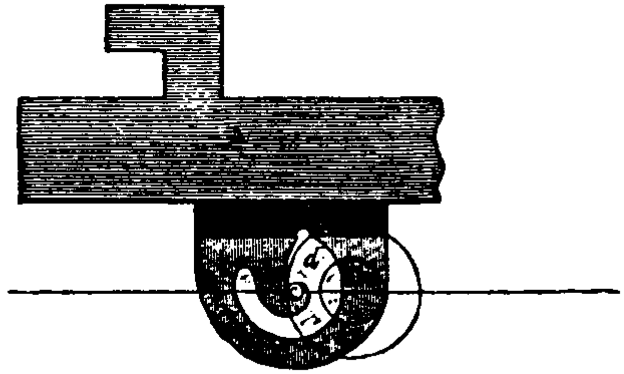


Figure 135. The Bolt

The locking-plate fits upon the cylinder at e e, (figure 133). The key, as shown in the upper part of figure 133 has six notches or cuts at the end of its pipe or shank, which are cut to different depths to correspond with the true notch on each slider. The small projection, 10, near the end of the pipe, is fitted to enter the notch D in the cylinder (figure 133).

The bolt of the lock, (figure 135) when locked, is prevented from being forced back by the stud c in the bottom of the plate P, through the cylinder coming in a direct line with its center of motion, and in this position no force applied to drive the bolt back would have any tendency to turn the cylinder around.

We consider the adoption of the central spring a great improvement, and one that quite accords with our views in relation to inventions, as it was effected, not by the addition of more parts to the mechanism, but in a lock with sixteen sliders, by actually dispensing with fifteen limbs.

The additional security thus obtained, consists in obliging the operator, who attempts to pick the lock by depressing the sliders separately by means of any small pointed instrument, and who by chance might bring two or more of them to the proper depth for turning round, if he pressed any one too low, so that the true notch went below the locking-plate, to release the central spring *6*, (figure 133). This would force the whole number of sliders to their original position, and would compel him to commence the operation de novo.

After Mr. Chubb read his paper "on the construction of locks and keys," in 1850, before the Institution of Civil Engineers, an interesting discussion followed on several of the principal locks, when Mr. Farley observed, relative to the Bramah lock,

“that the mechanism of locks had been a favorite subject with him, from an early period of his studies, when he had the good fortune to be intimate with Mr. Joseph Bramah, and had acquired a knowledge of his locks, which were then in high repute. The secret workshops wherein the locks were manufactured contained several curious machines for forming parts of the locks, with a systematic perfection of workmanship which was at that time unknown in similar mechanical arts.

These machines had been constructed by the late Mr. Maudslay with his own hands, whilst he was Mr. Bramah’s chief workman, The machines before mentioned, were adapted for cutting the grooves in the barrels, and the notches in the steel plates, with utmost precision. The notches in the keys, and in the steel sliders, were cut by other machines, which had micrometer screws, so as to insure that the notches in each key should tally with the unlocking notches of the sliders in the same lock. The setting of these micrometer screws was regulated by a system which insured a constant permutation in the notches of succeeding keys, in order that no two should be made alike.”

Mr. Bramah attributed the success of his locks to the use of those machines, the invention of which had cost him more study than that of the locks; without the machines, the locks could not have been made in any great number with the requisite precision, as an article of trade. There was great originality in those machines, which were constructed before analogous cases (beyond the clock-maker’s wheel-cutting machines) were in existence.

He said further, that “the security of Bramah’s lock against being picked, depended upon the circumstance that its several sliders must, each one for itself, be pushed in so far and no further; but how far the lock afforded no indication. It was nevertheless very objectionable that the sliders should be so completely exposed to view.

It had been suggested that a universal false key for Bramah’s locks might be made with the bottoms of its several notches formed by as many small steel sliders, extending beyond the handle of the key, so as to receive pressure from the fingers for moving each one of the sliders within the lock, with a sliding motion in its own groove, independently of the others; and during such sliding motion a gentle force could be exert4d, tending to turn the barrel round.

Under such circumstances, supposing that the motion of the barrel

was prevented by any one slider only, that one having to resist all the turning force would be felt to slide more stiffly endways in its groove, and therefore it could be felt when its unlocking notch arrived opposite the steel plate, and left some other slider to begin to resist the turning force; such a circumstance presumed a palpable inaccuracy in the radiating correspondence between the notches in the steel plate and the grooves for the sliders in the barrel, which could not happen with Bramah's workmanship."

The universal pick above alluded to, is, without doubt, a most formidable instrument when employed on a badly-made or spurious Bramah lock. In the hands of a practical locksmith, or an ingenious amateur, the probability of opening such locks by its aid is certain.

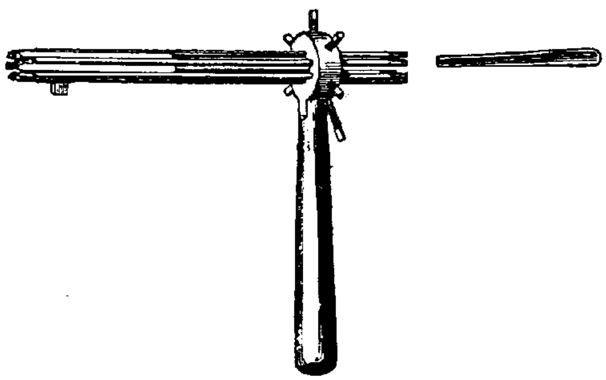


Figure 136. Universal Pick for a Bramah lock with Six Sliders

We shall merely illustrate and explain the instrument here, as all other particulars relating to its use will be found in the chapters on the Lock Controversy.

This ingeniously constructed instrument consists of a stem with six grooves, in each of which a sliding wire moves up and down. The stem and sliding wires are fitted into the cylindrical part of the handle *a*, and the sliding wires are held in any required position by the setscrews *e.*

In operating upon the lock, the bottom of the pick, *b*, is forced into the keyhole, when the bit *c* comes in contact with the neck of the barrel, which presses the cylinder, and the latter causes the steel sliders of the lock to bind more or less against the locking-plate.

The setscrews *e*, etc., all being released, a small handler is

screwed on to the end of one of the sliding wires at *d*, when a gentle pressure is applied to discover if that one binds. If not, the next is tried in the same way, and so on until the particular steel slider that binds is found, when it is gently set free, and the setscrew is turned round until the sliding wire becomes fixed in that position.

One slider being thus released, another of the remaining five will be found to bind in the same way as the first, when it is relieved in the same manner, and so on until the whole six are set free, when the pick becomes as complete a key as the true key itself. When the bottom of the pick, *b,* is put in the keyhole, it at once takes away the force of the central spring.

We must, however, mention, that the above pick will only do for a six-slide lock of the particular size of the pick; consequently, though it has been called "universal," a separate pick would be required for every lock which had more or less sliders, or which had a keyhole of a different diameter.

We have now so fully described and illustrated the Bramah lock, that we feel assured its merits cannot fail to be understood and appreciated by all our readers. It will be apparent that although many persons talk of opening the Bramah lock with a turkey quill, a pocket-pencil case, or other similar simple instrument, that it is only when these locks are made with wide slots in the locking-plate and sliders, or when the sliders are purposely made too short to reach the locking-plate, that they can so easily be opened with a pick of that description; or, as is the case with thousands of locks with "Bramah's Patent-Secure" stamped upon each, which are made without any sliders at all.

Many such locks(484), on examination, appear to be filled with sliders, but upon a closer examination, what appeared at first to be sliders are found to be only bits of iron wedged across the neck of the barrel. It will be readily conceived how all such locks can be opened by a quill or a pencil-case.

The principal cost in making a Bramah lock secure is the time consumed in carefully fitting the several internal parts, which careful fitting the lock is worthless, and it is to produce these locks at lower prices that the above deceptions are practiced.

A three-inch till lock with sliders, and well-made, is worth five shillings, whilst a lock of the same size and similar in external appearance with wide slots in the locking-plate and sliders, and

other parts as carelessly made, is worth but three shillings, and one without any sliders at all, only two shillings.

The public have to thank themselves, in the first instance, for the insecure and worthless locks they are furnished with, as they usually expect to be supplied with a genuine Bramah lock at the same price as the spurious imitation, and this remark will equally apply to all the other kinds of locks.

Instances have come under our observation, where locks of this description have been required, when the party giving out the order has stated that he did not care how they were made so that a certain price was not exceeded, for instance, two shillings for a three-inch box or desk lock. We only wonder that more robberies of ladies' cabinets and workboxes, gentlemen's writing desks and dispatch boxes, etc., do not occur.

In such cases the principle of the lock must not be condemned on account of the niggardly disposition of the purchasers, or the want of integrity on the part of the maker of the lock, or the manufacturer of the article to which the lock is attached. If the public wish to have good locks, they must give fair prices.

In concluding our remarks upon the Bramah lock, we feel bound to state that we consider it, when well-made, a most difficult lock to pick, even by a practiced and scientific locksmith. As to the merit of the invention, we cannot find words to express our admiration of the great mechanical skill and ingenuity of Mr. Bramah, so clearly exhibited in the beautiful construction of this lock. That he was no ordinary mechanic is evident from the number of his meritorious inventions.

He held, we believe, at one time, not less than **twenty patents(485)**, among which may be mentioned the hydraulic press; the force-pump; the beer-engine; the machine for numbering notes at the Bank of England (now in use); a patent pen, until in great demand; the mounted fire-engine, also now used; the water closet; a planing machine, extensively adopted; the ever-pointed pencil case; a slide cock, which has superseded the use of steam valves; and various other improvements in the details of the steam-engine.

We must not forget to mention **Mr. Russell(486)** in connection with the Bramah lock, who in the year 1817, as before named, introduced the false notches in the sliders as shown in figures 118, 126, 127, and 134, thereby increasing the security of the

lock so considerably. The value of this improvement, effected so simply and without any appreciable cost in the manufacture of the lock is of the greatest consideration.

It may be proper to remark that we shall so far depart from describing the various locks in their strictly chronological order of invention, as to describe the whole of the improvements introduced by the same inventor into the same lock, in their consecutive order.

BRAMAH'S SPECIFICATION, dated May 3rd, 1798.

This patent has two objects: the first is to make a lock that shall not require a key, which shall put all the sliders right simultaneously; and the second is for the construction of a kind of universal or changeable-bit key, by which the sliders shall be adjusted, one after the other, to a scale of variations supplied by the owner at the time of purchasing.

The patentee states distinctly in his Specification, that he abstains from giving any details, as he takes out the patent as a claim to the principle of such modes of constructing locks and keys, reserving to himself the right to make any mechanical arrangements for its proper carrying out that experience may show him to be the most suitable.

In the absence of any drawings or detailed explanations in the specification, we cannot tell how the " two objects " were to be effected, and from the circumstance of the present firm of Messrs. Bramah and Co. being ignorant of what the patent was for, we are inclined to think that the intentions of the patentee were never carried into operation.

TAYLOR's LATCH LOCK, invented about 1784.

The latch or spring bolt of door locks on the common construction (whether mortise, case, or rimmed locks) is very liable to be out of order as soon as the oil is dried up between the tumbler and tail of the latch, from the erroneous manner in which the tumbler is made to act; and more especially when the lower arm of the tumbler is engaged, for then the friction is very great, and the bolt very hard to be moved.

To remedy these defects, Mr. Taylor constructed "the tumbler and tail of the latch or spring bolt in such a manner that the lock might be constantly used for many years without any oil to those

parts, and always move alike both ways, that is, by turning the knob or handle either to the right or left, and with less force of the hand in turning it.

"The alteration which constitutes the difference between this lock and those in common use is, that the tumbler is reversed and the tumbler acts against two stubs fixed on the tail of the latch and thrusts it easily back, whether, the knob is turned to the right or left in opening the lock; behind the tail of the latch is also fixed a guide, having within it a groove wherein runs a small friction-wheel, serving to keep the latch in its direct situation, and lessen its friction; the arms of the tumbler are not so long as they are generally made, because the latch or spring bolt must move the easier by their being shorter.

“By the above construction, those parts of the tumbler and tail of the latch that are in contact move in a line, the nearest to the chord of a circle, whose radius is the arm of the tumbler, and consequently pass over the greatest space under the least angle possible. The friction-wheel before mentioned being placed on a stub rising from the tail of the latch, and in a line with the center of the tumbler, and having the spring that pushes the latch or bolt forward, touching also in the same line with the friction-wheel, is a still further improvement for all kinds of latch locks, though low-priced locks will do very well, according to this construction, without it.”

The inventor of this lock was rewarded by the Society of Arts with the silver medal.

MARSHALL'S SECRET ESCUTCHEON, Invented About 1784.

As before observed, this is one of the many attempts which have been made to construct a machine possessing the properties proposed by the Marquis of Worcester in No. 72 of his “Century of Inventions,” viz.:

“The owner, though a woman, may with her delicate hand vary the ways of coming to open the lock ten million times beyond the knowledge of the smith that made it, or of me who invented it.”

The construction of this escutcheon is an improvement on the principle of the common letter lock, and consists in allowing the owner to produce an almost infinite variety of **changes(487)** in one minute and in such manner “that even the maker would be as unlikely to open it as he would be of gaining the highest prize

in a lottery by the chance of a single ticket."

"A, (figure 130) the barrel in which the bar B slides; part of this barrel is concealed within the rollers, but the ends of it appear at a and b, figure 137. B, the bar with projecting teeth, by which the rollers C prevent its being drawn back till the nick in the recess is brought exactly over the tooth; the square end of this bar is seen at C, figure 138. C, a roller, of which there are five, each composed of two circle, the outer circle having four rows of letters at equal distances engraved on the surface, with small knobs, for the more commodiously turning the rollers round, the inner circle D being moveable within the outer one on the barrel A; to the surface of each of the inner circles is fastened a small spring d, serving to keep the outer circle in its place, till an alteration in the position of the letters, which are the foundation of the secret, is intended to be made; and within the inner circle is a recess to prevent the bar *B* being drawn back, unless the teeth and the nick are in their proper situations, at which time, by drawing back the bar by the square end *c*, (figure 138), which is otherwise retained in its proper place by means of the feather-spring *h*, the catch *e*, (figure 137) is released, and the door of the escutcheon is thrown open by the spring *g.*



Figure 137. Marshall's Secret Escutcheon.-(Back)

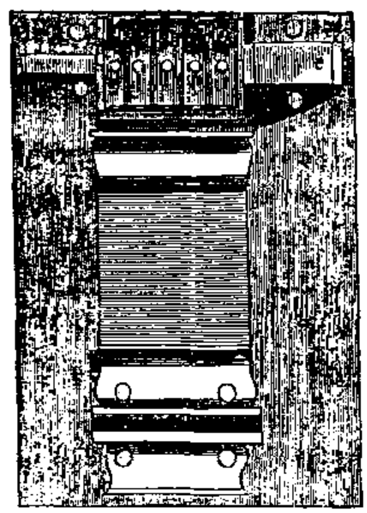


Figure 138. Marshall's Secret Escutcheon.-(Front)

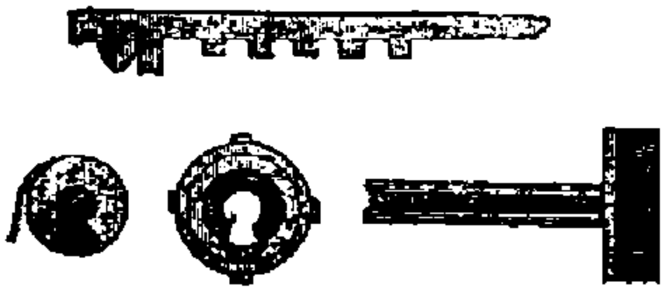


Figure 139. Details of Marshall's Secret Escutcheon

"When an alteration of the arrangement of the letters on which the secret depends is desired, the bar *B* must be held back by the square end *c*, while one or more of the outer circles are turned round until the letters chosen are uppermost. The escutcheon cannot afterwards be opened until that same arrangement is again made, and so on according to whatever situation of the letters the owner may choose."

"Hence, it is evident that whichever of the letters have been chosen must, at the time of opening the escutcheon, be brought in one line to the upper surface of the rollers; and then the bar being drawn back, the door of the escutcheon will be thrown open."

"Figure 137 represents the under or inner side of the escutcheon, and figure 138 the upper or outer side; and appears as when fixed over a lock, and covering the keyhole."

This escutcheon would be secure only so long as the combination could be kept secret. See the description of the letter-lock appears subsequently. The inventor received a bounty of ten guineas from the Society of Arts, in 1784, for this secret escutcheon.

BICKERTON'S FIRST LOCK, invented about 1784.

This was a good step in advance on the common tumbler lock, by adding to the common tumbler a double-acting limb at the back of the bolt, very similar to a detector. The front end of this limb, when at rest, presses against the main bolt, and holds it fast. If over-lifted by the tumbler, the back end of this limb grasps the bolt, and detains it until the exact height of the lift is discovered.

CORNWAITE'S LOCK, invented about 1784. Patent dated July 7th,

1789.

This lock comprises one of the most simple movements ever invented. Its construction is an improvement on the common tumbler lock, and consists of four levers, which are pivoted at one end, and at the other end have a *tongue* which works into a corresponding slot in the bolt-head. When the bolt is locked out, these tongues fit into the slot, and make the bolt, as it were, quite solid.

When unlocked, the levers are forced downwards by the springs. It is worth noticing that the curve in the bolt-head gives a wide range of combinations to this lock. There is no stump in the bolt, neither are there any slots or racks in the levers; and the peculiar construction admits of it being made particularly strong. This lock obtained a premium of ten guineas from the Society of Arts in 1784, though it does not appear to have been patented until 1789.

ROWNTREE'S LOCK, Patent dated February 23, 1790.

Rowntree's is a very elaborate tumbler lock, and contrasts remarkably with the simplicity of Barron's lock. This lock is constructed with tumblers in combination, with revolving discs or wheels. Its mechanism may be understood from the following description and engravings, which we have copied from Mr. **Tomlinson's Rudimentary Treatise on the Construction of Locks.**

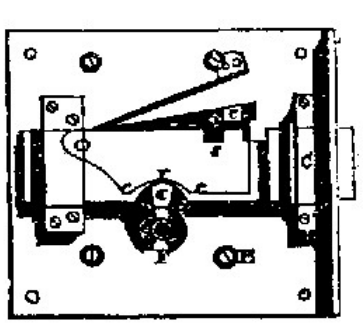


Figure 140.

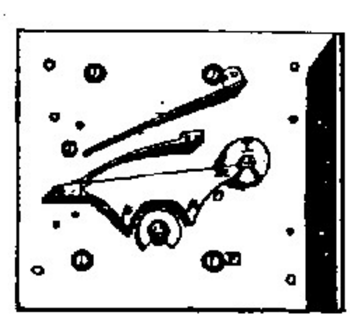
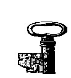


Figure 141.









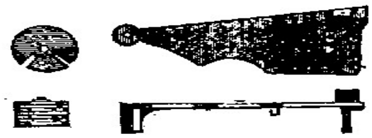


Figure 142.



Figure 143.



Figure

The same letters refer to the same parts in the several figures: A A is the plate which encloses the whole mechanism of the lock, and fastens it to the door; *B B* is the bolt guided in its motion by sliding under the bridges *C D*; *E E* are pillars which support a plate covering the works; *F* are the circular wards surrounding the center or key-pin; and *a* shows the position of the key, which, in turning round, acts in a notch *r* in the bolt, and propels it.

G, the tumbler, is a plate situate beneath the bolt, and moving on a center-pin at *d*; it has a catch or sump, *e*, projecting upwards, which enters the notches *f* or *g* in the bolt, and thereby retains the latter for backward or forward motion, as the case may be; *H* is a spring which presses the tumbler forward.

The key *a*, in turning round, acts first against the part *c c* of the tumbler, and raises it so as to remove the stump from the notches; it can then enter the notch *r* in the bolt, and move it. So far there is no particular security; but Mr. Rowntree sought to obtain it by the following means.

There is a piece of metal *h* fixed to the lower side of the tumbler, called the *pin;* when the tumbler is caught in either notch of the bolt, the pin applies itself to a cluster of small wheels I, fitted on one center-pin beneath the tumbler; the edges of these wheels stop the pin, and prevent the tumbler from being raised. But each wheel has a notch cut in its circumference I; and it is only when the wheels are so placed that all their notches lie in a right line that the pin can enter this compound notch and allow the tumbler to rise. The wheels must therefore be all adjusted to position; and this is effected by a number of levers, *k,* centered on one pin at *k.*

At the opposite end, each lever has a tooth *m* entering a notch in the wheel belonging to it; so that when any lever is pressed outward, it turns its wheel round. Now this pressure of the levers is brought about by a spring *n* applied to each; and when so pressed, the levers rest against a pin *o* fixed in the plate. The key is so cut as to determine the extent to which the levers shall act upon the wheels.

The key first operates from the curved part *p p* of the levers *k*, and, raising them, turns all the wheels, *I*, at once into the proper positions; in turning further round it then operates on

the part *c c* of the tumbler, causing the latter to rise and to release the bolt; and in turning until further round, it (the key) seizes the notch *r* of the bolt, and shoots it. The key is cut into steps of different lengths, as shown at *v v*; each step operates on its respective lever *k* in a different degree from the others; the notch at *s* acts upon the tumbler, and the plain part *t* moves the bolt.

BIRD'S LOCK, Patent dated October 29, 1790.

The peculiarity of this lock consists in the levers and springs being attached to the bolt, and moving with it, so that the bolt, the levers, and the springs, in locking and unlocking, all move together, and the stump which in other locks is generally fixed in the bolt, is, in this lock, fixed in the plate. Before the bolt and the levers, is fixed a contrivance which we shall designate the grate, through which the steps of the key have to pass to reach the bolt and the levers. This "grate " is identical with the "barricaded guider" of Mallett's lock, patented at a subsequent period.

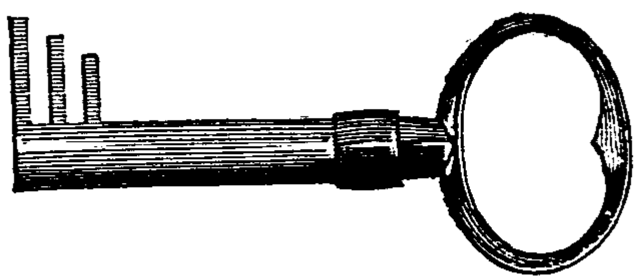


Figure 145. Key to Bird's Lock

FERRYMAN'S LOCK, Patent dated July 19, 1791.

This lock is described as "acting by lever, tooth-wheel, and drop, chiefly without springs, simple in principle, and not liable to be injured by accident or friction, applicable to prisons and other places where strong fastenings are required."

BICKERTON'S SECOND LOCK, invented about 1792.

The construction of this lock is an improvement on Mr. Bickerton's first. It has a double-acting tumbler, having a stump on each end of it, and works in racks at the front end of the bolt, and also at the back of it. The center of motion is in the middle of the tumbler. There is a pin fixed fast in the

lock-plate, and the bolt in locking and unlocking is lifted over it, thereby giving to the bolt an oscillating motion. Should the true position of the tumbler be found, the bolt will not move until lifted over the fixed pin.

ODELL's LATCH, invented about 1792.

This invention is commonly called, and is well known by the name of, a French latch, and is very curiously constructed. The keys are cut of various patterns in the form of letters, figures, etc., with secret contrivances attached in various ways before the keyhole, but which in use, are found to be very objectionable, more especially in the dark.

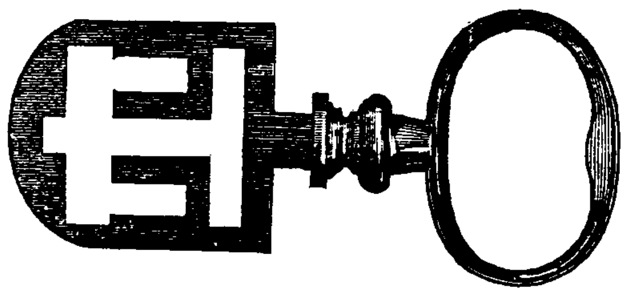


Figure 146. Key to French Latch

The peculiarity of the **construction(488)** consists of a large tongue, which drops down behind the keyhole, and has merely to be lifted up to unlock. This is the night-latch, which gentlemen who have lost their keys, open with their address cards, a very convenient substitute when used by themselves, but not a very desirable safeguard to the domicile.

MASON'S LATCH, invented about 1796.

The improvement introduced by Mr. Mason was chiefly in the latch bolt, by jointing it to a swinging piece similar to a "follow," to prevent friction, and which required considerably less action in working the knob. Also by adding a bar across the gating of the main bolt above and below, one fast and the other loose. To prevent a false key opening the lock, the bolt, if preferred, was shot twice, and the lock required **two keys(489)**, one of which locked out and the other, was a master key. It is supposed that the “shifting or reversing bolt" was the invention of Mr. Mason.

TURNER's LOCK, invented about 1798.

This is what is called a flush-bolt lock, i.e., the bolt of a desk lock, when unlocked, does not project above the fore-end or selvage, as in most other locks of this kind. The peculiarity of the construction consists in the key working within a cylindrical cup, which fits within another cup. There are three or more levers.

The outer cup, which is moveable, drives the bolt, whilst the inner one is stationary. The levers receive a sliding motion at right angles with the face of the cups. The lock has a nozzle similar to Bramah's, and the key is also as convenient in size. It must be noticed that the key reaches to and moves inside the levers.

PEDLEY'S LOCK, invented about 1798.

Pedley's lock was an ordinary tumbler lock. The peculiarity was the key. The bit of the key was jointed to the pipe or shank, and the lock had no drill-pin. A round tube was fixed on the cap, into which the key was inserted, and when it reached the back-plate, the key-bit moving in the joint at a right angle reached the bolt and tumbler, and required the reverse action of the key to act on the spring bolt on the ancient secret principle, before the lock could be opened.

BULLOCK's LEVER LOCK-BOLT, invented about 1800.

The lever lock-bolt is for folding doors, by means of which the upper and lower bolts are withdrawn with ease by the turn of a common door handle, and the same bolts shot and fastened merely by pressing the door to its proper place.

The handle, in external appearance, resembles the round door-handles in general use; when moved, it acts in a double chain 'follow;' the lower chain communicates with a lever which has a pivot near its center, the extremity of which lever raises up the lower bolt of the door when shut.

The upper chain communicates with another lever connected with the upper bolt, which it draws down by moving on a pivot near the center of the lever; and thus the bolts are opened. The upper bolt being stopped down by a reliever at the top of the door, the bolts are prevented from grating either at the top or bottom of the door. On shutting the door, the reliever is pressed in by the wood-work at the top of the door, which sets the bolts at liberty. The lower bolt then falls down, and the upper bolt is

propelled by two springs that act upon the upper and lower levers, and the door remains firmly bolted.

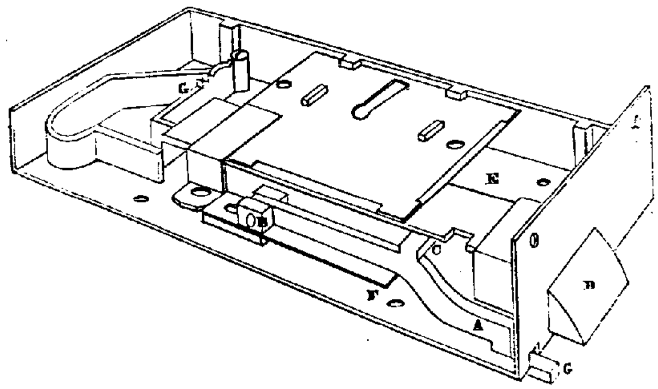
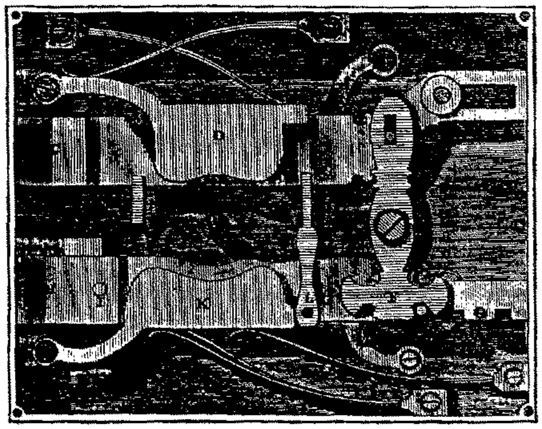


Figure 147. Bullock's Lever Lock-Bolt

A great advantage arises in the use of this invention, from the whole of the machinery acting upon pivots, which are not liable to rust, but allow a regular and easy motion to the bolts.* The inventor of this lock was rewarded by the Society of Arts with a bounty of ten guineas.

ARKWRIGHT'S LOCK, invented about 1798.

This is a "double-bolted" lock, with a double-bitted key. Its peculiar construction will be understood from figure 148.



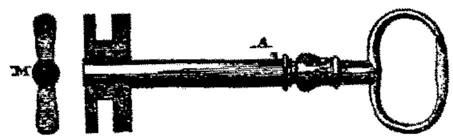


Figure 148. Arkwright's Lock

"*A*, the pointer on the shank of the key; *B* the pin on which the key turns; *C*, the top-bolt of the lock; *D*, the upper tumbler for the top bolt; *E*, another tumbler for the top bolt, and placed underneath it; *F*, a lever which works both bolts, and moves on a center *G*; *H*, the lower bolt, with a joint, *I*, upon its head; *K*, the lower tumbler, with two joints *L L*, which fall into two notches of the top-bolt."

"Underneath the lower-bolt is another tumbler similar to that marked E. There are five springs within the lock, four of which act upon the upper and lower tumblers, the other on the point-bolt H. M is the bottom part of the key. The dark ring in the center represents the hollow to be applied to the lock pin, B, above-mentioned."

To work the lock, it is necessary first "to place the head or bolts of the lock towards the left hand; then take the key with the right-hand, with the small pointer *A*, in the shank of the key towards the right: after this, put the key down to the bottom of the socket upon the center-pin *B* in the lock, and give one half-turn with the pointer in the shank of the key, upwards; by which the bolt *C*, at the top will be locked.

In the next place, draw back the key about one inch, so that the webs or bits of the key may clear the tumblers in the lock; then

turn the key with the small pointer towards the right hand, and put down the key in the manner above-mentioned. After this, make one-half-turn with the pointer in the shank of the key downwards, by which means the lower bolt *H* is locked, and the higher bolt *C*, unlocked.

Then draw up the key as aforesaid, and turn it with the pointer in the shank to the right hand. In the last place, thrust down the key, and give one half-turn with the pointer in the shank of the key, upwards, by which operation both the bolts, *C* and *H*, will be locked; so that, when the bolts are to be unlocked, the pointer in the key must be towards the left hand, and must be worked as above directed."

DAVIS'S LOCK, Patent dated April 11, 1799.

Davis's lock was made with a double chamber, and had wards on the sides of the keyhole. The key was inserted into the first chamber, and turned a quarter round. It was then pushed forward into the inner chamber, where there was a rotating plate, containing a series of small pins, or studs, which were laid hold of by the key.

By turning the key, the plate was moved round, the tumbler was raised, and the bolt shot backwards or forwards. This lock was now used to some extent on the cabinet dispatch boxes; but it was expensive, without affording any very great security.

A circumstance occurred some years ago (1815) which will serve to illustrate the amount of reliance which was then placed upon the security of Davis's lock. One of these locks, by some chance, was sent to Wolverhampton to have a key fitted to it, and was for that object given into the hands of a certain locksmith, who, on taking it to pieces, discovered an inscription inside the lock, stating that into whosoever hands that lock came to have a key or keys fitted, the individual, on application to Mr. Vansittart, the Chancellor of the Exchequer, should receive the sum of twenty guineas.

The amount was applied for, and was duly paid by the right honorable Gentleman, who also offered to the said locksmith a further sum of 100 Pounds if he would give up the name of the person who had sent him the lock. We can vouch for the correctness of this statement, having seen the original letter, dated 25th April, 1815, from Downing-street, which enclosed a bank post bill for the amount, and requesting a receipt for it.

On a similar occasion Mr. Davis posted from Windsor direct to Wolverhampton, to get possession of one of his locks.

There is another anecdote in connection with the inventor of this lock, which we cannot refrain from giving here. Mr. Davis was an inhabitant of Windsor, where he carried on his business as a lock manufacturer, and who was honored with the patronage of his late majesty, King George III, who paid the patentee frequent visits, and who also evidently took a great interest in his welfare.

On one occasion, when in his workshop, his majesty offered to confer on Mr. Davis the honor of knighthood, which Mr. Davis respectfully and humbly declined, saying to his majesty "Sire, it would sound very odd, were I to meet a gentleman in the street, and he were to say, Sir George Davis, please to come and mend my smoke-jack." We need not say that no further reason was required by his majesty, who seemed much pleased with so sensible and consistent a reply.

NORTON'S LOCK, invented about 1800.

In this lock, the key, instead of being adjusted to the main bolt, is gated to a wheel, and the wheel is gated to the bolt. There is also a tumbler, the stump of which works in a semi-circular slot cut in the wheel or disc. There is another slot cut in the wheel or disc from the circumference towards the center, through which is fixed a slide and setscrew, and by means of such slide and setscrew the bolt can be made to shoot out a longer or a shorter distance as the slide and setscrew is nearer to or further from the center of motion.

In ordinary locks, if it is desired to give the bolt a long throw, it is effected by the length of the key-bit, but in this lock, no matter whether the bolt is required to be shot out much or little, it can be done at pleasure by merely altering the position of the slide and setscrew.

HOLEMBURG'S LOCK, Patent dated June 24th, 1801.

This lock is simple in construction, its principal peculiarity being the circular bolt. Figure 149 is a front representation of the lock. *a* is a screw which secures the spring in its place on the lock-plate; *b* is an inside tumbler gated to a stump on the extremity of the orbicular bolt, *c; d* is the key-bit which works inside the orbicular bolt; *e* is a stud for stopping the return of the principal bolt; *f* is the quadra-circular conductor for the

principal bolt; and *g* is the catch which answers to the link-plate in other locks. A fastening for sashes, shutters, and doors, the patentee claimed, which is constructed on the same principle.

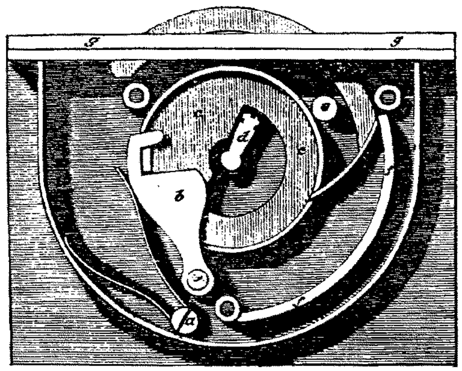


Figure 149. Holemburg's Lock

EAGLE's LOCK, invented about 1801.

The peculiarity of the construction of this lock consists in the employment of spring wards. The wards are produced in two separate parts, with the back part made to fall out of the true circle, towards the center or drill-pin; so that a key cut to correspond with the front wards in moving round would come in contact with and would be stopped by the end of the spring wards. The true key has the cuts of the bit made sufficiently wide to pass both the front and the back or spring wards, and is thus enabled to reach the tumbler and move the bolt. In all other respects it is a common tumbler lock.

DOODY's LOCK, invented about 1804.

This lock is constructed on the secret principle with wards. It is so made that the key will pass round either way without acting upon the tumbler and bolt. The back part of the ward is cut out in two places for the purpose of allowing the key, (by being drawn towards the keyhole), to pass through one of the openings when it comes in contact with the talon of the bolt, which is thus moved, and the key is then pushed through the other opening moved round, and withdrawn in the usual way. The wards of the key are cut to correspond with this "shifting" action. Two studs are fixed in the cap of the lock to prevent the key revolving, unless pushed in to the proper depth.

The inventor of this lock was favored by the authorities of

Stafford Gaol with the repairing of the locks connected with that establishment, and about the year 1812 he was unfortunately in pecuniary difficulties, and became an inmate of the gaol for debt.

By some means, he picked the locks placed between him and liberty, and made his escape, but finding he was likely to be punished if again caught, in the words of the narrator, "he went and picked himself in again." This is one of the many facts which might be brought forward to prove the inferiority and insecurity of the locks in use at that period.

STANSBURY's LOCK, Patent dated May 18th, 1805.

The inventor of this lock, an American, came over to this country in 1805, and patented it, “and was very assiduous in endeavoring to get it introduced; in which attempt, however, he met with so little encouragement, that it might be deemed a failure. Nevertheless, there was sufficient originality in his **contrivance(490)** to merit a notice in this place; the key was of the ordinary shape of those with a pipe, but longer and narrower in the bit, on the lower side of which were a number of pins projecting from its surface; the key had no wards, and the lock, consequently, none.

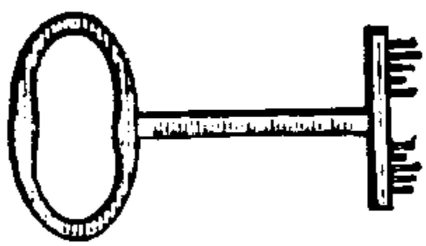


Figure 150. Key to STANSBURY’S LOCK

The bolt was not moved by the key immediately, but through the instrumentality of a revolving circular plate, attached to and underneath which was a fixed pin that took into a notch in the bolt. It was therefore the office of the key to remove the impediments to the motion of the revolving plate, which impediments consisted in a number of pins passing through it and another *fixed* circular plate or bridge underneath, the said pins being pressed through both and made flush with the surface of the upper plate by the action of springs riveted to the bridge.

The two plates thus locked together were separated by the projecting pins upon the key, which, entering the holes in the

upper plate, pressed the spring pins out of them and turned the plate round. The pinholes in the circular-plates were not opposite to the keyhole but on one side leading towards the bolt; so that, to find them out, it was necessary to push the key slightly against the plate whilst turning it round.

THOMPSON's LOCK, invented about 1805.

This lock is constructed with one single-acting tumbler combined with one double-acting tumbler, and is especially adapted for sliding doors, or such doors as are divided in the middle, and which at this period were generally in use. One bolt of the lock shoots into the door-frame, and the other bolt, which is hook-shaped, shoots into the lower part of the door. These locks in former years were very extensively used.

MACE'S LOCK, invented about 1807.

This lock is constructed on what is commonly called the “sun and planet" wheel, and the action is both easy and beautiful. There are double-acting tumblers, the stumps of which are gated into semi-circular slots in the wheel or disc for a long or short shoot of the bolt, as the case may be. The key passes into slots or openings cut in the tumblers, and so moves them into their proper position, moves the wheel, and shoots the bolt. The inventor of this lock was considered in his day one of the best and most ingenious locksmiths of Wolverhampton. His locks were well made and particularly strong.

COX’S LOCK, invented about 1808.

This lock was invented particularly for **fastening(491)** the glazed doors or sashes of rooms opening onto lawns. Many contrivances have been adopted for this purpose, both in this country and in France, but it is questionable whether any of them have surpassed this in effectiveness and simplicity of action. By the use of a rack and pinion, a bolt is shot at both the top and bottom of the one door at the same time as another bolt at right angles to the others is shot into the other door. The inventor of this lock was celebrated for the general quality of his other locks, viz., rim and mortise.

ROBERTS' LOCK, invented about 1809.

The peculiarity of the construction of this lock consists in the employment of a circular disc, which is placed on the drill-pin,

in which are two holes at certain distances from the center. On the bottom of the key-bit are two studs corresponding to the two holes in the disc. In using the lock, these studs enter the holes of the disc and move it round, which at the same time either lifts the tumbler or moves the bolt, whichever the maker of the lock may desire. The disc in this lock is the auxiliary which moves the bolt, and in this respect is similar to Bramah's design.

STUART'S LOCK, invented about 1810.

This lock is very ingeniously constructed, and is one of the many attempts that have been made to introduce into the construction of locks the tooth-wheel. The wheel or disc has cut into its circumference many notches, all of the same depth, except one, which is cut much deeper. There is also a double-acting lever, and a blade riveted on to the bolt, which blade works into the deep notch.

The action of the lock is as follows: the key is inserted and the bolt shot out in the usual way; the key is then lifted up against the cap and moved round six, seven, eight, or more times, until the requisite number of the shallow notches are passed and the true or deep notch or gating of the wheel is moved away as many notches as may be desired.

To open the lock, the exact number of times the key has to revolve before meeting with the deep or true notch of the wheel must be kept in mind, otherwise it would be a question of time how long it would take to open it. As a lock on the secret principle, perhaps it is second only in security to the letter-lock.

This lock would much puzzle a person to open even if he were possessed of the true key. The shallow notches on the disc correspond to the false notches which were subsequently introduced into the lever. The notches in the lever of Strutts lock are upon the same principle.

TOMPSON’S LOCK, Patent dated December 29th, 1808.

Tompson’s was a flush bolt lock, with two tumblers; one was gated to work the bolt up, then the key met another talon and tumbler placed at right angles to the first, and shot the bolt. This lock in its day had a good sale. Tompson was the first to *cast* the projections in flush-bolt and other locks, to save the time

and trouble occupied in fixing them in the manner previously adopted.

ALPORT's LOCK, invented about 1812.

The peculiarity of the construction of this lock consists in the introduction of moveable wards into chambered locks, that is, where there are one, two, or more platforms raised off the lock-plate, and with the keyholes set in various positions in the platforms. These locks are made to lock twice or thrice, as desired.

In using them, the key is inserted in the lock and pulled up towards the cap and passed round, which unlocks one shoot of the bolt; the key is next pressed down on the first platform, tried round to discover where the second keyhole is, and when found, the key is then passed through to perform the second operation of locking, and in the same way for the third or bottom tier, when the key comes in contact with wards that move with the key.

There are two clicks which the nose of the key has to pass, which press against these moveable wards; and should the key nose be too long, it lifts up the first click, which then falls down behind the key, so that it cannot be brought back again, and in passing further round meets with and is blocked against the nose of the second click, which forces a stud on the back of the first click into the main bolt, and prevents the lock from being opened. To shoot back the bolt, violence must be resorted to, the key being held fast in the lock. We may remark that the chambered lock is very ancient, and the inventor of it unknown.

DANIELL'S LOCK, invented about 1814.

Mr. Daniell's, a justly celebrated lock-maker, was one of the first, who in inventing an improved lock, abandoned the complicated constructions of those locks which had preceded it, and by taking the common tumbler and placing another stud upon it, made it a *double-acting* one, without materially augmenting the cost (say two-pence per lock).

It is to be regretted that he did not proceed with his simplifications, but most probably the time was not ripe for the introduction of such simple movements, as his next improvement, viz., the *security-bolt* for latches or spring locks for front doors, is not so simple in construction, but it is very excellent; in fact nothing to the present time has been invented

to supersede it.

Previous to the date of this latter invention, anything that could reach the bolt of spring door latches would easily shoot it back, but Daniell's added a secondary, bolt either above or below the main bolt, and the tumblers or levers being gated upon it, the bolt could not be easily tampered with until the security part of the lock was passed. The general quality of Daniell's locks in his day was second to none, and the locks at the present time, made by his successors are of a very superior quality.

GILES'S LOCK, invented about 1814.

Mr. Giles was the inventor of the padlock, in shape of a ring, and of various other similar forms. They were jointed in the ring part, and the lock was sometimes made as a slip upon the ring and frequently with a projecting barrel, through which the key was forced to reach a spring latch, or sometimes to turn a screw. These locks were remarkably cheap and very useful for all ordinary purposes.

MITCHELL AND LAWTON'S LOCK, Patent dated March 7, 1815.

This lock, invented by Mr. J. Lawton, is one of considerable merit. The principal peculiarity of its construction is the employment of a sliding steel curtain before the keyhole. Figure 151 "represents a six-inch dead lock with the cap removed. *A* is a circular steel curtain, with two keyholes pierced in it, connected with the curved aperture shown at *A*.

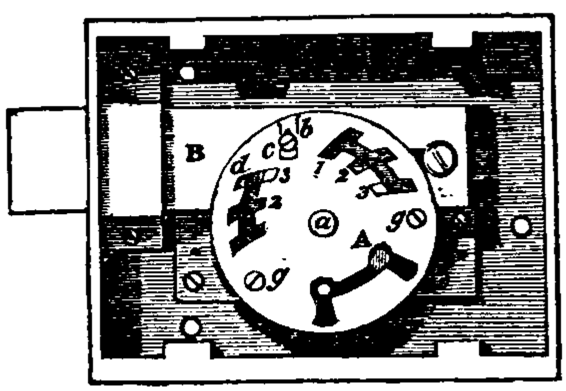


Figure 151.

The curtain *A* turns upon the center pin *a*, and is united to the bolt *B* by the screw *b*, which passes through the curtain, and

enters the stud *c*, to be described hereafter; the stud *c* moves in a slit shown in dotted lines at b; d e represent two stumps fixed to and being part of two tumblers which are placed below the curtain A; these stumps drop into the racks or notches made to receive them in the curtain 1 2 3, 1 2 3, and while there, prevent the bolt A from moving either way.

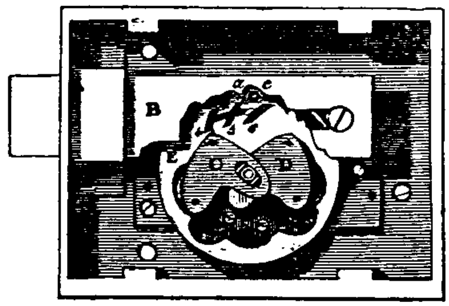


Figure 152.

The action of this part is similar to Barron's principle; but in this lock the motion of the parts is compound; for while the bolt B moves in a straight line, the curtain A turns at the same time upon the center-pin a, and consequently it moves in a circular direction.

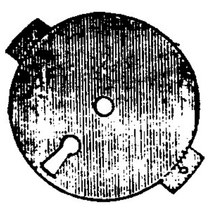


Figure 153.

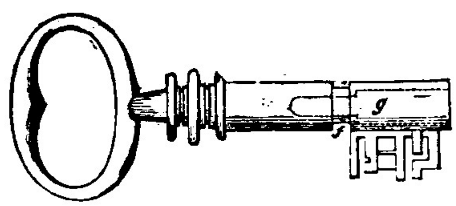


Figure 154.



Figure 155

Figure 154 represents a key; *f* shows a groove formed in the cylindrical part to admit a portion of the steel curtain to enter and move therein, while the key is employed in moving the bolt either backwards or forwards, as occasion may require.

Figure 155 represents the key-pin of the lock detached, so as to give a correct idea of its form, which exactly corresponds with the hole drilled in the key shown in dotted lines at g, figure 154.

Figure 152 represents a lock with the steel curtain removed, so as to show the position of two of the tumblers *C,D*, the stumps of which enter the notches of the curtain, and keep it stationary.

The circular plate *E* has a rack or set of notches *4, 5, 6,* in which a third tumbler acts similar to those that have been described. *c* shows the position of a strong stud, fixed in the circular plate *E*, which comes through a slit formed in the bolt. This stud is tapped to receive a screw, which unites the curtain to the bolt *B* and circular plate *E*. See *b*, in figure 151. Figure 153 shows the cap of the lock detached.

SCOTT's LOCK, invented about 1815.

The peculiarity of the construction of this lock consists of one of the most elegant and simple movements ever introduced, viz., a pair of tumblers gated into two circular discs or wheels. The security of this lock is equal to Barron's.

Figure 156 represents this lock as it appears on the base of *Aubin's Lock Trophy. A* is the bolt; *B* the tumblers; *c c* the two discs; *D D* the studs of the tumblers in their true position in the lower disc. The action is as follows: when the tumblers are lifted to their true positions, the discs revolve, and the studs in the tumblers appear stationary, but when the bolt is shot back, they fall into their original positions in the wheels or discs.

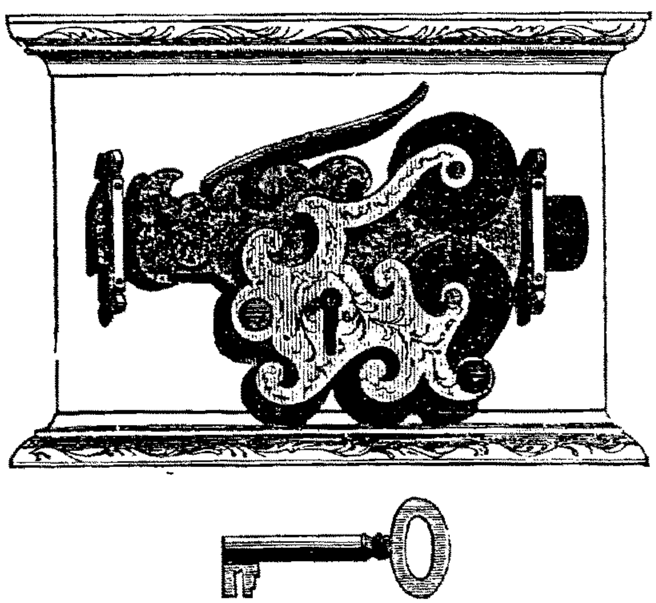


Figure 156. Scott's Lock

We regret that this is the only invention bequeathed by Mr. Scott

to posterity, as he evidently understood the beauty and desirableness of simplicity. This is nearly the last simple movement we have to chronicle, as in most of the other locks we have yet to describe a complicated construction prevails.

DEANE'S LOCK, invented about 1815.

The peculiarity of this invention consisted in combining a Bramah with a Barron lock, the Barron at the front, the Bramah, at the back. The security was of course increased, but at the expense of adding considerably both to the complexity of the lock and the cost of making.

SOMERFORD'S FIRST LOCK, invented about 1815.

The peculiarity of this lock consisted in its being constructed with one double-acting draw-tumbler, which is the reverse of the principle of Barron's lock.

RUXTON's LOCK, Patent dated May 14, 1816.

This is unquestionably the most meritorious lock invented to this period (1816) since that of Bramah's, and is essentially a *detector* lock, and the first of its kind.

Figure 157 represents a drawer or till lock, with the cap removed to show the works. Location *2* is the drill-pin; *3 3* is a ward. The two parallel lines below *2*, and apparently connecting the ends of this ward *3 3*, are two other wards.

The key passes these wards, having apertures or cuts (technically called the wards of the key) for this purpose in its bit. These wards are riveted to the plate of the lock. *A A A A* are the screw holes, through which the screws are put that fasten the lock to the drawer. *B* is the bolt, which has a cap or metal cover, being a plate that is screwed on by the screw a. *c* is a steel fence, to guard against the effects of any instrument that might be introduced at the keyhole. Figure 158 represents the inside of the lock when the cap of the bolt is removed.

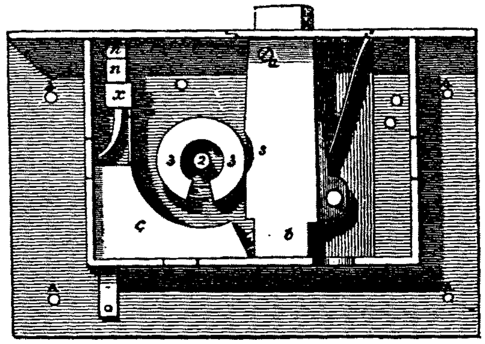


Figure 157. Ruxton's Lock

This cap in figure 157 conceals from view what here appears. *c* is the lever turning on a pivot *a,* and acted on by the spring *2 2*. *B B* is the bolt, the motion of which, up or down, is not hindered by the pivot *a*, nor by the spring *2 2*. *a* is the hole into which the screw goes that screws the cap of the bolt. This screw is seen in figure 157 where likewise the cap of the bolt is seen.

The pivot *a* (figure 158) projects from and is fastened to the lock-plate. The upper end of the spring *2 2* is also fastened to the main bolt. The bolt *B B* can move up and down. Its upper part moves through the selvage, and its bottom moves through the lower part of the rim. In figure 158 the bolt is locked out.

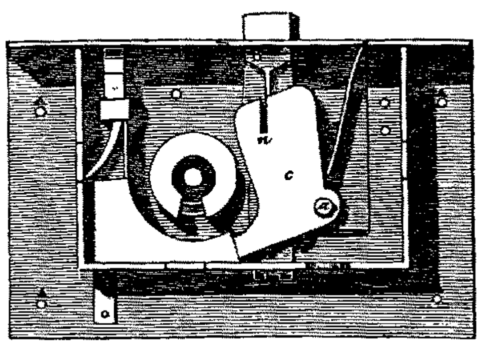


Figure 158. Ruxton's Lock

In the lever *c* is a slit *n*, and unless this slit be placed under the blade *r*, which is a part of the bolt, the bolt cannot descend. Figure 159 shows the position of the bolt after the operation of unlocking has been performed; and here the blade of the bolt appears in the slit of the lever.

It must be observed that there are three levers, and that the

slit in each is differently situated, and that the tails of the levers are of unequal lengths. The tails of the three levers, when in the locks, are concealed from view by the steel fence *c*, figure 157. The three levers being on their pivot are acted on by the springs *2 2*, figure 158, or rather each of them is acted on by one of the three tails which the extremity of *2 2* forms.

The edges of the three levers, when on their pivot, and when the operation of locking has been performed, present an even smooth surface perpendicular to the main-plate of the lock for the key to act on in its progress through the lock. Each lever yields to a moderate pressure and may be moved by such pressure far beyond its limit. On removing the pressure, it regains its former position.

The patentee states that for greater security he sometimes makes the steel fence *c* (figure 157) extend round as far as the bolt *B*. These levers admit of six permutations; four should admit of 24; five of 120; seven of 5,040; and eight of 40,320. The maker, therefore, has it in his power to increase the means of security to any extent at pleasure. Such is Ruxton's lock in its simplest form, but it was also constructed with the addition of a *detector.* As before stated, the fence *c* (figure 157) conceals from view the tails of the levers, but in figure 160 the tail of one of them appears.

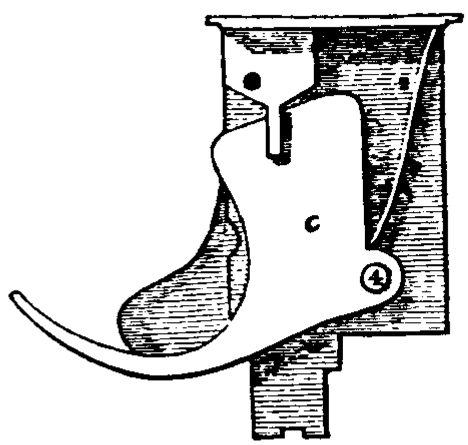


Figure 159. Ruxton's Lever

The ends *d* of all the tails come close to a small and thin plate of metal, which the patentee calls the prop, *1*, (*figure* 160). The outer edges of the tails touch the cheek *4 5* (figure 160). The prop has two pivots, and one part of it is lower than the other.

The prop, though it turns on pivots, cannot turn *towards* the tail *d* of the levers further than to be perpendicular to the main-plate of the lock, but it can turn from the levers so far as to be flat against the main-plate, with its edge, *1*, removed from the levers. To prevent the prop turning too far towards the levers, the spring *a b* that presses on it has a *shoulder,* against which shoulder the prop rests.

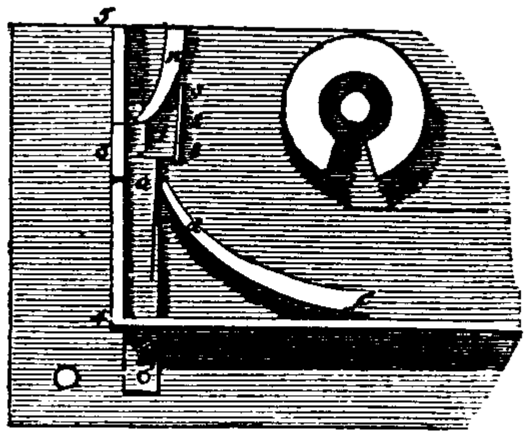


Figure 160. Ruxton's Detecting-bar

At location n, figure 160, is the lower termination of the detecting-bar, the only support for which is the spring a b. In figure 157, the whole of this detecting-bar is seen; it is there marked with the letters n n, and it moves in a piece of metal, x, riveted to the main plate of the lock.

A portion of the upper part of the detecting-bar is larger than the rest of it, in order to prevent its passing down too far through x, and likewise to prevent its passing too high its upper end is, except when violation is attempted, on a line and even with the selvage of the main-plate of the lock, as represented in figure 161. Location w (figure 161) marks the spot occupied (except when there is an attempt to violate) by the upper end of the detecting-bar.



Figure 161.

An attempt at violation is to be supposed to have occurred, and

such an attempt would cause the detecting-bar to fall as far as *x* (figure 157) would permit it. If the prop 1, (figure 160) should be pushed or stirred by the tails *d* of the levers, or by any one or more of them, it must turn so as to lie flat against the main-plate of the lock.

The spring *ab* must press upon, that is, lie flat upon the prop, and the detecting-bar, losing its only support, must fall down. The lock being screwed on to the front of a drawer, the detecting-bar is perpendicular to the plate of the horizon, and therefore, losing its support, it must fall.

It has been mentioned before that the tails of the levers were of different lengths. They are so placed, and the prop *1* (figure 160) is so placed, as that if the tail of either of the levers should move in the slightest degree beyond their true position, the prop would be pressed upward, the spring *a b* would press it so as to make it lie closely to the main-lathe of the lock, and the support of the spring which would have followed the prop would fall, leaving to the view of the proprietor the lock, when he should next open his drawer, a hole in the upper part or selvage of the lock, as in figure 161, which hole, had there been an attempt at violation, would be filled to a level with the surface of the selvage with the detecting-bar.

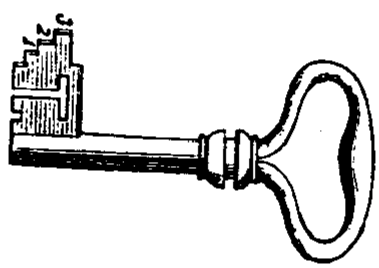


Figure 162. Ruxton's Key

In the specification the patentee names other modes of employing this detecting apparatus. In order to facilitate the readjustment of the detecting apparatus, after an attempt to violate, a part of the main-plate of the lock is sometimes made moveable, up and down, in grooves; which moveable part, when withdrawn, brings with it the detecting-bar, the prop, and the lever, if there be a lever.

The simplicity of the lock is not affected by this apparatus for betraying clandestine efforts to open it, the operations of locking and unlocking being quite independent of such apparatus,

and therefore the lock may be considered to be independent of it.

The patentee further states that, in order to deter from any attempt at violation, he sometimes constructs the lock so as that such an attempt must produce an alarming noise, which may be effected in various ways. Also, that an attempt to violate it causes to be exhibited all indication that such an attempt was made to every person who may chance to look at the thing secured, as, for instance, a drawer.

This is effected by the disengagement of the spring *a b* (figure 160) letting fall a bar within the lock, the end of which bar is, until an attempt to violate be made, on a level with the outer surface of the front of the drawer, but, falling, a cavity appears in the front of the drawer.

Another mode of adapting the principle of a detecting apparatus is (where local situation does not forbid) to construct the lock so as that the person making the attempt will, without sustaining personal injury, be caught in the act; but the particular mode of effecting it the patentee thought it better not to publish.

The patentee states also that he sometimes constructed this lock so that an attempt to violate it must cause the false instrument used in the attempt to be detained; but then such an effect is produced that the lock becomes unopenable by any means, even by its legitimate key, all recourse must then be had to the sledgehammer, the saw, the drill, or the chisel.

He further states that he sometimes so constructs the key so as that, if lost or carelessly kept, a person finding or procuring it shall not be able to perform the operation of unlocking. This object is attained thus; in some spot of the nose of the key, from which should issue no projection, a mock projection is affixed, so contrived as to be removable in a moment, and without trouble.

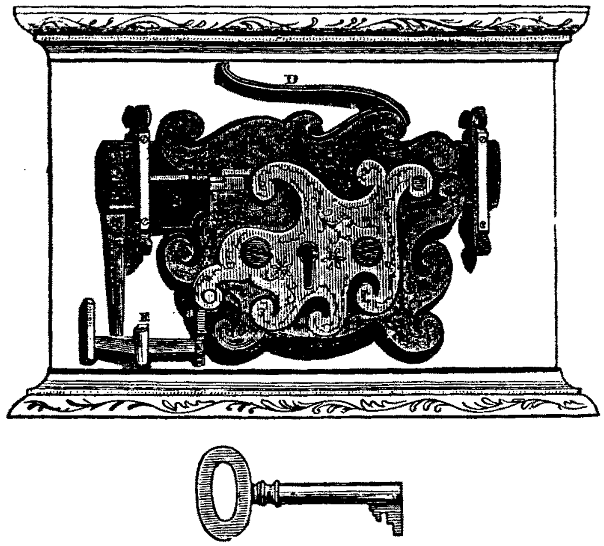


Figure 163.-Ruxton's Tell-tale Lock.

KEMP'S LOCK. Patent dated May 27, 1816.

The security of this lock consisted in the adaptation of tumblers or sliders, operated upon by two, three, or more small concentric tubes of different lengths, placed inside the barrel of the key. These tubes were made of such a length as to push back the pins or sliders that detain the bolt to the required positions, until each one corresponds with the notch that is cut in it for the projecting part of the bolt.

Mr. Kemp calls his invention the union lock, from the circumstance that it unites the qualities of Barron's and Bramah's locks; and from the manner in which the combination is effected. It affords, according to the inventor, a greater degree of security than either of the former, or than both of them together, supposing a lock of each kind was placed on the same door; and that a dishonest servant, who does not possess any particular ingenuity, may be instructed by a locksmith how to take the requisite impressions of either Barron's or Bramah's keys, even if he could be entrusted with them only for a few minutes.

This cannot be done with the key of the union lock, as it would require the locksmith to examine it himself, and to make several tools to ascertain its different dimensions, which he could not do without having it in his possession for some considerable time, with leisure to make repeated trials.

In this remark of Mr. Kemp's we entirely coincide; and it applies to all locks hitherto made (1834), that the *keys,* when in the possession of a workman, *may be copied;* and, in many, without possession. Mr. Kemp's invention may supply a partial remedy for this defect; but until a complete one is provided the art of lock making is imperfect, and no locks are inviolable.

Viewing the subject in this light, it affords the editor of this work (Hebert's Encyclopaedia) much satisfaction to state that he has in his possession a lock, the key of which *cannot be copied;* a locksmith possessing no tools by which an exactly similar one can be made; and the machine by which the original one was made is so arranged as to be deprived of the power of producing another like it.

The lock is very simple, very strong, and can be very cheaply made. The cost of a complete machine to make them would be about one hundred pounds; with that they might be manufactured at one-half the expense of any patent lock. The inventor is desirous to have the subject brought before the public under a patent, but want of time to devote himself to such an object at present obliges him to lay it aside.

The machine here referred to has not to the present time (1856) been patented, and therefore nothing is known of its particular construction; but that such a machine is capable of being constructed to do all that has been stated we verily believe. Further, we believe that such a machine may even be made self-acting. If the attention of the Lancashire machinists were to be given to the manufacture of locks and keys, a perfect revolution in the trade would be the result.

SOMERFORD'S SECOND LOCK, invented about 1816.

This lock is constructed with a lever and two tumblers, but with the tumblers so arranged that one is made to ascend, and the other to *descend,* before the bolt can be shot. The lower ascending tumbler has an iron plate attached to it, the use of which, besides receiving the key and thus bringing it down to its central place, is, that it stands as a complete guard in front of the riding tumbler which descends. The lever on the top of the bolt is also a new construction, having the tumblers working in its racks, and refusing to let them pass until it is brought to its proper position; on which account the inventor calls it the *master lever.*

Figure 164 is a front view of a door lock, with the cap or upper plate removed; *a a* is the bolt, having a longitudinal perforation in each side of which are four notches opposite each other; *b b* is a plate of brass fixed to the bolt by the pin and collet *c*, under which it freely moves. This plate has a perforation, with four notches in the upper side, and three in lower, corresponding with the notches in the bolt, but deeper.

d d is a spring fixed to the top of the bolt acting on the protuberance *b* of the master lever *b b*, and pressing it on one side, so as to prevent the notched perforation corresponding with that of the bolt.

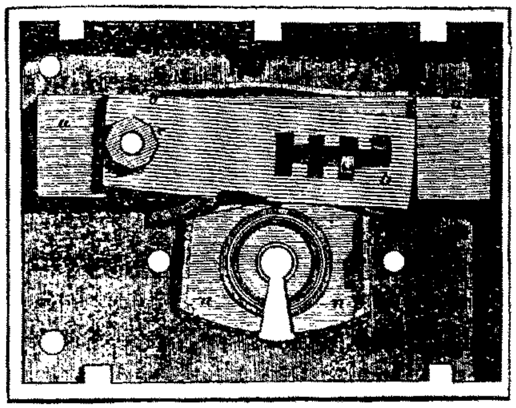


Figure 164. Somerford's Lock

Under the bolt are two tumblers, one standing before the other, both working on a center pin fixed in the bolt under the lever at the letter of reference *c*, and their stumps working in the slots and gatings of the bolt and master lever. By the aid of a double spring acting on the tails of the tumblers, the stump of one tumbler is kept in one of the upper notches of the bolt, while the stump of the other tumbler is kept in one of the lower notches. While in these positions, the bolt is kept from moving backwards or forwards. Therefore, to move the bolt, the key (figure 165) must by its hook *l*, traveling in the groove of the under tumbler *f*, pull the stump just out of the upper notch, and no more, while the front of the key, pushing the second tumbler, moves its stump just out of the bottom notch, and no more.

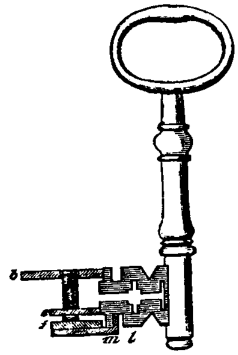


Figure 165. Somerford's Key

Now the stumps being even, the bolt is free of them, but is locked by its upper plate, or master lever *bb,* catching them in two of its upper notches; therefore the upper front of the key must raise this master lever to make its perforation or gating coincide exactly with that in the bolt.

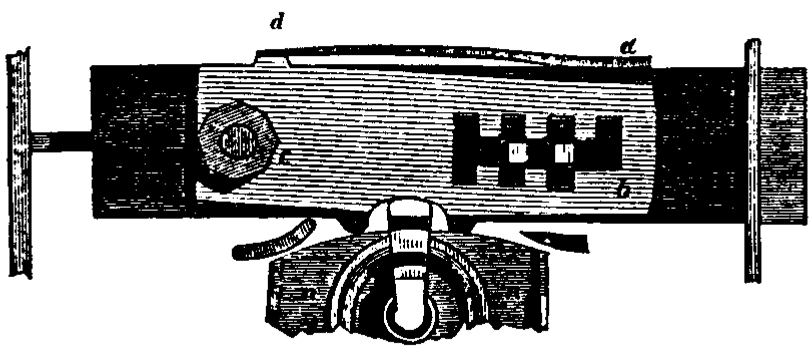


Figure 166.

Then it is quite free, as in figure 166, where the key is in its place, moving the bolt. Figure 167 shows the bolt advanced, the key just left it, when one stump rises into the upper notch, and the other sinks into the lower notch of the bolt, and the main lever, *bb,* falls with one of its notches on the upper stump, by which the bolt has three securities, and these are divided by the plate *n n,* or bridge-ward, which passes through the middle of the key, two being below and one above.

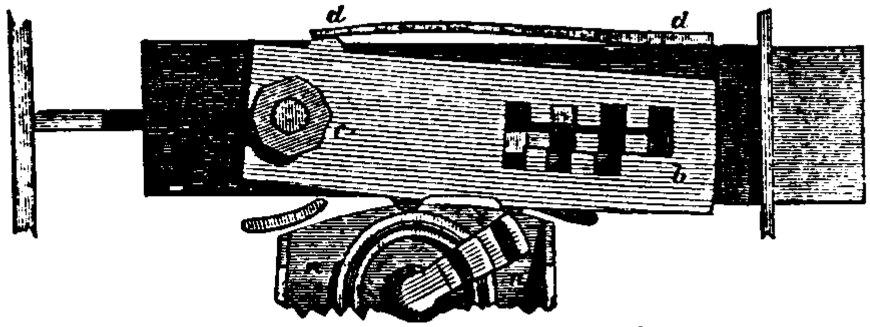


Figure 167.

BURTON'S LOCK, invented about 1816.

The improvements introduced by Burton were in locks for doors made in two parts and for sliding doors, and consisted in making the bolt-head hollow for the purpose of containing the tumbler, and which is the full length of the bolt. On the end of the tumbler there is a hook, so that when the bolt is shot out, the tumbler being attached to the bolt and projecting from the hollow bolt-head fastened onto the lower part of the door; or if sliding doors, then the tumbler hooked behind a plate fixed to the one door and so secured both. There is a stud in the lock-plate for the tumbler to catch and hold on.

DUCE'S (SENIOR) LOCK, invented about 1816.

This is a very simply constructed lock. Its peculiarity consists of a plain bit of iron, which forms both the bolt and a double-acting tumbler. The lock is nearly as secure as Barron's, and can be produced at a lower price than any other lock that is equally secure that we know of.

The action is as follows: the piece of plain iron that forms the bolt and tumbler is gated through a cheek or other projection of the lock-plate. in such projecting piece is cut a slot for the bolt to move through, and a corresponding slot in the bolt; the bolt has either an up or down motion from the key. A light steel spring being riveted to the bolt or the lock-plate, forces the bolt either up or down; and this forms the combination against the cheek or other projection of the lock-plate.

We should recommend the locksmiths of the present day to take this specimen of simple but effective mechanism and count the few limbs it contains. This lock appears to be almost unknown, and it is not improbable that the absence of complexity in the

construction, and want of show in its appearance, were sufficient objections at that period to prevent its being more generally used.

The principle of this lock is similar to the principle upon which the *modern* medical man acts, and the dissatisfaction expressed by the purchaser of the lock and the patient of the doctor is equally the same. In the first case the buyer exclaims with astonishment, "Why there is nothing in it;" in the other case the patient exclaims when he receives his bill." By the powers! I have had nothing for my money."

Many persons in the one case think that to make a lock secure it must necessarily be *complicated;* in the other case they as certainly believe, that if the doctor is to do them any good, he must send them *plenty* of physic; and in both theses cases, when such a principle is carried out, they are fully satisfied of having had "value received" for their cash.

TOY'S IMPROVEMENTS, introduced about 1816.

It is to Toy that the merit is due for improving stock or wood locks, by the introduction of solid brass wards of peculiar and various designs, and also combining the common tumbler with a lever, and working both from one center of motion, thereby adding materially to the security of the lock, with but little addition to the cost of manufacture. He also introduced barrels of a peculiar form, which worked in the keyholes; and some of the latter had the drill-pin fixed in them.

All wooden locks are called stock-locks, from the circumstance of the mechanism being embedded in a piece of wood, the same as the gun-barrel; the locks are embedded in their wooden stock.

There is another lock of this description, called the "Banbury lock," in which the various limbs composing it are fixed separately in the piece of wood hollowed out for the purpose; whereas in the former the lock is first made complete on its plate, which is then inserted in the cavity of the stock prepared for its reception.

The Banbury locksmiths are in the trade called "wooden jewelers", but from what cause history doth not inform us.

HIGGINSON'S LOCK, Patent dated February 1, 1817.

This invention consists in the adoption of a cylindrical roller in a particular and novel manner attached so as to prevent the introduction of pick-locks for opening works.

Figure 168 is the representation of the external part of a cylindrical box, to be attached to or upon the cap-plate. The keyhole of the cylindrical box is reversed to that of the cap.

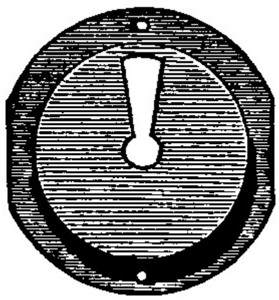


Figure 168.

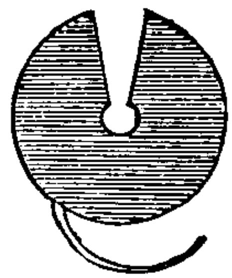


Figure 169.

Figure 169 is a roller, to be placed within the cylindrical box, with a slight spring only for the purpose of tightening it within the box. The object of this roller, which revolves (by turning the key) is to cover the keyhole from the introduction of a pick-lock; for when the key is out of the lock, this roller prevents all communication with the keyhole, and consequently with the interior; until by its revolution the aperture for the key to pass is brought opposite to the keyhole of the cap-plate.

Another mode which the inventor claims for the purpose of preventing the possibility of picking the lock is described in figure 170, and consists, first, of a cylindrical piece, *a*, sliding upon the circular ward, and closing or preventing all access to the works from the center. It has an aperture for the introduction of the key, by which the cylindrical piece is carried round, and upon withdrawing the key the aperture remains opposite to the hole of the cap-plate, or by the adoption of a revolving cross, fitting to and acting within the wards, so as to exclude all passage to the inner works.

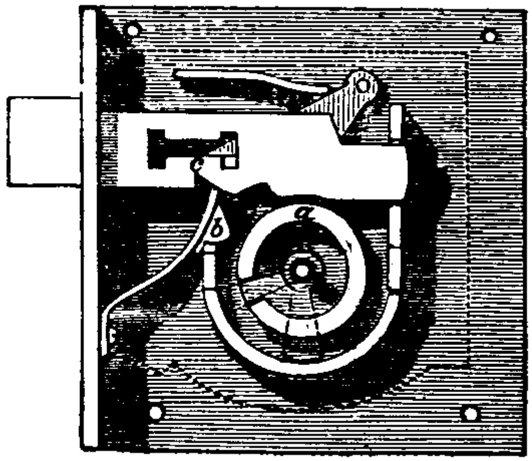


Figure 170.-Higginson's Lock

To preclude the introduction of a pick-lock through the outer channel of the wards, a projecting piece is placed marked *b*, bearing against the circular ward, and supported by a spring lever to admit the passage of the key. This piece *b*, if *attempted* to be raised by a pick-lock, or any other force, would recede into the notch *c*, and prevent the bolt from returning. In the alternative, instead of attaching this projecting piece to a spring, it may be suspended, against which a spring acts for the same purpose as the former, and by its receding into the notch, as before described, locks or confines the bolt.

***GOULD'S LOCK,* invented about 1817.**

Gould was the inventor of the lock with a *sliding* talon, i.e., the back talon or gating of the bolt is filed off, and a slide attached thereto which crosses the bolt, and is forced down by a spring at the back. On to the slide is riveted a spring with a stud upon it, and which holds to the main bolt. There is also a piece or bib which projects from the spring, which the key acts upon when required.

The locks were constructed with two or three levers, and sometimes with a common tumbler. The talon is the secret; for after locking the bolt out, the key is turned round again quietly to catch the bib and force the talon up, so that any key would pass by without moving the bolt. To bring the talon down again the key is used the reverse way.



Figure 171. Barron's Fly-talon

This is the second invention of a moveable talon. The first is that of Barron's, which was introduced soon after his patented lock, and was called the "fly-talon," as shown in figure 171.

LEES' LOCK, invented about 1817.

Lees' invention consisted of a peculiarly constructed *escutcheon* or *blind* for the keyhole of trunk locks, and although keyholes were in the locks, yet no keys were required to lock and unlock them. There were studs which had to be forced down in various positions, or sometimes these studs had to be pulled up to release the bolt. The escutcheon or blind was either lifted up or turned part way round, whichever was necessary to move the obstruction to the passage of the bolt.

BRUETON'S IMPROVEMENTS, introduced about 1817

The late Mr. Thomas Brueton, of Bilston, whose father and grandfather were dog-collar lock makers, introduced various improvements into these useful little locks. Some he constructed on the secret principle, others had two drill-pins, whilst some had fluted keys corresponding keyholes.

We have been presented with an assortment of these curious locks, selected from a stock left by Mr. Bureton, and now in the possession of his successor in the business, Mr. John Harper, jr., of Willenhall. We are indebted to this gentleman for several other specimens of locks and much interesting information, which we shall make use of in the course of the work.

CHUBB'S ORIGINAL LOCK, Patent dated February 3, 1818.

The patentee in his specification states:

"My improvements in the construction of locks are applicable

to all such locks as contain tumblers, sliders, or detents, for the purpose of detaining the bolt of the lock and preventing all motion, or withdrawing it, unless such tumblers, sliders or detents are first disengaged from the bolt. They also render these locks more secure, and likewise give **notice(492)** to the owner if any attempt has been made with a false key, or otherwise to violate the lock."

After describing the various kinds of locks then in use he states, "I do not make claim to the invention of any such lock as aforesaid, or to any particular combination of its parts, but my invention consists in the following improvements thereupon."

"First, in what I call detecting mechanism, of which the parts are as follow: the detector is a detent or lever, moving upon a fixed center-pin, and formed with a hook or catch, adapted to interlock with a notch or stud in the bolt of the lock, so as effectively to stop and resist the motion of such bolt whenever the detector is moved on its centerpin, so as to come into contact with the bolt. But if the detector is moved on its center-pin, so as to be clear of the bolt, it will then make no opposition to its motion.

The detector spring is a spring applied to the detector in such a manner as to urge its hook or catch towards the bolt when the detector is moved, or as to bring the said hook or catch nearer to the bolt than a certain position, which may be called the point of detection. The said detector spring will urge the detector hook away from the bolt whenever the same is at a greater distance from the bolt than the said point of detection.

The detector is so placed as to be operated upon by the tumblers of the lock when the whole or any of them are raised; and if any one of the tumblers is raised too high, that is to say, is moved further from the center of motion of the key than the required position in which the notch in such tumbler comes opposite to the stud of the bolt, as before described; then such tumbler, which has been too much raised, will move the detector beyond or within the point of detection.

In which case the detector spring will throw the hook of the detector into contact with the bolt, and the detector effectively stop any motion of the bolt, even though the tumbler, which occasioned the detection, should be restored to its proper position. Even though any one of the tumblers which may be raised too high will operate against the detector to throw its hook into

the bolt, yet there is no connection between such tumbler and the detector.

This can occasion the detector to leave its then position, as the true key of the lock will raise each tumbler to its required position, and no farther: it will never throw the detector beyond or within the point of detection, consequently the detector-spring will always keep the detector hook disengaged from the bolt.

If a false key or pick-lock be employed to raise the tumblers, there will be every probability that some one will be raised too high, and will move the detector beyond the point of detection, so that the detector-spring will then throw the hook into contact with the bolt. In this state, the lock is what I call detected, and the possessor of the true key has evidence that an attempt has been made to violate the lock, because the said true key will not now open it, for neither the true key or tumblers have, any means of communication with the detector after it has passed within the point of detection.

The remaining parts of my detecting mechanism are for the purpose of regulating the lock, or releasing its bolt from the detector; they are as follow: the regulating bolt is a bolt or slider within the bolt, adapted to operate upon the detector in such a manner as to raise or remove the hook thereof away from the bolt of the lock beyond the point of detection, and is operated upon by an adjusting instrument, which I call the regulating key, which may be similar in form to other keys, but will not open the lock, it being designed only to discharge the detector and restore the lock to such a state of adjustment that its own key will open it. For this purpose it has a different arrangement of the steps on its bit, one of which shifts or moves the regulating bolt.

The regulating bolt may be placed over or under the bolt of the lock, and has a pin or stud which projects from it, and applies against the same, or other tumblers, which are adapted to resist the motion of this regulating bolt, unless each one of the said tumblers are raised or moved into a given position, and neither more or less, by means of the several steps in the bits of the regulating key.

The regulating key being applied in its place in the lock, and turned partly round, its several steps will first raise each tumbler to its exact required position, and then it will move the

regulating bolt, by which means the detector will be moved without or beyond the point of detection, and the detector-spring will throw the hook of the detector out of the reach of the bolt, which may be effected by a small inclined plane, or wedge, upon the regulating bolt.

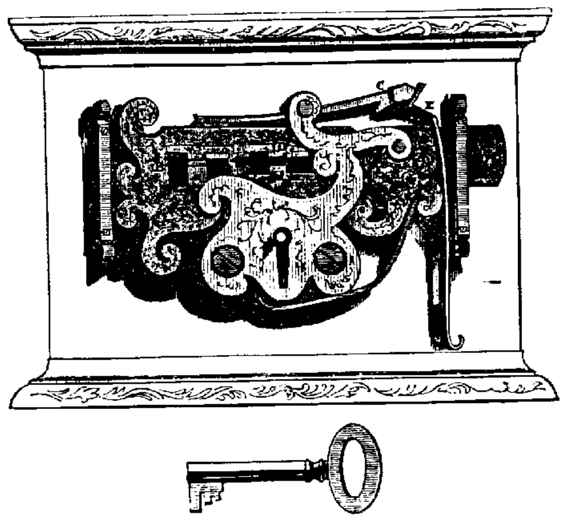


Figure 172. Chubb's Original Detector Lock

By this means the lock will be regulated or restored to its original state, and can be opened by its true key. Figure 172 represents a lock from Aubin's Lock Trophy, made according to this first patent. A is the bolt; B are the levers, or, as called in the specification, tumblers; c is the detector; D is the regulating bolt; E is the detector-spring.

There is an important difference between the original lock and all Chubb's other locks in the action of the "detecting mechanism." In the original lock the detector was released by a separate key acting on the regulating bolt, which left the main bolt unmoved; while in the others, in order to release the detector, the bolt has to be shot further out. This necessitates great care in the fixing of these locks, for unless sufficient play is allowed in the bolt-hole for the extra shoot of the bolt when the lock has been detected, the main bolt remains fixed in its detected position, and cannot be moved, and consequently the lock cannot be opened.

It is therefore necessary to allow from one-eighth to one-quarter of an inch, according to the size of the lock, in the depth of the bolt-hole, to allow for this second shoot of the bolt, in releasing the detector.

We may here remark on the subject of detectors in general, that we do not attach that importance to them that many do. The ready manner of releasing the detector lessens considerably its value as an indicator of the lock having been tampered with, for on attempting to unlock the lock with its proper key, the hindrance would in most cases be thought to be accidental, or arising from some misplacement, and in a moment, without consideration or reflection, the key would be reversed and the idea never occur that the detector had been thrown at all.

"The detector, although possessing some advantages is not without its evils, especially in locks where it is liable to be thrown by the tumbler being very slightly overlifted. In this case, the pressure commencing almost immediately upon the tumbler being raised to its proper elevation for allowing the bolt to pass, may indicate to the lock-picker the character of instrument to be used; and in such locks, when by long use the tumbler springs are considerably weakened, the detector may sometimes be started by a sharp movement of the proper key. Where there exists the remotest possibility of this occurring, the contrivance were far better absent, as the discovery of a detector being thrown is one of grave importance."

The editor of Hebert's Encyclopaedia, in his remarks on this subject, says "In Barron's and Bramah's locks, the picker has no means of knowing whether the tumblers are lifted too high or not; but in Chubb's he has only to put the detector hors de combat in the first instance, by a correct thrust from the outside of the door (which might be accurately measured), so as to fix it fast in its place; the detector then becomes a stopper to the undue ascent of the tumblers, and the extent of their range is thereby correctly ascertained; thus it appears to us the detector might be converted into a director of the means of opening the lock."

Our *greatest* objection to the use of detectors is, that these locks frequently, from various causes, detect themselves, and the mischief which may be caused in an establishment under such circumstances is most distressing to contemplate. The detector is thrown, and the proprietor at once jumps to the conclusion that some one of those who had access to the apartment or depository has been tampering with the lock.

Figure 173 represents Chubb's Lock as it was constructed at the time of the Great Exhibition of 1851. Having described the original invention, we shall here insert a description of this

lock from Mr. John Chubb's paper "On the Construction of Locks and Keys," read before the Institution of Civil Engineers in 1850, and which he afterwards published. We are indebted to Mr. John Chubb for a copy of this interesting paper.

Mr. Chubb stated that the lock bad been "improved upon by the successive patents of Charles Chubb, in 1824; by Charles Chubb and Ebenezer Hunter, in 1833; by John Chubb, in 1846; and by John Chubb and Ebenezer Hunter, in 1847." The last-patented lock, which, while retaining the peculiarities of the former inventions, has received such modifications and improvements as were, in practice, found to be necessary.

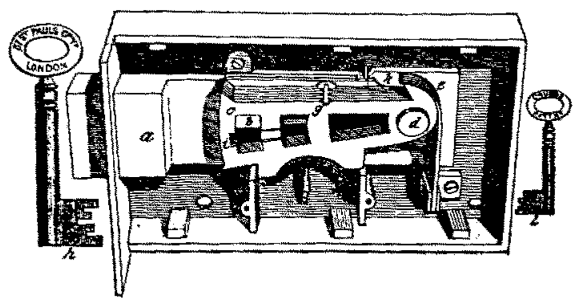


Figure 173. Chubb's Lock of 1851

It may here be stated, in order to render the drawing more intelligible, that Chubb's lock consists of six separate and distinct double-acting levers, with the addition of a detector, by which any attempt to pick or open the lock by a false key is immediately notified on the next application of own key. The detector is the great and peculiar feature by which Chubb's lock is so well known.

In figure 173, "*a* is the bolt, *b* the square stud riveted into and forming part of the bolt; *c* are the levers, six in number, moving on the center pin *d*, placed one over the other, but perfectly separate and distinct, so as to allow all of them to be elevated to different heights. *e* is a dividing spring, forming six separate springs, pressing upon the ends of the six levers. *f* is the detector-spring. It will be observed that the bottom lever has a tooth near the detector-spring. *g* is a stud or pin, fixed into and forming part of the bottom lever, and *h* is the key.

Now it will be obvious that the whole of the levers must be lifted precisely to the different heights required, to allow the square stud *b* to pass through the longitudinal slots of the levers, so that the bolt may be withdrawn. There is no means of

telling when any one lever is lifted too high, or not high enough, much less can the combination of the six be ascertained.

If a false key should be inserted, and any one of the levers should be raised beyond its proper position, the detector-spring *f* will catch the bottom lever *c*, and retain it, so as to prevent the bolt from passing; and thus, upon the next application of the true key, immediate notice will be given of an attempt having been made to pick the lock, as the true key will not then at once unlock it.

By turning the key, however, the reverse way as in locking, the levers will be brought to their proper bearing, allowing the bolt to move forward, and the stud *b* to enter into the notches *i.* The beveled part of the bolt *a* will then lift up the detector-spring *f,* and allow the bottom lever *c* to fall into its place. The lock being now restored to its original position may be opened and shut in the ordinary manner. It will be seen that when the lock is detected, nothing but its own key can restore it to its former condition.

The following **calculation(493)** will show the number of changes that may be made in the combinations of Chubb's locks. The same principle will, of course, apply to any other locks having a number of moveable levers, tumblers, or sliders.

The number of changes which may be effected on the keys of a three-inch drawer lock *1*, is *1* by *2* by *3* by *4* by *5* by *6 = 720*, the number of different combinations which may be made on the six steps of unequal lengths, as in figure 173, without altering the length of either step. The height of the shortest step is, however, capable of being reduced twenty times, and each time of being reduced, the *720* combinations may be repeated; therefore *720* by *20 = 14,400* changes.

The same process, after reducing the shortest step as much as possible, may be gone through with each of the other five steps; therefore *14,400* by *6 = 86,400,* which is the number of changes that can be produced on the six steps. If, however, the seventh step, which throws the bolt, be taken into account, the reduction of it only ten times would give *86,400* by *10 = 864,000* as the number of changes on locks, with the keys all of one size.

Moreover, the drill-pins of the locks and the pipes of the keys may be easily made of three different sizes, and the number of changes will then be *864,000* by *3 = 2,592,000*, as the whole

series of changes which may be gone through with this key.

In smaller keys, the steps of which are only capable of being reduced ten times, and the bolt step only five times, the number of combinations will be *720* by *10* by *6* by *5* by *3 = 648,000*. On the other hand, in larger keys, the steps of which could be reduced thirty times, and the bolt-step twenty times, the total number of combinations will be *720* by *30* by *6* by *20* by *3 = 7,776,000*.

Our readers will most likely remark that this lock ought indeed to be secure, combining, as it does, improvements secured by no less than six patents, but most of the so-called improvements we consider the reverse, as we believe the *original* lock, with its simple detector and regulating-bolt, the most meritorious, as well as the most secure, of any of the subsequent inventions.

DYASS'S LOCK, invented about 1818.

Dyass was the inventor of the semi-circular bolt lock. The bolt of the lock was flush, and there were no limbs projecting from the link-plate. This contrivance made the lock very convenient to use. It was cheap, and had an excellent sale.

It is supposed the same inventor introduced the common *flush-bolt or dog-lock,* in which the bolt is moved by a limb called a "dog" working on the drill-pin.

SMITH'S LOCK, invented about 1818.

Smith is supposed to have been the inventor of the *flush-bolt* Bramah desk-lock. The bolt, which is of a semi-circular form, works out of the selvage, and is driven forward by a curiously-formed scroll or eccentric perforation in the bolt. He also very much improved the flush-handle.

WRIGHT's LOCK, invented about 1818.

The peculiarity in the construction of Wright's lock was that no key was required to open it. The drill-pin was riveted into a slide that formed a spring-catch. To open the lock, the drill-pin was pulled down with any convenient instrument to release the catch; but if a key were put on the drill-pin, the keyhole being made very close, it would not come down. In trunk, letter-bag, and similar locks, the thumb-nail was sufficient to pull down the moveable drill-pin which released the bolt.

STRUTT's LOCK, Patent dated October 18, 1819.

Although the construction of this lock rendered it tolerably secure at the period of its invention, and although it was not an expensive one to make, its adoption was never considerable, and at the present time it is scarcely used at all.

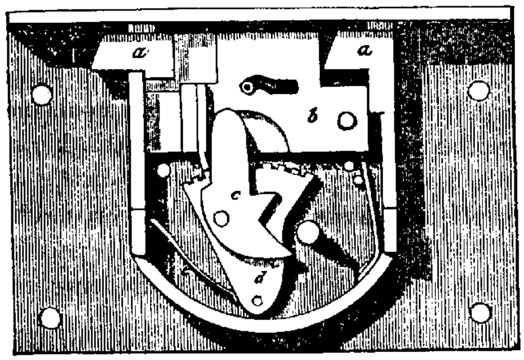


Figure 174. Strutt's Lock

A serious objection to its use is the circumstance of the key having a *reverse* action, *i. e.* after locking, the key is moved a short distance in the opposite, or unlocking direction, before withdrawing it from the keyhole.

Figure 174 represents a spring-box or desk-lock; *a a* are those parts of the bolt *b* which lock into the link-plate. *i* is the top lever which moves the bolt at the same time that the under-levers with the notches on their circumference are acted upon by the true key.

We cannot better explain its construction than in the words of the patentee himself. He states that "the advantages attempted to be obtained by the patentee of this (which was originally invented for private use) are: *perfect security, simplicity, strength, and durability, moderate price,* and a construction allowing the use of *one master key* to a very great number of locks.

"The security of the lock depends on combination carried to a very great extent, so far that any person acquainted with the principle would never think of attempting to *pick* a lock of this kind. In addition to this, deceiving notches on the edges of the plates or levers most effectively mislead the pick-lock, and make him think he is proceeding properly, when he is as far from doing

so as possible.”

“Much has been said about the facility of making false keys to any locks of moderate price. In this lock the key acts upon the plates near their center, and the notches (which allow the bolt to be shot when they coincide) are at the circumference; hence the slightest variation in the false keys from the true one causes these notches not to coincide, and until that is the case the locks cannot be opened."

It must also be remembered that the true key is made at random, and the notches in the plates made afterwards. Now the chances are almost innumerable against the steps on the web of the key being any regular curve, or the curve of one step being similar to the curve of another step. It is impossible, too, for any person to ascertain on what part of each step on the key each plate or lever rests; and the difficulty of taking any impression in wax, etc. sufficiently accurate to work from, will be very obvious to any person conversant with this subject.

“For the strength, simplicity, and durability of this lock, it will only be necessary to say that the parts are all large and strong, the friction very trifling, and the use of springs unnecessary in all larger sorts of locks, such as are used for doors, gates, etc. This in external or damp situations contributes materially to their durability.”

“It allows of a master key to suit of any number of locks, and even of a sub-master key, without increasing the works, or diminishing the simplicity in the least degree: for suppose any number of locks of the same size to be made, each having a different key, if another key having its steps made at random was introduced into each lock, and a set of nicks cut in the plates to allow the bolts to be shot, it would then be a master key capable of opening that set of locks.”

“Again, let another key be made at random, and introduced into any part of that set, say 10, 20, or 30, and nicks made in the plates to allow the bolts to shoot, that would then be a sub-master key, capable of opening that 10, 20, or 30 locks and no other. It must be observed that the space obtained on the circumference of the plates is so very large as to allow of several sets of nicks, and yet to leave an immense number of changes. Locks in suit may be made capable of millions of changes.”

"Another of advantage is, that if the master key to a large set of these locks is lost (a very serious thing in all other locks), the nicks in the plates brought into action by that key may, at a very trifling expense, be soldered or otherwise filled up, a new key and fresh nicks made, and the lost key thus rendered entirely useless."

In this lock, the stump is loose and is attached to the main-bolt, but does not move with it; but as the bolt moves there is a stump on the main-bolt which works through a curiously-formed slot in the loose tongue which carries the stump or blade. As soon as pressure is applied to the lever that works the main bolt (which may be termed an auxiliary, the key not touching the bolt), the stump on the loose tongue falls into the false notches in the levers. This is consequently the first *moveable stump* lock on record, as well as the first with *false notches.*

SPICER'S LOCK, invented about 1819.

This lock is constructed with *double fly-talons* or *detents,* which are applicable also to spring-bolts or latches, and which by this improvement are made self-acting or locking. A small stud projects out of the selvage or fore-end of the lock, which by coming in contact with the staple or striking-plate releases the main-bolt, which then shoots and fastens into the staple.

This inventor is supposed to have been the first who introduced the imitation or "sham" Bramah lock; also the first who shut up the keyhole of locks by the limb termed "bang-up," which consists of either a thin steel spring working over the drill-pin, or a scroll spring driving up a thin disc of metal.

He also introduced the common book-lock, so very extensively used at the present time. He was considered in his day one of the most ingenious workmen in the trade, and when he declined the business he *sold* his principal workman for 42 Pounds to a manufacturer in Birmingham. This custom of buying and selling workmen still prevails in the trade. We shall make some observations on this practice in a future chapter.

We may observe in connection with Spicer's book lock that about the year 1825, the late Mr. Mordan introduced a Bramah book or ledger-lock, which was cast solid in the same manner as the solid locks of Milner, recently patented.

MALLET'S LOCK, Patent dated December 14, 1820.

This lock is of a complicated character, and is constructed with sliding guards in the place of tumblers or levers. These sliding guards, with a "**barricaded-guider(494)**" and a *barrel and curtain,* form the peculiar limbs of this lock, and it is quite evident that the "barricaded-guider" was intended as an improvement upon **Bird's** lock, invented in 1790, and described earlier. Figure 175 is a perspective representation of the lock with the key in it, and the bolt *b b* half way in the passages or gatings of the sliding guards. *a a* is the lock-plate.

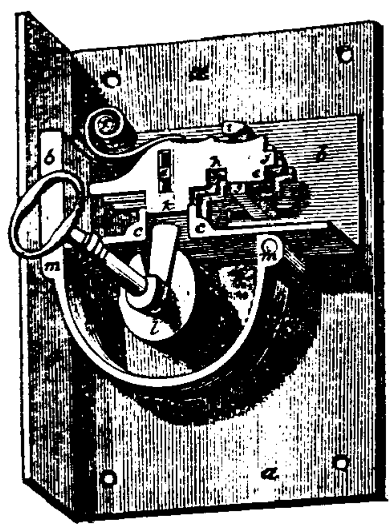


Figure 175. Mallets Lock

On the bolt is fastened the barricaded-guider *c c; d* is a guide-stud which keeps the sliding-guards *e e e,* when moving in a parallel line, from much friction; *f* is the center-pin on which the end of the split-spring is fastened, and round which it plays.

The barricaded-guider *c*, the guide-stud *d*, and center fixed pin *f*, are all attached to the bolt *b*, and move in the lock-plate, *a a*, forward and backward in locking and unlocking is a stud riveted to the lock-plate *a*, which keeps the bolt locked or unlocked by standing beyond the sliding guards when the bolt is shut out or locked; and the notch *h*, when the bolt is withdrawn or unlocked.

i is a guard-stud, also riveted to the lock-plate, between which

and *g* the sliding-guards must pass with great nicety in locking and unlocking. There is a small projection *i* on the back of the sliding-guards, which, when they are all raised to the height wished by the manufacturer, keeps the lines or surfaces of them which are exposed to the action of the key, or any other instrument, by which the lock might be attempted to be picked, in the same plane with each other, higher, but parallel with the surface of the barricaded-guider, or in a variety of places different from the steps of the keybit as required.

The use of this arrangement is to prevent any indication of the corresponding steps of the key-bit, which, if they were not thus stopped, could be ascertained by raising them. *L* is a moveable collar, playing in circular holes, into which it is fixed in the cap and plate of the lock; the part of the collar at the letter of reference (1) is the entire breadth or depth, and it prevents, therefore, the plates being crushed together, while its outer diameter is so large that its periphery comes nearly in contact with the bolt, barricaded-guider, and sliding-guards in their passage, occupying the space of the ward with more effect and at less expense, and therefore rendering it difficult, if not impossible, to introduce the pick-locks in general use to operate on the sliding-guards to open the lock.

m m is the outer rim of the lock, which meets the bolt and the barricaded-guider at each extremity, and when the cap is on, prevents damp and dust from rusting or impeding the action of the spring or the works.

There is a notch in the top of the front of the collar, into which falls a lever-bolt, for the purpose of preventing the collar from being turned round. When the key is introduced and passed through the collar, it presses the reverse end of the lever, and brings the lever-bolt out of the notch, by which the collar is enabled to turn round. This, the patentee states, "is an additional security to the lock, as it is obvious that without lifting the lever, the collar could not be passed round so as to get at the sliding-guards."

A plainer description of the modern “barrel and curtain," patented by Mr. De la Fons in 1846, and claimed by him as his own original invention, could not be written.

AINGER’S LOCK, invented about 1820.

In the construction of this lock, the two following objects were

proposed: In the first place, to render it more difficult of violation by a pick than those in general use; and in the second, to apply a key to it, of which no ordinary person could take an impress, and which, even in a workman's hands, would be very difficult of imitation.

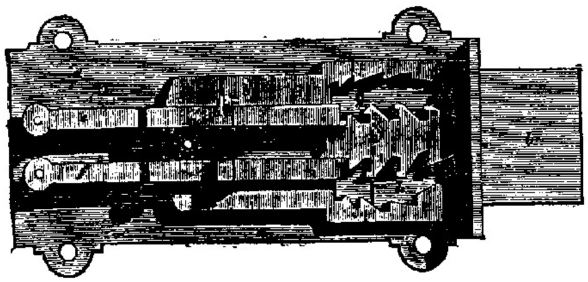


Figure 176.

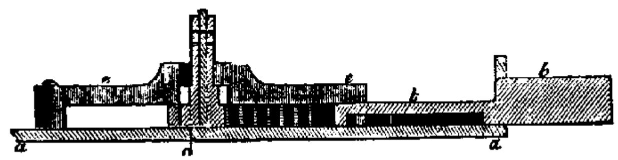


Figure 177.

Figures 176 and 177 represent a plan and section of the lock divested of the key, and of the springs which press the tumblers towards each other: *a a* is the plate or case of the lock; *b b* the bolt which is moved by a pinion *c*, acting in a rack *d; e f* are the tumblers of which four or more might be used, though two are sufficient to exhibit what are deemed the improvements.

These tumblers have projections at their ends, which clip into the grooves *g h* cut in the bolt. The projection of *e* (see figure 177) is equal to twice the thickness of that part of the bolt in which the grooves are formed, but the projection from *f* is only half that quantity, in order to avoid in its passage the spring *i*, which is seen across the groove *h*, and whose situation under the bolt is described by a dotted line.



Figure 178.

The shape of the projection is shown at *k,* figure 178: they are guided by the key through the grooves, as will be described. It is first, however requisite to explain the nature and effect of the spring *i*.

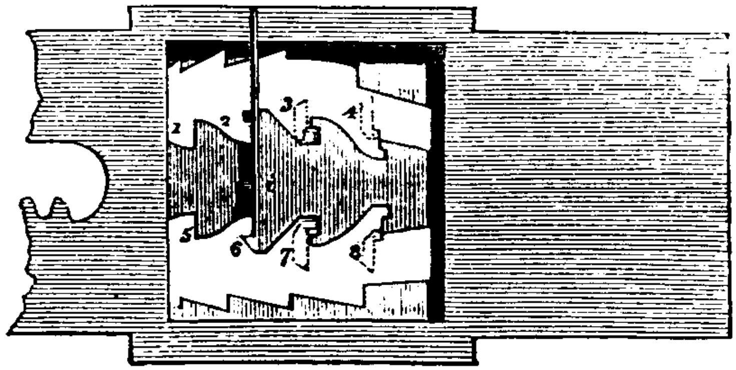


Figure 179.

Figure 179 shows the underside of the bolt, with the grooves and the notches on a larger scale; it also exhibits the partial reduction of half its thickness, in order to contain the spring. The notches *1, 2, 3, 4, 5, 7,* and *8* are similar in their nature and mode of action to the securities already applied to locks of various descriptions: it, will be seen that the notches *2, 3, 4, 7,* and *8* have a hook or beak not attached to Nos. *1* and *5*.

In the notch *8* this hook or beak is formed by a catch at the end of the spring *i*, so that it will recede towards *7* by a slight pressure on its beveled edge; its capability of doing this totally prevents the possibility of disengaging one tumbler from the notches at a time, which is the practice pursued in attempting to pick locks, and by which means the tumblers are removed from the situations in which the pressure of the springs places them, as is shown by the dotted lines in *3* and *7*, and they are placed one after the other, as described in *4* and *8*, in which position they offer no impediment to the motion of the bolt.

This effect cannot be accomplished in the notches *2* and *6*, care being taken that the projection made by the spring be somewhat greater than that in the opposite notch. When this is the case, if, for instance, it was attempted to relieve the tumbler out of No. *2* first, it is evident it would fall in again before No. *6* could be disengaged, and the contrary mode is impossible, because, as soon as the pick ceases to act on the tumbler, its pressure would repel the spring, and it would again take its old situation.

"The form of the key is described in figures 180 and 181; the lower part of figure 181, is supposed to be a section showing the internal chamber, or pipe, in three divisions, the upper and lower being circular, and the middle one triangular."



Figure 180.

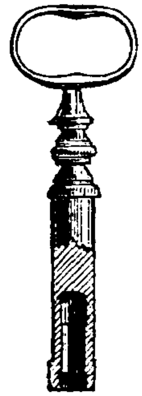


Figure 180.

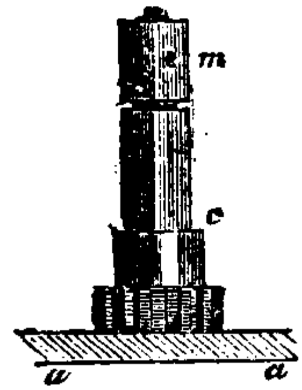
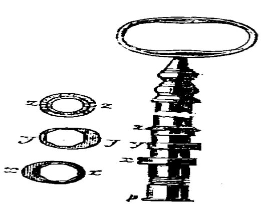


Figure 182.

The use of these three parts may be better understood by referring to figure 182, which is the pinion *c*, drawn on a larger scale; *a a* is part of the lock-plate in which an iron pin is fixed; round this pin the cannon-pinion *c* turns, having the lower part of its barrel circular, and the upper part formed of as large a triangle as can be inscribed in the circle, and having one side circular, as seen in figure 176.

Immediately above, on the extremity of the iron pin, is fixed a similarly shaped piece of metal *m*, secured from revolving by a pin passing through it. When, therefore, the key is introduced, this part not turning, with the rest, it requires that a second portion of the chamber should be cylindrical, to permit its remaining stationary during the motion of the key.

To the lower extremity of the key are attached two irregularly curved collars, *n* and *o*, figure 180, each of which acts on one tumbler, and causes them, during the motion of the bolt, to describe curves similar to the grooves *g* and *h*. To prevent either collar from touching the tumbler for which it is not intended, a portion of each of the latter (being the upper part of one and the lower part of the other) is removed. (See figures 177 and 178.)





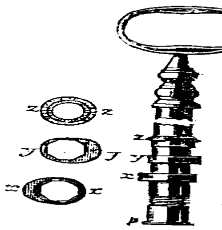






Figure 183.



Figure 184.

Figure 183 describes the means of making a secret or master key on this principle: the lower part of the pipe (which is supposed to be manufactured in two lengths, and afterwards brazed together), is formed into an octagon and surmounted by a screw; the pieces *x* and *y*, similar in their nature to the collars before described, and having octagonal perforations, are to be slipped on to the pipe of the key, and followed by the screw-nut z. The two lengths of the key, being then soldered or brazed together, the three pieces x y and z can never be lost, being secured from coming off by a small fillet p, which buries itself in a recess formed in the piece x for that purpose.

The appearance of the key, when the collars are on the octagon and the nut screwed down, is described in figure 184. Though the collars cannot be wholly removed, it is evident that by withdrawing them from the octangular to the cylindrical portion of the key, they may be turned round, and made to take any required position on the octagon; and if letters or figures were engraved on each of its sides, the collars might be withdrawn and returned to their places by the person acquainted with the secret, while to others there would be 512 chances to one against their being able to make use of it.

"Figures 185 and 186 exhibit the means of rendering a drawback lock as difficult to pick when on the first shoot as when doubled locked: q q is the bolt acted on by the spring t, and having the piece s attached to it; r is an inner or secondary bolt, to which may be applied any species of security now in use for locks. It requires only to be made long enough to receive the apparatus for giving it such security, and therefore its length is not defined. It is connected with the bolt q by a stud holding in the piece s, thus permitting the latter to recede by striking against the staple, while the keyhole having communication only with the inner or secured bolt r, there will be as much difficulty in picking it while on the latch or first shoot as in other cases when double locked."

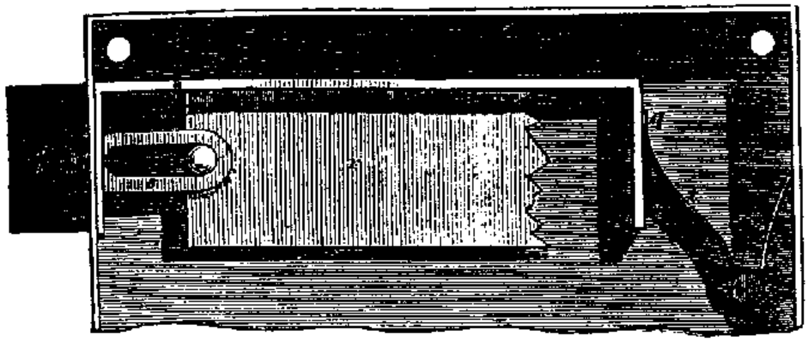


Figure 185. Drawback locking mechanism



Figure 186. Drawback locking mechanism

COPE's LOCK, Invested About 1821.

Cope was the inventor of the rivet lock, and also the lock in the form of a pocket telescope, as well as the doubled-bolted escutcheon lock, the mortise padlock, the fancy or ornamental portfolio lock, the secret link lock, and the jointed link lock, i.e., making the links to lie flush with the link-plate.

FAIRBANK's LOCK, Patent Dated July 10, 1823.

This lock is the invention of a foreigner, who communicated the construction to Mr. Fairbanks, an American gentleman, who at the time resided in London. "The improvement consists simply in the employment of a spiral or worm spring, instead of the Scotch spring." In other respects it is simply a common tumbler lock. The advantages claimed for this lock are that the bolts or latches are moved with greater ease than by any other sort of spring; and also that the spiral springs, whether constructed to exert their force by expansion or contraction, are more durable, and less likely to get out of order than any other description of springs hitherto applied to locks and latches.

WARD's LOCK, Patent Dated November 13, 1823.

This lock was constructed with five levers; two lifted up and two were drawn down, and the top lever worked across the others, and kept them form moving either up or down. The key was made with a

jointed bit, and so constructed that when it was inserted in the lock and turned round the bit elongated, and thus carried the bolt or levers, whichever was desired.

DUCE's QUADRUPLE LOCK, Invented About 1823.

This lock was especially invented for the purpose of securing iron safes and chests. With a single turn of the key it throws out four bolts, one at right angles to each side of the lock; and would, therefore, prevent any door to which it is applied from being opened, even if the hinges were cut away. "It is a combination for four distinct single-bolt locks, fixed in the same frame and opened by the same key; the bolts, therefore, are shot or withdrawn in succession, and present the two following advantages: whatever time and trouble may be required for picking one of the locks must be quadrupled before the whole can be opened; and as the key opens the four locks in succession, the strain on the wards will be much less than in those cases where two or more bolts are moved simultaneously.

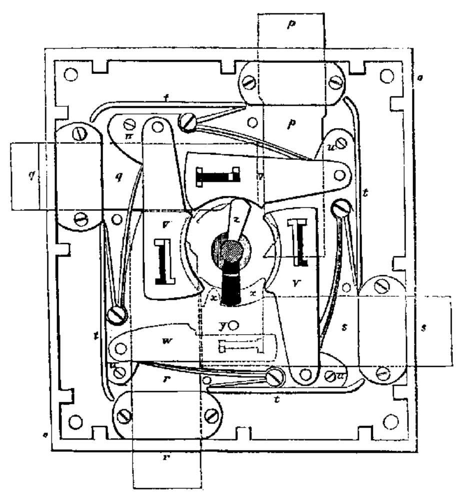


Figure 187. Duce's Quadruple Lock

Figure 187 represents a front view of the lock with the bolts shot out. *o o* the case, *p p* the first bolt, *q q* the second, *r r* the third, and *s s* the fourth bolt; the upper plate is removed, and the lock rests on the inner casing *t t t t*; *u u u u* an inner plate, *v v v* three levers lying on it for the three first bolts.

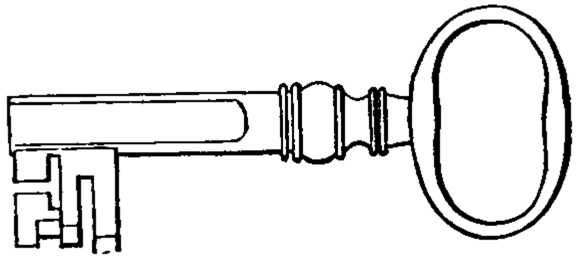


Figure 188. The Key

Beneath each of these levers, and under the plate *u u*, are two more levers, making three for each of these bolts; the last bolt *s s* has but one lever *w*, placed under the plate *u u*, which is moved by the corners of an intermediate piece *x x*, which turns on the pin *y*, as is shown by dotted lines: the key *z* is represented as having thrown out the first bolt *p*, and beginning to protrude the second *q* ; it then acts on the bolt *r*, and lastly on the bolt *s*, moving them to places shown by dotted lines. It withdraws the three first bolts in a reverse order, but finishes with the last *s s*, in either case. The levers are of the ordinary kind.

YOUNG'S LOCK, Patent dated May 14th, 1825.

The construction of this lock was intended as an improvement on Barron's, and was particularly adapted to *stock* locks. The tumblers have two stumps each, one behind, and the other before the bolt, which is racked both on the top and bottom edges.

Over-lifting would in place of lifting a single stump (as in Barron's, out of one notch into another in the bolt) lift the bottom stump in the tumbler into the rack in the bolt. If under-lifted, the top stump would not leave the top rack. In addition to that, there is a revolving-plate working round the drill-pin at the bottom of the lock, which revolving-plate or "swivel," as the patentee calls it, is acted on by a forked spring having a tendency to drive it towards the front of the lock.

This plate has a notch in it, and there is a projection or hook fixed to the back-plate, corresponding in position with the notch in the plate. When the key is pushed in, it depresses the plate, and allows it by means of the notch in it to descend below the hook and pass under it. The swivel also has a pin in it, which locks into a hole in the bolt until it is depressed by the key. As any instrument pressed into the lock would depress the plate and free both it and the bolt, it is manifest that this "swivel"

is of no benefit whatever, while the reversal of the Barron's tumbler affords no improvement in security, and we should think was not quicker made. The improvements were applicable to all kinds of locks.

Another improvement consists in a peculiar mode of cutting out the wood in stock locks. Previous to this period, the oblong-shaped cavity in the stock for the works of the lock to occupy was sawn out; but by this improvement the chamber is formed of a circular shape, which is cut out by a tool in a lathe; and this gives the lock a much neater appearance.

FRIEND'S SECRET LOCK, invented about 1825.

This is a dial lock, which requires the aid of a key to lock and unlock. The inventor states that "Keys or pick-locks are of no use in opening it. The key that belongs to it is of no use to any person without the guide, which is so portable as to be put into a pocketbook, and can be varied in such a manner in a few seconds, by such an indefinite number of movements, as to put it out of the power of any person to open it, even if he is in possession of *the guide,* unless he is acquainted with the numbers to which it is set.

This renders it safe, strong, compact, and secure. To open the lock, you will observe on the guide two circles, with the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, on each, and the stops are now set at 2, 6. Put on the guide to the front of the lock, with the number 1 upward toward the bolt, so that the stops go into the grooves in the plugs. Introduce the key and turn it round, until you can take it out again. You will find the lock open.

Now if you take off the guide, it cannot be shut or locked so as to take out the key; because every time the key comes to be taken out it is open. To shut the lock, put on the guide, and turn the key any part of the way round; then take off the guide. You will find it shut and secure. You may turn the key as often as you please without any effect.

The advantages which the inventor conceives the lock to possess are: (1) That it cannot be picked, (2) That a *facsimile* key cannot unlock it, (3) That the true key cannot unlock it without the guide, (4) That even with the true key and the guide in the hands of strangers, the lock is secure, unless the secret of the numbers set to the lock be known.

Figures 189 and 190 are back-views of the lock, the plate being removed; *A* the bolt; it has two arms with studs *b b,* projecting forwards, and a point *c*, which form three bearings or supports, all or either of which are sufficient to keep the bolt out; *d d,* a spring, the action of which is to withdraw the bolt; *e e,* two similar plates, with notches to receive the studs *b b; f*, a third plate, with a notch to receive the point *c*.

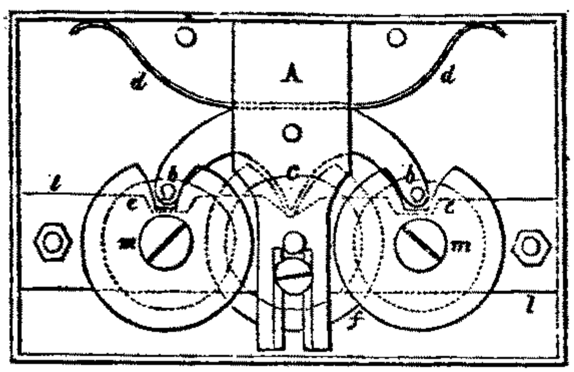


Figure 189.

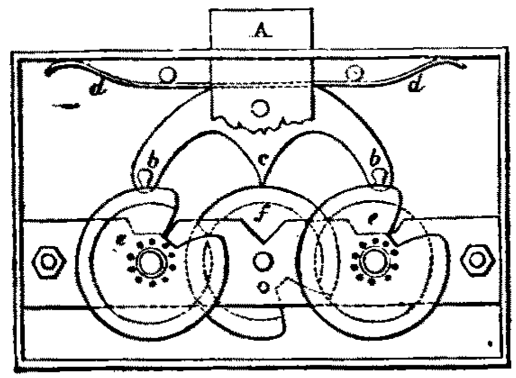


Figure 190.

In figure 189 the notches of all the three plates coincide with the studs, the obstacles to the action of the spring *d,* therefore, are withdrawn, and the bolt retracts. Figure 191 shows the front of the lock. When the key is introduced and turned, it moves the plate f, figure 189, and thus, by raising the point *c* out of the notch, it protrudes the bolt, and as the three plates are connected together by three toothed wheels, shown in figure 192, they all move and keep the bolt protruded, but when the key is turned quite round to withdraw it, the plates again agree with the studs, and the bolt is withdrawn or unlocked; the notch in the middle plate *f* always agrees with the point *c* when the key is withdrawn. Therefore, to leave it unlocked it is requisite to derange the three plates, as shown in figure 190.

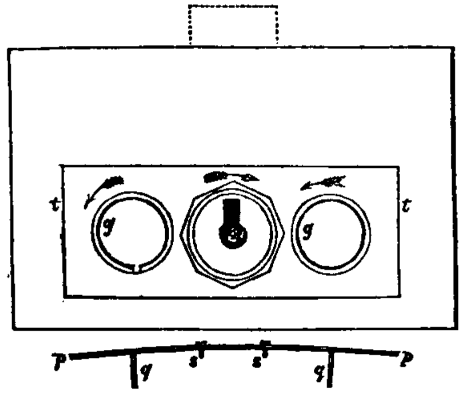


Figure 191.

This is effected by the peculiar construction of the axis *s*, which carries the plates *e e,* one of them is shown, with all the parts separated in figure 198*; g* the axis (the bottom face of which is seen in *g,* figure 191, showing a groove nearly all round it, in which is fixed an upright pin *h.*

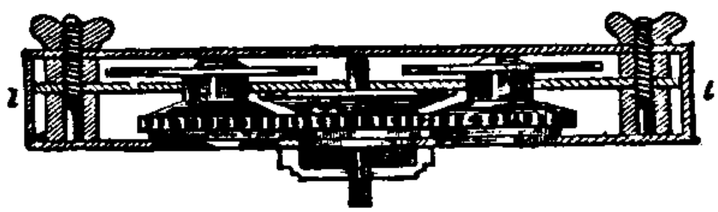


Figure 192.

i is the toothed wheel which first goes on the axis *g; j* a strong spring nut which follows it, and is pinned on so as to hold the wheel very tight, and yet allow it to move alone by applying additional force. Over this goes the bar *l l,* figures 189, 190, and 192, the holes of which are large enough for the nuts *j* to project through.

Over this is lastly put on the notched plate *e*, which fits on the axis *g*, and is screwed tight against the nut *j* by the screw *m*, which enters the end of the axis *g*. In figure 190 the screws are removed to show the plates *e e* and the end of axis *g*. Now in order to prevent each of these plates from turning without its axis *s*, there are ten holes round the center hole, shown in figure 196, and a pin *k,* figure 193, is fixed on one side of the top of the nut *j*, which enters one of these holes and secures it.



Figure 193.

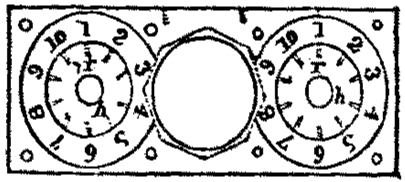


Figure 194.

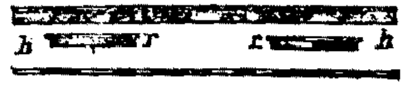


Figure 195.

Figure 197 shows the middle toothed wheel and notched plate *f*, with the axis *o* separate; they are all screwed together by the side screw. Figure 198 shows the front of the axis, with the notch to receive the projection *n* of the key, figure *199.*

o, figure 197 is the end which enters the key. Having described the wheels and their axis, it remains to describe the governor or secret guide plate, which, with the key, either arranges or disarranges the plates. Figure 194 shows the guide plate.

Figure 195 is a section with the parts separated; it has an octagonal hole, which fits on the octagonal projection round the keyhole in figure 191, on each side, and within the circles of numbers are moveable circular-plates r r, having ten holes round their circumference corresponding to the ten numbers.

p p is a spring which screws against the edge of the plate by the screws s s, but is separated here to show the pins q q, each of which, passing through the edge, enters one of the ten holes in the moveable plates r r, and secures them from turning round, by which means the steps or guide-pins h h are fixed at any chosen number.

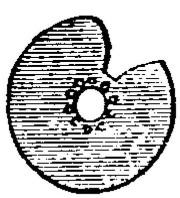


Figure 196.



Figure 197.

Here they are at 6 and 3. Now when this guide plate is put on the face of the lock, as shown by the dotted lines *t t*, figure 191, the pins h h enter the grooves round the face of the axis *g*, and it will be seen that the stops or ends of the grooves correspond with the stopping pins *h*; then, on turning the key any portion round, the middle plate *f* turns and protrudes the bolt, while the two side-plates *e e* are prevented from turning by the pins *h h* in

the grooves *g g*, their respective toothed wheels only turning.

Then, on removing the plate and continuing to turn the key, they will all three move and appear as in figure 190, all supporting the bolt as they disagree.

By continuing to turn the key, the bolt can never be withdrawn, though when the key is taken out, the side-plates only support the bolt. Then to unlock it, put the guide-plate on again and turn the key; all the three notched plates will now move until the end of the grooves *g g,* figure 191, come in contact with the stopping-pins *h h,* which detain the side-plates *e e* in their right places, as figure 189, and continuing to turn the key until it will come out, the middle-plate also agrees, and the bolt is thrown down by the spring *d*.

If it be required to alter the secret, raise up the spring *f*, figure 194, withdraw the pins *q q,* then turn the plates *r r* until the pins *h h* coincide with the intended numbers, and the pins *q q* will fix them.



Figure 198.

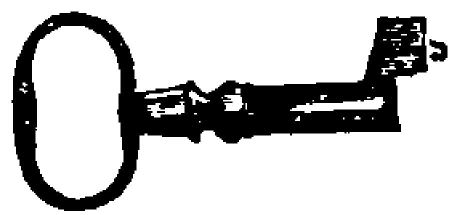


Figure 199.

Then put it on the face of the lock, introduce the key, and turn it quite round, and take it out again; the stops will then have detained the axis *g g* at the right places.

Then open the back of the lock, withdraw the screws *m m lift* up the notch-plates *e e,* which will be found in some such position as in figure 190 (but the middle-plate, when the key is out, is always found as in figure 189), and place them on again as figure 189.

The ten holes round their centers allow ten changes of position in each, screw them fast, and finally shut up the lock. If either one or both the moveable guide-plates *r r* be altered, the lock cannot then be opened; they must be returned to the right numbers which you keep secret before it can be opened.

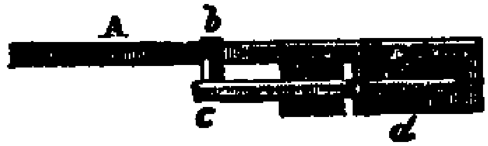


Figure 200.

In figure 190, the tail of the bolt is broken away to show the under parts. Figure 200 a side view of the bolt.

RUBERRY'S BAG-IRON LOCK, invented about 1826.

Ruberry was the inventor of the "bag-iron," and the bag-iron lock so extensively used for carpet and leather bags. He entered a caveat to secure the invention, but would not complete the patent, as he thought it was too simple, and was afraid the locks would not sell. His timidity lost him a large fortune, as the sale of them was from the first very considerable.

RICHARDS' LOCK, invented about 1827.

The inventor called his device a *fixed* lever lock. The peculiarity of the construction consists in the shape of that part of the levers that come in contact with the v-end of the detector. When one or more of the levers are over-lifted in any surreptitious attempt to open the lock, the projecting arms of the levers are forced beyond the v-end of the detector, which keeps them in a fixed position. The detector is released in the usual way, by turning the key in the direction of locking out the bolt.

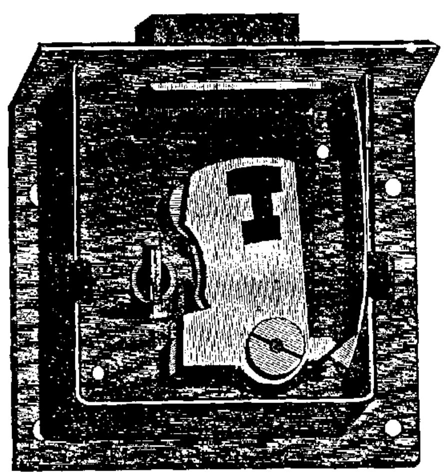


Figure 201.-Richards' Fixed Lever Lock

MACHIN'S LOCK, invented about 1827.

The peculiarity in the construction of Machin's lock consisted in having eccentric wards, which required a key with an expanding bit. “In this key the bolt or lever which raises the tumblers and shoots the bolt is moveable on a countersunk pin, so that it may slide thereon, and thus be drawn one-eighth of an inch from the barrel.”

“The hole in the escutcheon-plate is of such a length as to admit the key only when the bit is pressed close up to the barrel. When the key in this state is introduced, and is begun to be turned round, one of the notches in the bit takes into a raised circular edge of steel, placed eccentric with regard to the lock-pin; so that as the key is turned the bit is drawn out, and is at its greatest elongation when it arrives at the tumblers and other moveable parts of the lock. Hence it is obvious that no common or skeleton key that could pass the escutcheon-plate would have a bit long enough to reach the tumblers and shoot the bolt."

In figure 202 *a a* and *b b* (figure 203) are the wards which are made eccentric, the shortest distance being under the keyhole, and the longest towards the bolt. The shortened key is provided with a sliding bit *c* (figures 205, 206, and 207), which is gradually brought out by the eccentric wards until it becomes long enough both to arrange the tumblers and move the bolt, and continuing to turn the key round, the sliding bit *c*, is returned or slid back until it is short enough to come out of the hole.

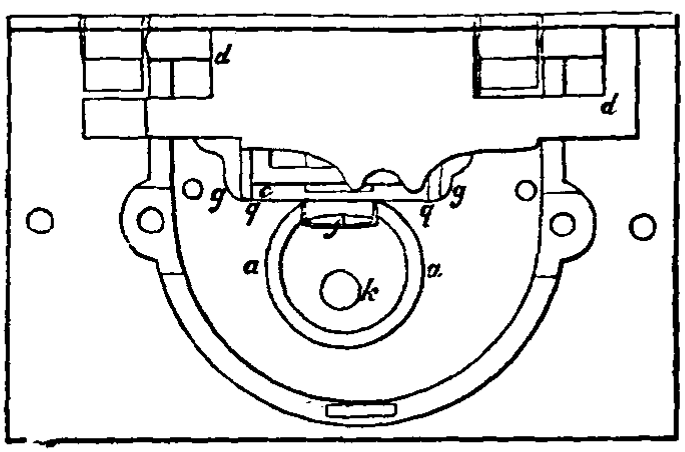


Figure 202.

d d (figure 202) is the bolt, and *e* and *f* parts of the tumblers

under it.

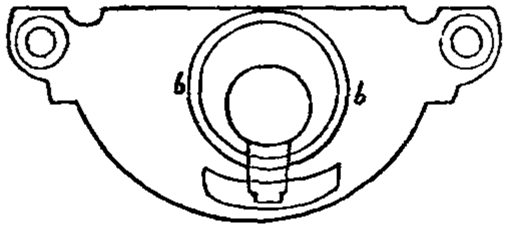


Figure 203.

Figure 203 represents the inside of the cap, which contains the upper ward *b b.*

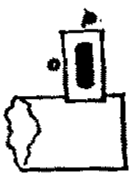


Figure 204.



Figure 205.

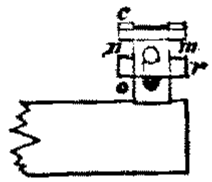


Figure 206.



Figure 207.

The key (figure 205), is partly sectioned, and at different places, purposely to show the thin tube within the pipe which retains the spring and the loose metal plate *s* in their places; the sliding bit *c* is here close, ready to enter the lock; in figures 206 and 207 the bit *c* is shown extended long enough to move the bolt.

CHUBB'S COMBINATION LATCH, Patent dated May 7, 1828.

The object of the improvements introduced by, Mr. Chubb was to render latches of the ordinary description more secure from being lifted or unfastened from the outside of the door or gate by means of pick-locks or false keys. In his specification he states,

"The essential principle of my improvements in the construction of latches, which may be used for fastening doors or gates, consists in combining, two, three, four, or more distinct moveable latches to act in concert for one fastening. They are applied side by side in parallel planes, or one behind the other, all being mounted on one center-pin, and being moveable about the same, but so as that each latch may be capable of such movement by itself, quite independently of the movements of all the other latches, and the outer or moveable ends of all the said combined latches are adapted to engage or catch which or behind the hooked

part of one fixed hasp, and thereby to secure the door or gate from being opened in the same manner as the single latch commonly used."

In addition to the said fixed hasp, so adapted to receive the ends of my combined latches, it is formed with two hooked or catching parts, one disposed opposite to the other, in such manner that the combined latches cannot be unfastened, unless the outer end of every one of the separate latches is previously raised, moved, or lifted (either by the key or by the pick-locks, or by the handle) in such manner as will place all those ends in one precise position.

They must all resume that position at the same time, for in that position alone can the outer ends of the combined latches be disengaged or unfastened, so as to withdraw them from between the opposite points of the double-hooked catches or catching parts of the fixed hasp, because by my arrangement of such combined latches and double catches to the hasp, if the outer end of any one of the latches is moved too far or beyond that precise position, or if any one is not moved far enough, that one latch which so fails of being precisely placed will catch behind one or other of the hooked parts of the hasp in a sufficient manner to secure the door, even though all the other latches may be properly placed, so as to offer no impediment to unfastening.

WALTON'S IMPROVEMENTS IN LOCKS, invented at various periods from 1828 to 1846.

The inventive genius of this family of Wolverhampton locksmiths has perhaps never been equaled by any other members of the trade. They have for many years manifested a happy turn in introducing such improvements into the construction of locks as made them very showy and tolerably secure. They appeared to be always ready with some fresh notion, or with an old one improved. We shall here enumerate such improvements as are known to have emanated from them.

They invented:

The double-handed lock and latch, so constructed as to suit either the right or left hand side of a door;
The double keyholes to locks and latches;
Bolts to double-handed cupboard locks;
The stock lock called “Steele's patent," which is a double-handed stock lock, the lock being inserted in the cavity cut out of the

stock, or mortised therein;
The Gothic-formed cupboard and other locks;
The solid-bolt stock lock;
The boxed-up stock lock;
The back-racked stock lock;
The moveable nose-ward lock;
The H-formed slide lever lock. The levers in this lock are forced down by a spring and follow motion, one to each lever;
The crank-shackled padlock; the round padlock; the solid padlock; and the revolving-wheel padlock;
A beautiful wheel motion to locks. The levers are made of a peculiar form, and worked in racks cut out of the back part of them. A blue-steel ward is fixed upon the levers, so that the key takes both wards and levers, which, by moving together, shoot the main-bolt. This lock had an excellent run;
A very peculiar latch-bolt, which worked from a small pin motion, the key working through a niche into the bolt to draw it back;
Detecting levers, which detect by an under-lift as well as an over-lift. This is effected by a v-formed nose-spring catching in notches on the face of the levers.

They also improved the narrow mortise lock, by cutting out a channel in the main-bolt and working the latch therein, or *vice versa.* This is a neat and useful contrivance, as when the main-bolt is locked out, it also fastens the latch, making together a very strong bolt.

We are sorry to record that for want of a cheap mode of securing inventions to the inventors, the benefits which ought to have accrued to the Messrs. Walton have been entirely lost, for no sooner had they brought out a new lock, or introduced an improvement into others, than the same articles were made by **other makers(495)**, of lighter materials and in a much inferior manner, and being offered to the factors at lower prices, were invariably purchased, and thus completely shutting the inventors out of the market. They have used their talents for upwards of a quarter of a century in inventing and improving locks, without receiving that remuneration which such ingenuity and unwearied exertions justly merit.

There is a custom that prevails almost universally, not only in this but almost in every other trade, which deserves to be censured, and which in the absence of any law to the contrary, can only be amended by a strict regard to a sense of honor and integrity. We mean the practice of procuring all invention or a

design from a person, giving him a small order for the particular article, and then giving the pattern to another maker to be made at a lower price.

Another feature of this same principle is one manufacturer copying the designs of another, and also the size, and shape, and character of his name-plate or trade-mark, and in some cases, the name of the manufacturer also, in order to give the imitation the exact appearance of the original and genuine article.

GOTTLIEB'S LOCK, Patent dated June 21, 1829.

The improvement for which Mr. Gottlieb took out his patent "consisted in the application of a piece of paper over the keyhole, so secured as to prevent its being removed without the introduction of a key passing through it; and hence any attempt to break open the lock would be indicated by the fracture of the paper."

"The paper is introduced and secured by means of a folding-shield with a hole in it, similar to the keyhole in a lock-plate; this shield is kept down by a spring-catch, which cannot be disengaged for the introduction of a fresh piece of paper except by the proper key, which is furnished with a projecting stud on the side of the key-stem, for the purpose of disengaging the shield-catch when turned."

"As a source of further security, the patentee proposes to employ cheque-paper, with some design engraved upon it; and by having this paper bound in a cheque-book, and a leaf torn off when required, so that the paper found in the keyhole at any time being compared with the edge of the leaf in the book, the substitution of another paper would be discovered. There are few cases in which this plan can be advantageously employed."

STANLEY's LOCK, invented about 1829.

Stanley's lock was constructed with a double set of levers, and with a double-bitted key, or rather it was two locks in one; a lock on each side of the keyhole.

CARPENTER & YOUNG'S LOCK, Patent dated January 18, 1830.

The object of the inventors appears from the specification to be the production of locks of greater security and stability than the common locks, without augmenting the cost; and also to

construct a latch-lock somewhat more convenient in use.

The greater degree of security is obtained by having a double set of tumblers, one set attached to and moveable with the bolt, and the other attached to the plate of the lock in the usual way. Projections from the stationary tumblers fit into slits in the moveable ones, when they are simultaneously elevated to a given position; and, in addition to this, there are notches cut in the upper and lower sides of the moveable tumblers, to fit fixed pins projecting from the plate, just above the notches on the upper side, and just below those of the under side when the door is locked, so that the bolt cannot be withdrawn except by a key, which raises each tumbler to an elevation coinciding precisely with the cuts in the original key, and upon this depends the security.

Instead of the usual latch or spring bolt to room-door locks, the patentees cause this part to drop into a notch in the striking-plate after it has been elevated by passing over an inclined plane upon it. In connection with this latch is a tumbler, by which it is elevated through the instrumentality of a key, by a handle on one side of the door and a key on the other, or by the key, without using the handle. These contrivances have manifest advantages, and are easily executed by any locksmith.

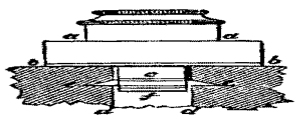
MORDAN'S LOCK PROTECTOR, invented about 1830.

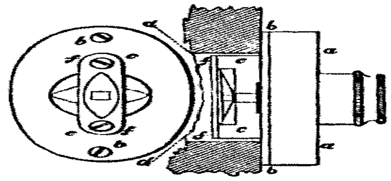
Traveler's' chambers at inns are sometimes robbed because the locks on the doors are generally very insecure, and all on the same construction, so that a key which will open one lock will open them all. In order to prevent this, Mr. Mordan has invented a very portable escutcheon, by means of which a traveler may secure the door of his room from being opened during his absence, unless actual violence be used.

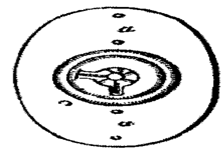
This escutcheon, or protector, has a short pipe, which, after the door has been locked, is thrust into the keyhole, and is furnished with a small lock, on the principle of Bramah's, or any other equally good, so contrived that, on turning its key, two lancet-shaped pieces fly out laterally and bury themselves in the wood; thus preventing the removal of the protector unless its own key is applied.

Figure 211 is the top or front of the lock; figure 210 a side view; figure 209 a back view; and figure 208 an end view.

view; figure 209 a back view; and figure 208 an end view.







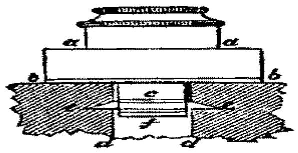


Figure 208.

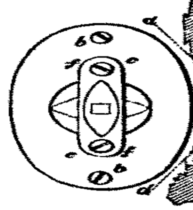


Figure 209.

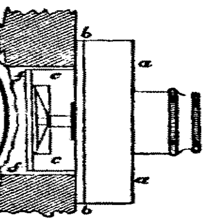


Figure 210.

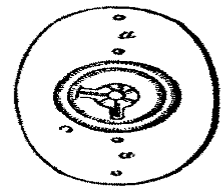


Figure 211.

a a the cap or case; *b b* the back-plate, from which rises a projection or pipe *c c,* formed to enter a keyhole with but little shake. Figure 210 shows it merely introduced, but not secured in the keyhole *d d,* which is in section. Figure 208 shows it secured.

This invention is a modification of the Bramah lock as applied by Mr. Russell to liquor cocks. "Within the case *a a* and its cylindrical prominence is a barrel or cylinder containing seven sliders; it ends in a strong central pin, which passes through the projection *c* into a recess, where it is squared to receive on it the steel-piece *e e,* (figure 208), which is pointed at each end like a strong, short penknife with a thick back. The cutting edges are, of course, on opposite sides, so as to follow.

Over this, and but just touching it, is screwed the steel-plate to guard its cutting edges when out of use, and keep it from coming off. When this is put into a keyhole, as figure 210, and pressed close, its key is introduced with the nib in the lower opening of figure 208, and turned until it comes out of the side opening.

It will then have turned the double cutter *e e* from its longitudinal position under the plate *f* to a cross one, both of which are shown by dotted lines in figure 209, and it will be secured to the lock by the two blades having cut their way into the wooden sides of the keyhole, as shown in figure 208, and cannot be pulled out until its own key has returned the cutters *e e* into their sheath *c c.*"

WALTERS' LOCK, invented about 1830.

The peculiarity of this lock consisted in the employment of levers above and below the chambers, which construction added considerably to the security as well as to the secrecy of the lock.

AUBIN'S LOCK, invented 1830.

The peculiarity of the construction of this lock consisted in working one tumbler under the bolt, and three or more levers on the top of the bolt; the whole working in combination with each other, together with a barrel and curtain.

About the same period, Mr. Aubin constructed another lock for room doors, to prevent seeing through the keyhole. This was accomplished by placing the keyhole on the one side of the lock, in a position at right angles to the one on the other side.

When the pin-end of the key was forced into the lock, it moved a slide from before the circular part of the keyhole, which thus allowed the pin to enter. Some of these locks were constructed the same as a one-sided lock, thereby giving the same amount of combination. Such locks of course had two keys, one for each side of the door; the bit on the one key was simply reversed on the shank of the other; that is, the terminal step in the one bit was at the bottom, while in the other it was at the top, and so with the other steps.

Mr. Aubin also constructed these locks with the pin-end of the key loose, so that it would move round independently of the key-bit, similar to a universal joint. This plan effectively prevents burglars' nippers having any effect upon the key-bit when the key is left in the lock.

Another contrivance by this inventor for securing the door of a room from the outside independently of the key, consists in what he calls “a protector," which is placed inside the keyhole, and secured by a padlock outside. To persons who engage rooms at hotels, and desire to be certain that no one can open the door, although he might have a duplicate key, this is undoubtedly a valuable contrivance.

He also invented an expanding wedge to place from the inside of the room under the bottom of the door, which was so constructed that by pushing the door from the outside only made the door the tighter.

Subsequently, Mr. Rudhall improved this wedge, by inserting between the bottom part and the top part a detonating ball, which the instant the door is forced from the outside, explodes with the report of a pistol-shot.

These simple contrivances are very useful and effective where the lock on one's chamber-door is a bad one, or where there is none at all.

RUTHERFORD's LOCK, Patent dated April 14, 1831.

The application of an inviolable lock to boxes sent by mails or other conveyances containing money or other valuable property, that can be opened only at stated **times(496)**, is, of course, an object of desirable attainment in a commercial country like this. For effecting this object, this patent was taken out in 1831 by William Rutherford, jr., of Jedburgh, in Scotland.

This gentleman being a bank agent, had no doubt sensibly felt the importance of having the means of transmitting, from one town to another, bankers' parcels with perfect safety. With this view he introduces against the end of the bolt a circular stop-plate, to prevent the withdrawal of the bolt until the circular plate, which is put in rotation by clock-work, shall have revolved so as to bring a notch opposite the end of the bolt.

Now as this notch can be set at pleasure to any required distance from the end of the bolt, the lock may be secured against being opened by its own or any other key, until any assigned number of hours after it has been locked. As the rate of traveling is known, the box can be secured from robbery until it shall have reached its destination.

When this fastening is used for portable boxes or packages, it must be put in motion, and its motion regulated by springs; but when it is to be applied to closets or safes, the most simple mode of giving motion will be by a descending weight, and of regulation by a pendulum; the actuating weight may then be made to rest upon, and disengage a locking-bar, in connection with the bolt of the lock, at any assigned number of hours after the fastening has been effected.

In this case all that is necessary is to cause the weight to descend down a vertical scale, divided into hours, and to raise it to any assigned number when the door is locked. A still further security is obtained by the locking-bar itself being prevented from being disengaged by any pressure, except by the descent of the weight, which is made to come, in its descent, into contact with an inclined projection from the lower end of the hour scale, sending it back and disengaging the locking-bar from a notch therein.

BARNARD’S LOCK, Patent dated May 23, 1831.

The specification states this invention to consist, “First, in having the handle which moves the spring-catch fixed to a separate lever or crank, acting upon the arm which projects from the catch, but distinct from it, by which means the said arm may always be of the same length, however thick the door is.

Secondly, in placing the spring which acts upon the catch, at the front part of it, and fastened to the plate which is fixed to the front edge of the door, by which position of the spring I am enabled to use a much longer, and consequently a much more pliant spring.

And, lastly, in a small plate of metal cast upon the key so as to get the exact impression from it, and then, brazed on to the lock-plate to form the keyhole, whereby the pattern of the key is so exactly formed in the keyhole, that it would be very difficult afterwards to make any other key to fit the same hole, and which is, therefore, a very great additional safeguard to the lock."

YOUNG’S IMPROVEMENTS, Patent dated July 27, 1831.

The following account of Mr. Young's improvements in locks and latches is copied from *The Repertory of Patent Inventions.* “Here are no fewer than four new kinds of locks, with as many combinations of springs and plates, and levers for security. ‘Security!’ The word is banished from the modern vocabulary: it is to be described only by negations, as complicated and as numerous as Mr. Young's means of attaining it. Mention the word to your banker or your lawyer, or whisper it to your clerk; ask any one of them for a definition, or put the question to yourself in your own chamber and mark the answer.

"The latched door and the unguarded garden, the cornfield without a scare-crow, and warehouse without watch or ward, are emblems of security. Whoever passed by *Coutt’s* after nightfall without feeling the doubt, and jealousy, and uncertainty, and insecurity, which are the undeviating attendants of wealth, steal upon him?”

Napoleon at St. Helena was free in the midst of guards set to keep him in, when compared with his slavery and imprisonment at St. Cloud, among the infinitely more numerous and watchful guards set to keep others out. Emperors and kings, however, must be

careful, and so must subjects of all grades, and Mr. Young will be most acceptable to the old, who love security, for his efforts to make locks lockable and bolts a security.

We have said that Mr. Young has employed four combinations differently to effect this desirable end. The first is exceedingly ingenious. It is called the '*fly-guard lock*,' and the name aptly describes it, for its principal feature is the "fly-guard."

The self-key of the lock, the very key made for the lock, the identical key which was made with the lock, will open it, but no other key will; for if the false key be a hair-breadth thicker or thinner, or taller or shorter, it will move one or more of a series of levers which will throw the fly-guard off its guard, or rather on its guard, for it forces the lock, or the bolt of the lock, out of its position, and then it so acts on the wards that the key (a false one) cannot by any effort force back the bolt.

Not only is the thief disappointed, but the attempt at theft is discovered; and although Othello, speaking of his mistress, 'felt not Cassio's kisses on her lips,' yet the owner of the patent 'fly-guard' will feel, or may *see* the action of the false suitor on his true lock. A ring on which the action fits, and a bell-shaped plate on which another series of levers act, and finally, a pendulum bolt which acts in a manner at once easy, elegant, and secure, are the securities of Mr. Young.

"A fourth invention is to cast in iron the whole process of a lock, staples, and all, and to add a plate of hammered iron. With these precautions, let the devil try to trench on your security. He'll try."

PARSONS' BALANCE-LEVER LOCK, Patent dated December 20, 1832.

The peculiarity of the construction of this lock consists in the levers being detached from the bolt, their center of motion being in the middle. The front end of the hooks of the levers, when the bolt is shot out, are all in one of the semicircular slots of the bolt.

The action is as follows: The key lifts the levers as near the center of motion as possible, and draws the front end of the hooks of the levers away from the bolt, until all the hooks are brought in a true plane with the edge of the main-bolt. The action may be compared to a scale-beam. The bolt cannot be moved

until the levers are at rest, for if either over-lifted or under-lifted the hooks at one or the other end catch in the slots of the main-bolt, and thus prevent its moving.

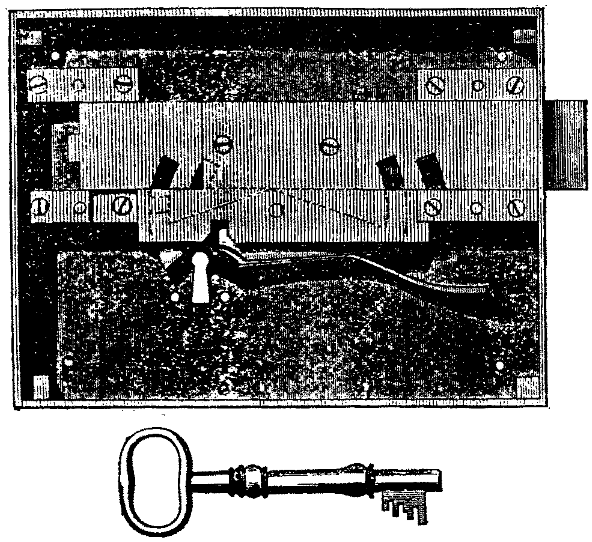


Figure 212. Parsons' Balance-Lever Lock

The above arrangement and the form of the levers and springs allow the levers to be made of very thin metal, so that many of them may be put in one lock without increasing its size to an inconvenient thickness. This is the first lever lock ever made by machinery, and none to the present period have surpassed it in point of correct and finished workmanship. It has continued to command a good sale from the period of its invention to the present time.

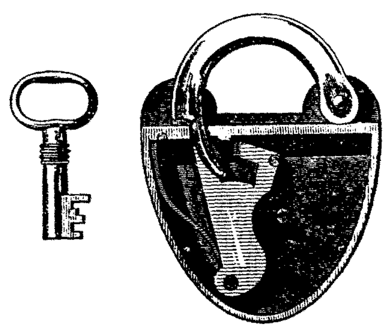


Figure 213.

Mr. Parsons was the inventor of what he calls *lever-tumblers* to padlocks and box-locks, which consists in so constructing the lever-tumblers that their ends form the bolt which locks into the

shackle of the padlock, or the link of the box-lock, as shown in figure 213.

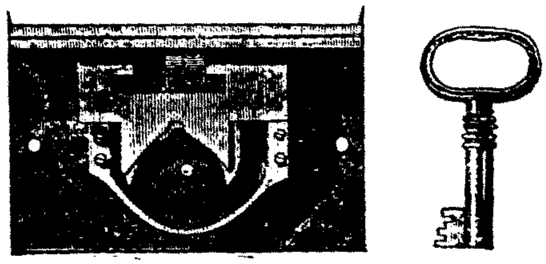


Figure 214.

Figure 214 represents a Parsons' slip-bolt or lever-tumbler lock of this description. This was found in practice very insecure from the circumstance that as there were no springs to the slip-bolts or lever-tumblers, they would shake out of the link, and the lock would thus be opened.

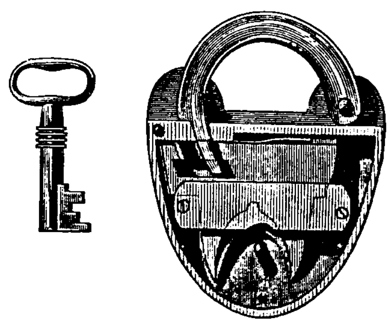


Figure 215.

Figure 215 represents Parsons' second movement for pad or box-locks, which is the same in principle as figure 212, with the addition of a binding or check-spring to each lever. The objection to this was that a blow or a jar would shake the works out of their true position.

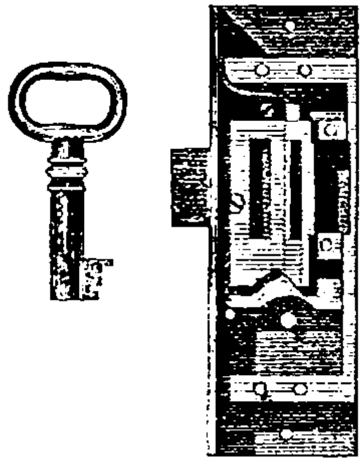


Figure 216.

Figure 216 represents the next improvement by, which the previous faults were corrected, inasmuch as the levers are vertical and slide up by the action of the key, and are forced downwards by the springs acting on their tops.

It must be particularly noticed that Mr. Parsons introduced an improvement into the *two-sided* locks which has never been improved upon or followed by other makers. It consisted in putting into such locks two drill-pins-one on each side of the lock and consequently each set of levers were differently gated, and the keyhole on each side of the lock being in a different position, prevented a direct aperture through the lock.

By this method the same amount of security is obtained in a two-sided lock as in a single-sided one. In all other two-sided locks the security is in the proportion of one to ten between them and one-sided, or the regular locks.

This plan effectively prevents the key-pin from being seen on either side of the door, and consequently is a certain guard against the lock being opened by means of nippers being applied to the end of the key-pin, as was the case in Liverpool and other places a short time ago, by a gang of American thieves, who succeeded in unlocking the doors of the chambers of commercial men, and robbing their pockets or portmanteaus of the convertible contents. We understand that the locks on the chamber doors in France are constructed in the same manner, though of a very inferior description.

Mr. Parsons, whom we rank in the same class with Mr. Bramah for mechanical skill, published a very elaborate table exhibiting the

additional security obtained in any lock by adding one or more levers; showing that each additional lever affords more additional security than many more locks.

He states that, “This table therefore shows the degrees of security attainable by the use of so many levers in one lock; since each change in the arrangement or place of any one of the levers would require a new key, independently of the alteration which might be made in any of their forms.

By this table also a comparison may very readily be made of the security of any two locks, each containing a different number of levers, as is in its last column, between locks with eight levers and every other lock wherein are from nine to twenty-six levers.

And let it not be forgotten that each of these large lever locks is equal; and, inasmuch as it may be better made and stronger, is superior to eight locks with seven levers or guards in each; to 56 locks with six in each; to 336 locks with five in each; and to 1,680 locks with four in each; and that one lock containing four levers or bolts is equal to four locks which contain only three levers or bolts in each; and to 12 of the best two-tumbler Barron's locks; whilst the common locks, with wards and a tumbler, which any pick-lock can remove from the bolt with ease, are worse than useless, as being only deceptive and soon out of order; the usual remedy for which is a removal of the wards by a locksmith, when the lock may be unlocked by any key.

ONE LOCK CONTAINING		**LOCKS WITH EIGHT LEVERS EACH.**
4 LEVERS ADMIT OF	**24 DIFFERENT COMBINATIONS**	
5 ""	**120 ""**	
6 ""	**720 ""**	
7 ""	**5,040 ""**	
8 ""	**40,320 "", AND EQUALS IN SECURITY**	**1**
9 ""	**362,880 ""**	**9**
10 ""	**3,628,800 ""**	**10**
11 ""	**39,916,800 ""**	**990**
12 ""	**479,001,600 ""**	**11,880**

**13 "" 6,227,020,800 ""
154,440
14 "" 87,178,291,200 ""
2,162,160
15 "" 1,307,674,368,000 ""
32,432,400
16 "" 20,922,789,888,000 ""
518,918,400
17 "" 355,687,428,096,000 ""
8,821,612,800
18 "" 6,402,373,705,728,000 ""
158,789,030,400
19 "" 121,645,100,408,832,000 ""
3,016,991,577,600
20 "" 2,432,902,008,176,640,000 ""
60,339,831,552,000
21 "" 51,090,942,171,709,440,000 ""
1,267,136,462,592,000
22 "" 1,124,000,727,777,607,680,000 ""
27,877,002,177,024,000
23 "" 25,852,016,738,884,976,640,000 ""
641,171,050,071,552,000
24 "" 620,448,401,733,239,439,360,000 ""
15,388,105,201,717,248,000
25 "" 15,511,210,043,330,985,984,000,000 ""
384,702,630,042,931,200,000
26 "" 403,291,461,126,605,635,584,000,000 ""
10,002,268,381,116,211,200,000**

This is a change or *permutation* lock of a peculiar construction, and was designed to afford immediately available protection against the danger of a key being lost or misused. The invention consists in introducing moveable supports or props between the levers which intercept the motion of the bolt and the levers upon which the key acts, which moveable supports are capable of adjustment, for the purpose of requiring longer or shorter bits to the key, according to the position of the said moveable supports.

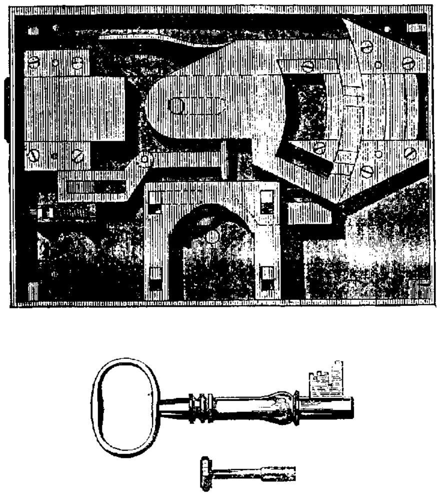


Figure 217. Parsons' Change Lock

The bits of the keys can be adjusted at pleasure to suit the situation of the moveable supports. The action is adjusted by means of the small screw-key shown in the cut, which works on a screw through the selvage or fore-end of the lock, and so moves backwards or forwards the slide, to the arm of which are connected the moveable supports. This adjusting screw changes the position, but not the relative positions of the levers, so that the same difference in the steps of the key must be retained, the change being made only in the length of the bits. The number of changes for each lock is very limited.

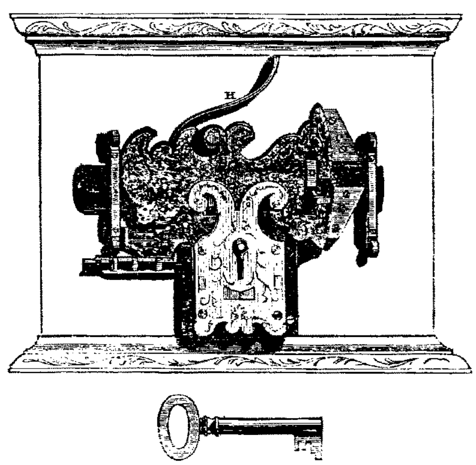


Figure 218. Parsons' Change Lock
(From Aubin's Lock Trophy.)

Figure 218 represents a modification of the change lock, in which the first tier of levers, as soon as the key begins to turn

round, shuts up the keyhole by sliding one lever over another, which effectively prevents any other instrument besides the key being put in.

It answers the same purpose as the curtain in other locks. *A* is the bolt; *B* the levers; *c c* the crescent; *D* the stump of the bolt ; *E* the regulating setscrew; *F* an opening in the cap to show the action of the levers in closing up the keyhole; *i* the slide, to which is attached the supports *G*; *H* the spring.

This is the first permutation or change lock patented in England, but that it had been invented previously is apparent from the circumstance of several old locks having been seen in which this principle was adopted.

MACKINNON'S PERMUTATION LOCK, invented about 1835.

The object of the present invention is two-fold to enable any person to **change(497)** at will the *pattern* or arrangement of the moveable parts in his lock and key, or to keep his key, except when actually in use, in such a state as to render it unavailing to any one but himself.

The bit of the key is composed of one piece marked a in figure 219, which acts on the bolt, and of as many other pieces, *1, 2, 3, 4, 5*, as there are levers in the lock; the pieces of the bit and their corresponding levers being stamped with the same numbers. That part of the stem of the key which carries the bit is not cylindrical but wedge-shaped, as shown at *b* (figure 219), which is an end view of it, with the piece *o* in its place.

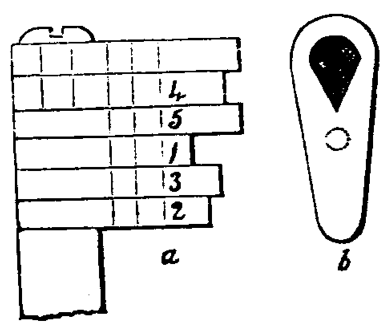


Figure 219.

The pieces composing the bit are thus prevented from moving round on the stem, and are until further secured from shake by means of a pin fixed to the underside of *a*, as shown by the dotted circle

in figure 219, *b,* and which passes through the lever-bits *5* to *1.* The piece *a* is fixed in its place by a small screw, as shown in the cut *b.*

It is almost needless to remark, that if the owner changes the order of the pieces composing the bit, he must change also, in exact correspondence, the order of the levers within the lock. It may sometimes be advisable to do this, when suspicion exists that a copy of the key has been obtained; and it might also in come circumstances be desirable to keep the key with its parts purposely misplaced, in order to foil any surreptitious attempts to open the lock even with its own key.

In figure 220, which represents part of the lock, *a a* is the lever No. *1, b* is an edge-view of a broad spring which acts on all the levers at once, depressing them after the four-sided stud of the bolt has passed, by the action of the key, from one notch in the lever to the other.

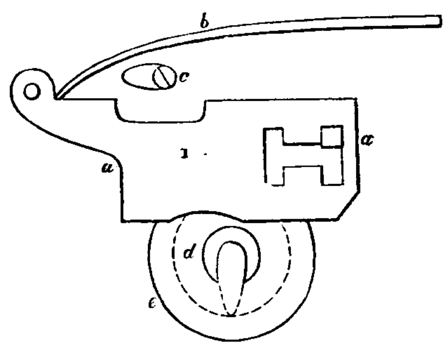


Figure 220.

It is evident that the relative position of the levers cannot be conveniently changed so long as this strong spring continues to act on them; but by applying a turn screw at *c*, and thus raising the button attached to it, the pressure of the spring is relieved, and then the levers may be displaced without any difficulty.

A collar or split-pipe *d* projects from a circular plate *e*, closely clipping the whole bit of the key, and turning round with it when in use. This prevents any of the pieces of which the bit is composed from being strained by any stiffness in the bolt or levers, or by any accidental obstruction.

Dr. ANDREWS' (America) LOCK, invented about 1835.

One of the principal constructions adopted in America a few years back for bank locks is that of Dr. Andrews, of Perth Amboy, in New Jersey. It was up to that time (1841) that it was believed that the best locks, both of England and America, were proof against any attempts at picking derived from knowledge obtained by inspection through the keyhole; but there still remained the danger that the sight of the true key, or the possession thereof, for only a few minutes, would enable a dishonest person produce a duplicate.

It was to contend against this difficulty that Dr. Andrews directed his attention; and he sought to obtain the desired object by constructing a lock, the interior mechanism of which could be **changed(498)** at pleasure. The lock of his invention is furnished with a series of tumblers and a detector. The tumblers are susceptible of being arranged in any desired order; and the key has moveable bits, which can be arranged so as to correspond with the tumblers. When the lock is fixed in its place, no change can be made in the tumblers, and consequently only one arrangement of the bits of the key will suit for the shooting and withdrawing of the bolt.

The owner can, however, before the fixing of the bolt, adopt any arrangement of tumblers and bits that he may choose. But though the tumblers cannot be actually rearranged in any new order within the lock while the latter is fixed, yet by an ingenious contrivance the tumblers can be so acted upon as to render the lock practically different from its former self.

The purchaser receives with his lock a series of small steel rings, each ring corresponds in thickness with the thickness of some one of the bits of the key; so that, by suitable adjustment, any one of the bits may be removed from the key, and a ring be substituted in its place. The effect of this substitution is that the particular tumbler which corresponds with the ring is not raised by it; it is drawn out with the bolt, as if it were part of the bolt itself.

Supposing the lock to be locked by this means, the original key would not now unlock it; for one of the tumblers has now been displaced, and can only be readjusted by the same ring, which displaced it.

If an attempt be made to open the lock by the original key, or by the key in its original adjustment, a detector is set in action,

which indicates that a false key or other instrument has been put into the lock. One, or more than one of the bits may be removed from the key, and rings be substituted, and consequently one or more of the tumblers may be disturbed in this peculiar way; so that the lock may change its character in all those permutating varieties which are so observable in most, "safety locks."

The shape of the tumblers is, of course, such as to facilitate this action; they have each an elongated slot, and also two notches. When a tumbler is raised by one of the bits of the key, one of the notches closes around a stump fitted into the case of the lock, and prevents the tumbler from being moved onward with the bolt; but when a ring has been substituted for a bit on the key, the tumbler cannot be raised at all; it is carried onward by a stump on the bolt.

Dr. Andrews is also the inventor of a lock that he terms the snail-wheel lock. A series of revolving discs, or wheels, taking the place of the tumblers, are mounted on a central-pin, on which the pipe of the key is inserted. Each disc has a piece cut out of it, into which the bit of the key enters, and, in turning round, moves the discs according to the various lengths of the steps on the key.

On the outer edge of each disc is a notch, and by the turning of the key all these **notches(499)** are brought into a line, so that a moveable tongue, or toggle, attached to the bolt, falls into the notches. The key is then turned the reverse way, by which means the bolt is projected."

MEIGHAN'S ALARUM LOCK, invented about 1836.

Among other contrivances for preventing locks from being surreptitiously opened, it has been proposed to connect the bolt with a bell, so that, on withdrawing the bolt, a spring shall be released, by means of which the bell shall be made to sound. The use of such a contrivance is in its application to street doors, that no persons may come in from without, or go out from within, unknown by the master of the house.

The former condition is fulfilled in a very simple way, by attaching a bell on a long vibrating string to the upper part of the door, as is actually practiced in many shops; but this contrivance will not answer the second condition, since a person within the house may muffle the bell before opening the door.

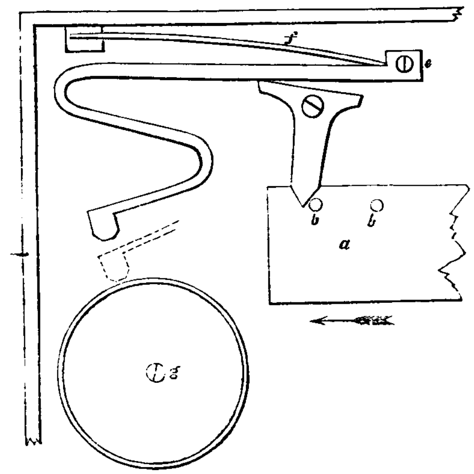


Figure 221. Meighan's Alarum Lock

Within Mr. Meighan's lock, the bell is placed within the lock itself and is, therefore, not to become at except by taking off the lock.

In figure 221, a represents the tail of the bolt in the act of unlocking, and moving, therefore, in the direction of the arrow. Two or more studs, *b b,* are placed on the bolt, one of which is shown pressing against the point of the tumbler *c,* and thus elevating the hammer *d:* this latter is attached to a crooked arm, which turns on the pin *e,* and is pressed upon by the spring *f,* which, when the stud has passed the point of the tumbler, throws down the hammer violently against the bell *g.* This notice will be repeated during the act of shooting the bolt, as many times as there are studs placed on the bolt in a position capable of acting on the tumbler.

This is the first of a number of locks invented at various periods, which are more curious than useful; for which reason none have ever come into general use.

MARR'S LOCK, **invented about 1836.**

This lock is constructed with a small bolt working at right angles through two studs in the main-bolt. If the levers are over-lifted, a small hook on the upper end of the small bolt is forced onto a stump fixed in the plate of the lock by a spring, which retains it. To release the small bolt the main bolt has to be shot a second time, in the same manner as Chubb's, to release the detector.

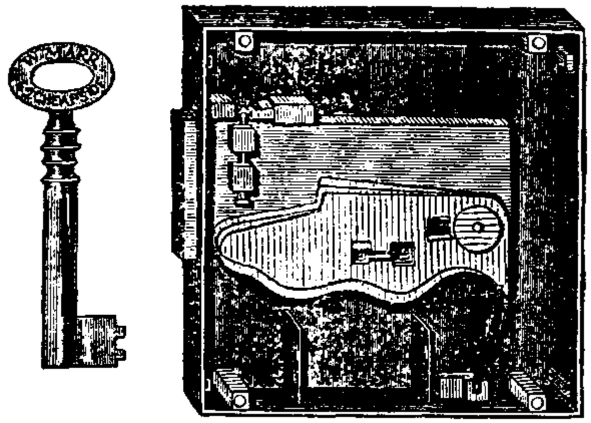


Figure 222. Marr's Detector Lock

THOMPSON'S (SALLY) LOCK, Patent dated November 13th, 1838.

The additional security sought to be obtained in the construction of this lock consists in the setting in motion of an alarm before any key can be introduced into the lock, or before the bolt can be withdrawn. This is accomplished, first, by placing before the keyhole a plate, forming a shutter to the keyhole, to be removed by being slid away, or by being turned on an axis before the key can be introduced into the lock. The shutter shall be in communication with an alarum, situated either within the lock or contiguous to it, or in a room or place to which the motion may be conveyed.

Secondly, it shall operate by forming a communication from the bolt of a lock to a sounding body, so that the motion of the bolt in being withdrawn shall cause a sound, or a succession of sounds, to be given at such place, within practicable distance, as the proprietor of the lock shall determine upon.

The principles of the invention admit of being carried into effect according to the local and other circumstances, in a great variety of forms and modifications. We believe this is the only invention in connection with locks and keys which can claim the honor of having been patented by a female.

SANDERS' LOCK, Patent dated June 12, 1839.

The peculiarity of the construction of this lock consists in attaching the levers to the main bolt, which, in the act of locking and unlocking, travel with it; hence called the "*traversing lever*" lock. It is simply Cornthwaite's lock

reversed. The construction of this lock has been applied principally to dead and stock locks, large quantities of which have been manufactured and sold by Messrs. Carpenter and Tildesley, of Willenhall.

NETTLEFOLD'S LOCK, invented and patented by John Charles Schwieso, July 20, 1839.

The peculiar feature of Nettlefold's lock was that as the bolt was shot out by the key, two teeth, or quadrants, were projected from the sides of the bolt, which took a firm hold of the plate fixed on the door or edge. It was much used for sliding doors, and was found to answer exceedingly well.

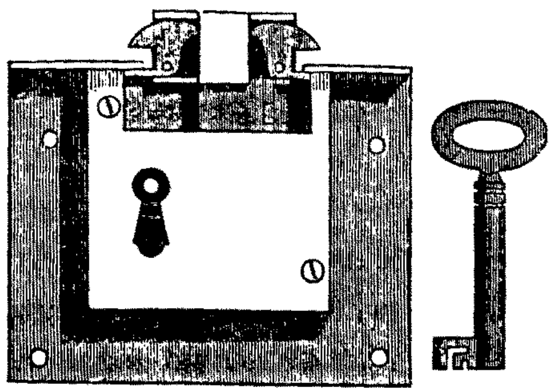


Figure 223. Nettlefold's Lock

The same peculiar movement had also been applied to many other locks, by different makers under the authority of licenses from Mr. Nettlefold."

GERISH'S IMPROVEMENTS IN LOCKS AND KEYS, Patent dated February 27th, 1840.

The Patentee observes that in large doors, where great strength and security are required, it is necessary to have a lock of corresponding size, the key of which is large and heavy, and therefore inconvenient for carrying about. To obviate this, he makes a knob or handle perform the office of a key and throw the bolts.

A lock contained within the knob, acted upon by a very small and portable key, has a forked bolt which locks into the escutcheon, and so renders the knob or handle and the bolts immovable. The patentee also claims the method of throwing a bolt out from the

escutcheon into the knob, and so producing the same effect. Claim is not made to any particular arrangement of lock: in the specification a common tumbler lock is adapted to the purpose.

The difficulty which this benevolent patentee has undertaken to remedy has no existence but in his own imagination. It must be pretty well known to most of our readers that the iron doors of strong rooms, the doors of large iron safes, etc. have long been fitted with knobs performing the office of a key, and throwing from four to ten, or even more bolts; such knob being secured by a small Bramah or other lock, fitted with the most portable keys, which threw a bolt into the arm of the large lock, thereby setting fast the bolts, knob and all. The small lock in this case is placed within the door, and is inaccessible; whereas, if situated in the knob, it is only to saw open or knockoff the knob, and all security is gone.

The next claim is for a mortise latch, contained within a cylindrical metal tube. The bolt, which is also cylindrical, lays along the tube, and is squared and turned up at the end, and a rack cut on its underside. A pinion or sector on the spindle or axis of the knobs turns back the bolt, which is urged forward by a spiral wire-spring coiled around it.

This latch may be secured by a lock in the handles, as before described. As regards originality, this contrivance is no better off than the former; the object is decidedly a good one, viz., to avoid cutting away the wood to so great an extent as is necessary for the usual run of mortise locks; to let in this lock it is only required to sink a circular hole with a center-bit to the proper depth.

Locks of this description, but infinitely superior in arrangement to the foregoing, have been made and used some years, invented, we believe, by Sir John Robinson, secretary to the Royal Society of Edinburgh.

The next *improvement* is in the construction of tumbler locks, with keys having four or more projecting “nibs” placed around the pipe of the key. In lieu of Barron's plan of several steps on one bit, this patentee adopts a separate “bib” for each tumbler, the advantage of which is not very apparent. A little extra trouble in making the lock and key, but no additional security will be obtained.

The claims set forth are, First, the application of a lock and

key to a knob or handle of a lock to secure the same, as herein described. Secondly, the mode of constructing a lock or other such like fastening, by combining a bolt, spring, and pinion, or tooth sector. Thirdly, the mode of constructing a key for locks and other such fastenings by having a series of nibs or projections around the axis of the key, as described.

WILLIAMS' LOCK, Patent dated March 20, 1840.

This lock, like Stansbury's, is a modification of the Egyptian lock. It is constructed with a series of pins, which reach through and are flush with the cap, and are pressed to their places by a key like a comb or rake-head, with teeth of irregular lengths.

On the inner end of each pin is a flat piece of steel, in which is cut a notch that allows the bolt to pass, when all the notches are brought in a line by the key. But as wither one or all of the pins can be pushed too far, they are what is termed "double-acting', and consequently appear to add much to the security of the lock. On the pins being pushed down by the key to their respective positions, the bolt is set at liberty, and is moved backwards and forwards by two springs, one of which is made strong enough to overcome the resistance of the other during the action of locking, and is forced back by the key to allow the weaker spring to act in unlocking. From this latter construction it would appear that its inventor had some idea of picking a lock by applying a pressure to the bolt.

There are several objections to this lock coming into general use. The size of the key, and having to change ends to lock and unlock, makes it both inconvenient and undesirable; and also the liability of the bolt being held by any bind in the bolt-hole, from the circumstance of the key having no control over it, and the easy manner by which a false key can be fabricated.

Soon after this patent was taken out, a joint-stock company was projected, with a capital of 30,000 Pounds, for the purpose of working it; but although the lowest amount of profit was estimated at 10,300 Pounds per annum, but few of the shares were taken up. The factory that had been established in Wolverhampton for the manufacture of the locks, was, in consequence, soon given up. Williams' Patent Lock Company was the first "joint-stock company" ever established for the manufacture of locks.

PEIRCE'S LOCK, Patent dated May 2nd, 1840.

These locks, which are upon Barron's principle, with numerous tumblers, are furnished with a detector, consisting of a sliding-bolt acted upon by any one or all of the levers. The opposite end of this sliding-bolt is jointed to a small lever, mounted on a suitable axis.

Within a tube, opposite the lower part of the keyhole, a dart, or sharp-edged punch, is placed upon a strong spiral spring; there is a notch on the underside of the dart, in which the detector-lever rests and holds the dart down upon the compressed spring. On attempting to open the lock with any but the original key, one or other of the levers is over-lifted, which, acting on the detector-lever, releases the dart or punch, which flies out through the keyhole, wounding the hand that holds the key. The face of the punch being in the form of a letter or figure, inflicts a wound that for several weeks identifies the aggressor; these locks have therefore been termed identifying detector locks. In order to prevent the accumulation of dirt, &c. within the pipe of the key, a metal stop is fitted so as to work freely within it, being kept flush with the end of the pipe by means of an internal spira spring, which yields to the pin of the lock when in use.

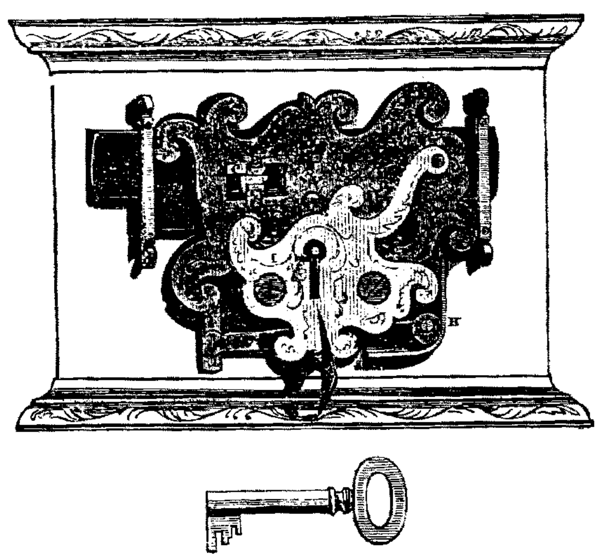


Figure 224. Peirce's Identifying Detector Lock

Figure 224 represents one of these locks as constructed on the base of Aubin's Lock Trophy A is the bolt; B the levels; c the stump of the bolt; D the detector; E F the detecting levers; G the dart.

The construction of this lock appears to have been suggested by the Marquis of Worcester in his Century of Inventions before referred to, where he says that " a lock may be so constructed that if a stranger attempteth to open it, it catches his hand as a trap catcheth a fox; though far from maiming him for life; yet marketh him so, that if once suspected he might easily be detected."

It is said that the inventor himself experienced the efficacy of the detecting apparatus by receiving the steel barb into his own hand, thus showing that, like other detector locks, it would detect on other occasions than when surreptitiously operated upon.

WOLVERSON and RAWLETT ' Lock, Patent dated June 13, 1840.

The improvements claimed in the specification are-first, a new kind of follow for latches; secondly, a peculiar mode of holding down the latch-bolt in latches and locks so as to lessen fiction thirdly, a lock-bolt, the bolt to be bevelled and the bevelled recess for it in the lock-plate to be formed by turning over the metal of the plate, so as to form a tube. They claim also several modes of making bolts work by the hand.

BAILLIE 's LOCK, Patent dated December 23rd, 1840.

The improvements in this lock, as applied in the first place to rim locks, consist in rounding off all the corners so as to prevent their tearing ladies' dresses, and in attaching the lock to the door by means of an angular stud rivetted on its inner side, which slides into a plate staple screwed to the door; the front of the lock being screwed on to the fore edge of the door in the usual manner. The boxstaple is made with a tenon at the back, which is let into the door-frame, and secured by long screws, which pass through the front plate of the staple into the door-frame and through the tenon.

"In the improved lock there is a stop, moved by a small handle on the outside, by turning of which the stop is caused to act against a notch or projectile on the toothed sector that wolks the bolt, and prevents the bolt from being thrown back. For street-door locks this stop has two tongues, which take into the teeth of the pinion that works the bolt, one of the tongues preventing the bolt from being thrown backs the other retaining it when it is thrown back, the tongues being placed so far

asunder that only one can act at a time.

"The claim is to the mode of constructing locks and their fixings or fastenings, whereby the screws passing through locks and staples are dispensed with. Also the mode of applying a temporary stop to locks, as described."

BROOKES LOCK, invented about 1840.

This lock was constructed with a nozzle working inside the Bramah nozzle, so as to shut up the keyhole; or to cut off all communication with the sliders. The key had to perform nearly one revolution before it could be pressed down on to the neck of the sliders to open the lock.

FOSTERS LOCK, invented about 1840.

The peculiarity in the construction of this lock consisted merely in the detector having a different action to the other detector locks in use. When a false key was introduced it was held fast in the lock, or the keyhole was shut up; and in attempting to shift the slide from before the keyhole, the operator was in danger of being struck by a dart when the slide moved. In other respects it was an ordinary lever lock.

PERRY'S IMPROVEMENT FLUSH-BOLT LOCKS introduced about 1840.

This improvement consisted in working the lock with three tumblers; one set in a position at right angles to that of the other two. When the key was forced into the lock it met with a tumbler and a talon on the bolt, by which the bolt was shot up vertically; the key in passing onwards then met with a pair of Barron's tumblers and another talon, and the bolt was thus shot forward horizontally. It is a great improvement in locks constructed on the secure principle, and we believe the only one of its kind. The inventor was upwards of forty years in perfecting it.

BENTON'S LOCK invented about 1840.

The peculiarity in the construction of this lock consists in placing two stumps on the bolt and double-racking the levers. This makes the lock showy, and adds some little to the strength, but not to the security. A specimen lock was exhibited at the Exhibition of Arts and Manufactures held in Wolverhampton in 1840, which obtained the second prize. The wards in this lock

were very nicely fitted, and as a whole it was a well-made lock, which entitled the maker, a working locksmith, to considerable credit, especially as it was his first attempt to produce a lock for competition.

This prize amounted to £1 6f which induces us to remark that such small sums are most inadequate to the purpose of rewarding meritorious inventors The abobe lock, no doubt, cost its maker four or five pounds in producing. The same remark will apply to the premiums offered by the Society of Arts and the result is that the society seldom draws forth an invention of much value.

COPE'S PIANOFORTE LOCK, invented about 1840.

This is a double-bolted pianoforte lock, one bolt of which shoots across and fastens the link, and also drives a crank that shoots a bolt out of the bottom of the lock. Mr. Cope was the inventor of the hardened steel nozzle for Bramah locks, and steel caps for various other kinds of locks, to prevent drilling into the lock-cases. He also invented the mortise padlock.

HICKIN'S CIRCULAR ESCUTCHEON LOCK, invented about 1840.

This neat and simple invention consists of a circular escutcheon for placing before the keyholes of iron safes, and constructed with a lock in the moveable part, which latter opens and shuts similar to the case of a watch, and requires but a very small key. Figure 37, page 55, represents a slide-escuteheon constructed on a similar principle and for the same purpose. Either kind is very useful and convenient where it is desirable to protect a keyhole from observation or prying curiosity.

WAKEMAN'S IMPROVEMENTS IN LOCKS AND ESCUTCHEONS, introduced about 1840.

One improvement consists in making locks with triple drill-pins. On the face of a nozzle fixed on the cap of the lock are seen the ends of three drill-pills, upon which the key formed to fit them passes into a chamber; it is then turned round to a right angle and forced into the interior of the lock, where either of the two bits meeting with the talon of the bolt and common tumbler shoots the bolt. It is a very simple, ingenious, and novel contrivance, and we believe the only one of its kind.

Wakeman improved the changeable letter lock by introducing false notches inside the outer rings; also by cutting a series of teeth

that work into a screw inside one of the rings, so that in attempting to open the lock by binding, this screw comes into action and binds all the rings, and at once prevents the true notches or openings being discovered. When the true position is found on the rings that are to move, the one that is in connection with the screw is turned round and opens the shackle. We consider this is one of the most important improvements ever introduced into the changeable letter lock.

He is also the inventor of the vertical letter locks, with three different actions. First, with the shackle to draw out; secondly, with the usual joint; and, thirdly, with the swivel-joit shackle. He also improved and simplified the various kinds of latches; and his sash-fasteners for utility and security are surpassed by none.

It is supposed this inventor was the first to abandon the ears on padlocks, by making them round with the shackle to pull up and turn round on a swivel-joint He made others to work without a key on the secret principle. His escutcheons were also made on the secret principle, and so contrived that no one could open them without a knowledge of the secret (**note**)(500).

DUCE (Junior's) LOCK, invented 1040, Patent dated May 24, 1842.

This is a lock with a quadruple motion, and was exhibited for competition with other locks at the Exhibition of Arts and Manufactures held at Wolverhampton in 1840, and obtained the principal prize. The action of the lock is as follows: One tumbler is drawn towards the key, another is driven backwards, while one lever works up and passes through a slot in the main-bolt, and another is pressed down, which also passes through a slot in the main-bolt. This motion is both beautiful and very secure, but as the lock comprises so many limbs it is expensive to make. The patented lock contained this additional improvement, viz., an adjusting-spindle when used for doors (**note**)(501). The peculiarity consisted in worming the edges of a square.

After the patent was sealed, Mr. Duce made these locks with only two motions. A tumbler under the bolt is gated into a slot cut to receive it, while a lever is gated to work up through a slot in a stud fixed upon the main-bolt, and moving with it. This lock is simple and tolerably secure, and being cheap has had an excellent run for many years.

It is supposed that this inventor was the first who made locks to

fire off a pistol to give an alarm if any of the levers in the lock were overlifted. He also invented the diamond detector lock. The detector is fixed to the main-bolt, and works upon a stiff joint; if the levers are overlifted it blocks the main-bolt against a stump fixed in the lockplate, and prevents the bolt from being withdrawn. In other respects it is an ordinary lever lock. This is an excellent movement, being simple, effective, secure, and cheap. He was also the inventor of the one-horned follow for locks, which works in a v-formed latch-tail to prevent friction. He also improved the details of mortise locks, and constructed them narrower the usual kind.

Mr. Duce, jr., is one of a very few master lock manufacturers who work at the vice, and he is considered an exquisite workman. He constructed a series of beautiful and interesting specimens of locks for the Great Exhibition of 1851, but from some cause declined to send them. He also invented a beautiful machine for splitting sheet-brass for the purpose of being made into springs for locks.

TILDESLEY and SANDERS LOCK Patent dated March 29 1841.

The first improvement consists in a mode of constructing the sliding-bolt of locks. The bolt in this case consists of a sliding-plate, with four levers and their springs, which moves upon a pin or stud, and carries in its front end an axis, upon which the levers are mounted. The other ends of the levels are provided with slots or openings, through which the pin protrudes, and passes when the bolt is moved by its proper key. But should a false key be introduced the openings in the levers will not coincide with the path of the pin, and the bolt will therefore remain immoveable. A detector is also shown as applied to this arrangement, by which the introduction of a false key is indicated.

The second improvement consists in the application of sliding-levers to the sliding-bolts of locks. A bolt of the ordinary construction has a portion of its upper part, near its middle, removed to make room for a projection affixed to the lock-case. This projection passes through a vertical slit formed in each of three vertical levers; there is a fourth, or bolt-lever, connected to the bolt and moving with it. In each of the extra levers there is a horizontal slot, through which a pin on the lock-lever enters, and allows the bolt to be slid back by the key, when it has brought all the levers into their proper positions. The extra levers have a vertical movement only, but

the lock-lever slides up and down a pin affixed to the bolt, and also follows the horizontal movement of the bolt, being contained in a recess in its side.

The third improvement consists in a peculiarly formed sliding and lever catch-bolt, suitable for drawer or other locks. This bolt is composed of a sliding-plate and three levers, which move on an axis affixed to the lower end of the plate. The levers have each tow notches near the top (one in each edge), and are provided with a spring, which gives the requisite movement to the lever while the bolt is being shot. When the bolt is shot, the notches in the levers are level with the face-plate of the lock, on which they catch, and the bolt cannot be withdrawn by any key unless it will cause the levers to range correctly together; for should any one of the levers be moved too far, its opposite notch will catch on the plate and hold the bolt fast.

HANCOCK'S LOCK, Patent dated May 6th, 1841.

The nature of these improvements is shown in their simplest form as applied to a cabinet or drawer lock. A round pin or nozzle projects form the front plate of the lock, through the centre of which a spiral channel runs from the end to end and forms the keyhole. The key consists of a single thread of a screw stripped from its axis (similar to a corkscrew), which is made to correspond exactly with the spiral channel. On the key being inserted in the keyhole, and turned round till its point reaches the inner end of the spiral channel, it there presses upon the heel of the bolt and unlocks it. On turning the key in the reverse direction, a strong spring throws up the bolt again. The point of the spiral key, when once passed through the spiral keyhole, forms a lever by which the bolt of the lock may be effectively combined with any of the known combinations of wards, guards, tumblers, or other contrivances for affording increased security.

These improvements, the patentee states, are also applicalbe to taps or cocks.

STRONG'S LOCK, Patent dated September 28th, 1841.

The construction of this lock is of a very complicated character, without affording any additional security. The specification, with drawings, is printed at length in the Repertory of Patent Inventions, from which we extract the patentee's various claims: "First, in the combination of a series of two or more tumblers

attached to the bolt of a lock and one to another, each tumbler of the series, near the end opposite to the fulcrum of that preceding tumbler, the first of the series having its fulcrum in the tail-plate or thin part of the sliding-bolt; thus the fulcrum of the tumblers are alternately placed near the opposite ends of the tail-plate, and consequently the alternate tumblers rise the one to the right hand and the other to the left, where the lock is held up in a vertical position, whereby a great complication of checks against the operation of a false key is obtained form a few tumblers.

"Secondly, in attaching a secondary-bolt sliding transversely in the main-bolt of a lock, and acting against an abutment, to form a detent in addition to the complicated effect of the alternating-tumblers described as the first part of my improvements; this transverse-bolt being to be drawn back by one of the tumblers before the main-bolt can be withdrawn."

"Thirdly, in the combination of the alternating-tumblers with a secondary-bolt attached to the lock-plate, and shooting into a noch in the main-bolt to prevent its being drawn back previous to the withdrawal of the bolt."

"Fourthly, in adding to the combination of alternating-tumblers a detecting-tumbler connected with the secondary-bolt above described under the second part of my improvements, which detecting tumbler on being lifted too high by a false key is there detained by a spring-catch until realeased by the true key."

"Fifthly, in the combination of a hooked catch-piece, with several tumblers acting on one common fulcrum, the whole of the tumblers constituting a substitute for the bolt, whereby a greater number of tumblers of a given thickness may be introduced into a thin lock than when the catch-piece is pierced through in the manner of a staple."

"Sixthly, in the application of a pair of links, one hinged to each side of the sliding-bolt of a spring-latch, each link terminated at the end opposite to the hinge by a hook catching on upon the follower, whereby the followers, whether turning right or left, act with very little friction withdrawing the bolt."

"Seventhly, in the formation of a hinge by casting alone in parts of the lock in which the motion on the joint is but small, for which purpose a notch is cast in one of the pieces of the

hinge of the form of about three-fourths of a hollow cylinder, into which notch a cylindrical protuberance or knuckle, cast with the other piece of the hinge, fits and turns in a small arc of a circle, such a hinge being peculiarly applicable to the joining of the links to the sliding-bolt of the spring-latch mentioned under the sixth head of my improvements."

"Eighth and lastly, in the application of a forked connecting-piece between the followers. and a lifting-latch for the purpose of communicating the motion of the followers to the latch with very little friction."

The above application of a jointed tail-piece to latches, where the follow-horn works, is an excellent plan for preventing friction.

Strong was also the inventor of the self-acting padlock-shackle. It is so constructed that when the key moves back the bolt, the shackle flies up; and to lock, it merely requires the shackle to be pressed down. The action and fastening is near the joint end of the shackle. Some of his shackles fastened in the centre.

NEWELL'S (American) LOCK, invented in 1841. English Patent dated April 15th, 1851.

This lock, commonly known as the American Parautoptic lock was invented by Mr. Newell of the firm of Day and Newell, of New York, in 1841, but was scarcely known in England till the opening of the Great Exhibition of 1851, in which year it was patented in this country, with the improvements introduced since the year 1841.

The specification states that "The object of the present improvements is the constructing of locks in such manner that the interior arrangements, or the combination of the internal moveable parts, may be changed at pleasure according to the form given to, or change made in, the key, without the necessity of arranging the moveable parts of the lock by hand, or removing the lock or any part thereof from the door. In locks constructed on this plan the key may be altered at pleasure; and the act of locking, or throwing out the bolt of the lock, produces the particular arrangement of the internal parts which corresponds to that of the key for the time being.

While the same is locked, this form is retained until the lock is unlocked or the bolt withdrawn, upon which the internal moveable

parts return to their original position with reference to each other; but these parts cannot be made to assume or be brought back to their original position, except by a key of the precise form and dimensions as the key by which they were made to assume such arrangement in the act of locking.

The key is changeable at pleasure, and the lock receives a special form in the act of locking according to the key employed, and retains that form until in the act of unlocking by the same key it resumes its original or unlocked stated. The lock is again changeable at pleasure, simply by altering the arrangement of the moveable bits of the key; and the key may be changed to any one of the forms within the number of permutations of which the parts are susceptible."

The "claims" put forth under this patent are the following:

1. The constructing, by means of a first and secondary series of slides or tumblers, of a changeable lock, in which the particular form or arrangement of parts of the lock, imparted by the key to the first and secondary series of slides or tumblers, is retained by a cramp-plate.

2. The constructing, by means of a first and secondary series of slides or tumblers, of a changeable lock, in which the peculiar form or arrangement of parts of the lock, imparted by the key, is retained by means of a tooth or teeth, and notches on the secondary series of slides or tumblers.

3. The application to locks of a third or intermediate series of slides or tumblers.

4. The application of a dog with a pin overlapping the slide or tumblers for the purpose of holding in the bolt when the lock is locked or unlocked.

5. The application of a dog, operated on by the cap or detector-tumbler, for holding the bolt.

6. The application of a dog, for the purpose of holding the internal slide or tumbler.

7. The application to locks of curtains or rings, turning and working eccentrically to the motion of the key, for preventing access to the internal parts of the lock.

8. The application to locks of a safety-plug or yielding-plate, at the back of the chamber formed by such eccentric revolving-curtain or ring.

9. The application to locks of a strong metallic wall or plate, for the purpose of separating the safety and other parts of the lock from each other, and preventing access to such parts by means of the keyhole.

10. The application to locks of a cap or detective-tumbler, for the purpose of closing the keyhole as the key is turned.

11. The constructing a key by a combination of bits or moveable pieces, with tongues fitted into a groove and held by a screw.

12. The constructing a key having a groove in its shank to receive the detector-tumbler.

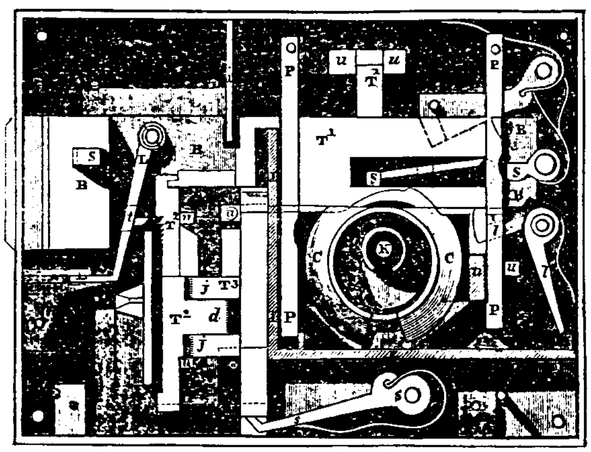


Figure 225. The American Parautoptic Lock, bolt unshot.

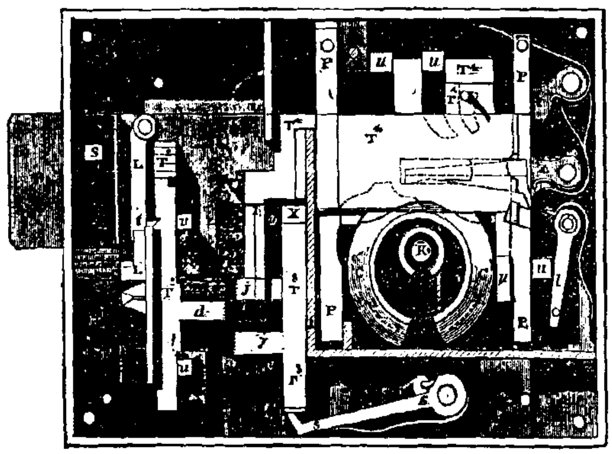


Figure 226. The American Parautoptic Lock, bolt shot.

We shall here copy the description of this lock from Mr. Tomlinson's work before reffered to:

"In figure 225 the lock is represented in its unlocked state, with the cover or top-plate removed; the auxiliary tumbler and the detector-plate are also removed. In figure 226 it is represented as locked, with the cover and the detector-plate also removed, and the auxiliary-tumbler in its place. In these two figures the same letters of reference apply to the same parts, unless otherwise stated."

B B is the bolt; T are the first series of moveable slides or tumblers; s shows the tumbler springs; t2 the secondary series of tumblers; and t3 the third or intermediate series, there latter coming between the first and secondary series; PP are the separating plates between the several members of the first series of tumblers; s1 are the springs for lifting the intermediate tumblers. On each of the secondary tumblers t2 is a series of notches, corresponding in mutual distance with difference in the lengths of the moveable bits of the key.

It thence happens that, when the key is turned in the lock to lock it, each bit raises its proper tumbler, so that some one of those notches shall present itself in front of the tooth t in the dog or lever LL. When the bolt B is projected by the action of the key, it carries with it the secondary tumblers t2, and presses the tooth t into the notches; in so doing it withdraws the tongues d from between the jaws jj of the intermediate tumblers t3, and allows the first and intermediate tumblers to fall to their original position.

By the same movement the secondary tumblers t2 become held in the position given to them by the key, by means of the tooth t being pressed into the several notches, as shown in the closed state of the lock. (Figure 226) Now let us see what results if any attempt be made to open the lock with any arrangement of key but that which it has been locked. In such case the tongues d will abut against the jaws jj, preventing the bolt form being withdrawn; and should an attempt be made to ascertain which tumbler binds and requires to be moved, the intermediate tumbler t3 (which receives the pressure), being behind the iron wall II, which is fixed completely across the lock, prevents the possibility of its being reached through the keyhole.

The first tumblers T are quite detached at the time, thereby making it impossible to ascertain the position of the parts in the inner chamber behind the wall II. K is the drill-pin on which the key fits; and c is a revolving ring or curtain, which turns round with the key, and prevents the possibility of inspecting the interior of the lock through the keyhole. Should, however, this ring be turned to bring the opening upwards, a detector-plate D, (figure 227,) is immediately carried over the keyhole by the motion of a pin p1 upon the auxiliary tumbler t1, which is lifted by the revolution of the ring c, thereby effectually closing the keyhole.

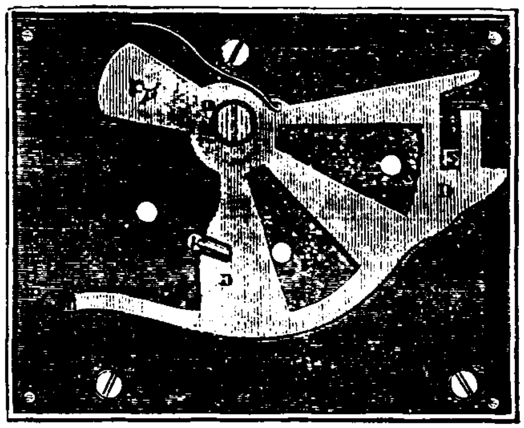


Figure 227. The Detector-plate.

As an additional protection, the bolt is held from being unlocked by the stud or stump s bearing against the detector-plate; and, moreover, the lever ll holds the bolt, when locked, until it is released by the tail of the detector-plate pressing the pin p1. l1 is a lever which hlods the bolt on the upper side, when locked, until it is lifted by the tumblers acting on the pin p1; x are separating-plates between the intermediate tumblers t3; uu1 are the studs for preserving the parallel motion of the different tumblers.

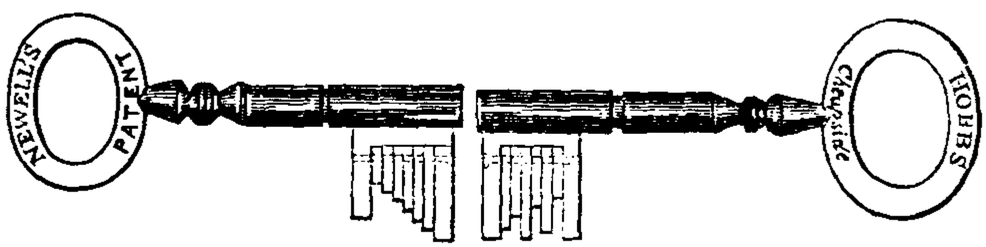


Figure 228

"Figure 228 represents the key in two different forms, or with the bits differently arranged. Either form will lock the lock , but the other will not then unlock it. The end of the key is represented in figure 229, showing the screw which fixes the bits in their places. This bits for a six-bitted key are shown separately in figure 230."



Figure 229

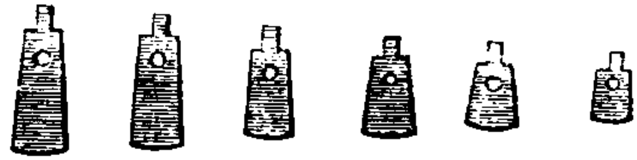


Figure 230

FIELDHOUSE'S IMPROVEMENTS, introduced about 1841.

This inventor was the first to introduce Barron's principle into the construction of the "Banbury" lock. He also introduced into the construction a double drill-pin, that is, fixing a drill-pin on each side of a plate to prevent seeing through the keyhole. The platform or bridge-plate was in connection with springs, so that when the key was forced into the lock, the plate on which the drill-pins were fixed gave was for the key to enter.

ROCK'S IMPROVEMENTS, Patent dated Dec. 29th, 1842.

These improvements consist, first, in a mode of applying friction rollers to the tumblers of tumbler locks.

Secondly, in applying friction rollers to the sliding bolts of back-spring locks, so as to facilitate their movements in the act of locking or unlocking.

Thirdly, in the application of a connecting-link or crank, to ease the friction of locking and unlocking;

Fourthly, in a mode of applying a stop to a sliding-bolt of a lock.

The friction-roller consists of a circular plate or disc, which revolves on a stud fixed to the end of a lever-tumbler, which latter works on a stud fixed in the main-bolt. The lever-tumbler and the friction-roller are kept in their true position by a spring. When the key is placed in the lock, in turning round it comes in contact with the roller, and in the act of rising with the lever-tumbler revolves, and so lessens the friction.

The friction-roller, when applied to the sliding-bolts of locks, is constructed so as to move on an axis affixed to the frame-cheek or case of the lock. In the under part of the bolt are formed two curved recesses, and the key acts on the inclined surface, so as to lift or throw the bolt, and cause it to rise

over the friction-roller, and in such a manner as to cause one of the curved recesses to pass away from the roller, and to bring the other curved recess over the roller. The friction-roller may also be applied to the bolt, and have fixed recesses; and it is not absolutely necessary that the recesses should be used, as the roller may be caused to rise and fall over a check-stop or bar.

THOMAS'S PRISON LOCK, invented about 1842.

This lock, invented by Mr. Thomas, of Birmingham, contains a common tumbler, a bolt, and a brass guard-flap, the latter retained in its position by a spring inserted at the back of the lock. The key in its revolution lifts the guard-flap at the same time that it acts upon the tumbler, and throws the bolt. The lock has also a handle on the outside attached to a trigger, which catches the bolt when shot back by the key in opening the door, and retains it until the handle is touched, which puts the bolt on half-lock.

This contrivance, the object of which is intended to save the time of the turnkeys, places the bolt in such a position, that on closing the door from the inside, the lock can only be opened by the application of the key from the outside. According to the rules of the Pentonville prison, where these locks are used, every prisoner is obliged to touch the handle of the trigger, and so shut himself into his cell. There is nothing very novel in the construction of this lock, neither does it possess any real security, its only recommendation appears to be its cheapness, the price being but ten shillings. It certainly cannot be picked from the inside, as there is no keyhole, and the escape of prisoners from the above prison some months ago was not effected by picking the locks.

AUBIN'S LATCH-BOLT, invented about 1842.

This improvement in the construction of lever-latches consists in placing the latch-bolt at the back of the levers, thus making it almost impossible to reach the bolt by any surreptitious instrument. The key works upon a detached bolt, to which are gated five or more levers, and when the latter are lifted to their true position the detached bolt draws in the latch.

Another important feature in the construction of this latch is, that the latch-bolt works independently of the other limbs of the latch; and, further, as there is a projecting lip or nib on one or more of the levers, the bolt is thereby fastened, so that the

thin piece of steel used by burglars, and inserted between the door and door-frame to force back the latch-bolt is useless, the bolt being fast. On the back of the latch-case is a knob, which releases the lip or nib, and which is used for drawing back the latch-bolt. In some of these latches there is a pin which revolves through the top of the knob and passes in and through the latch-plate, thereby doubly securing the latch-bolt.

The inventor of this useful latch has experienced a serious loss by it; but few have been sold, in consequence of the price (ten shillings) being more than a common one can be had for.

TANN'S LOCK, Patent dated November 25th, 1843.

The patentees state that "The Reliance Guarded Lever Lock has a decided advantage over other lever locks, a new principle being introduced, viz.: the protecting one, two, or more of the levers by a guard which, in addition to all the advantages of the lever-detector locks, presents an entirely new feature, and prevents the possibility of any keys yet made opening it.

"Secondly, The guards are placed on several of the levers, and protect the lever either above or below them, so that even if a false key or pick succeeded in lifting to the proper height all the levers with unprotected fronts, it could not possibly raise the one behind the guarded lever, and the slightest extra lift of the guarded levers at once fixes the detector, and then the proper key only can regulate it."

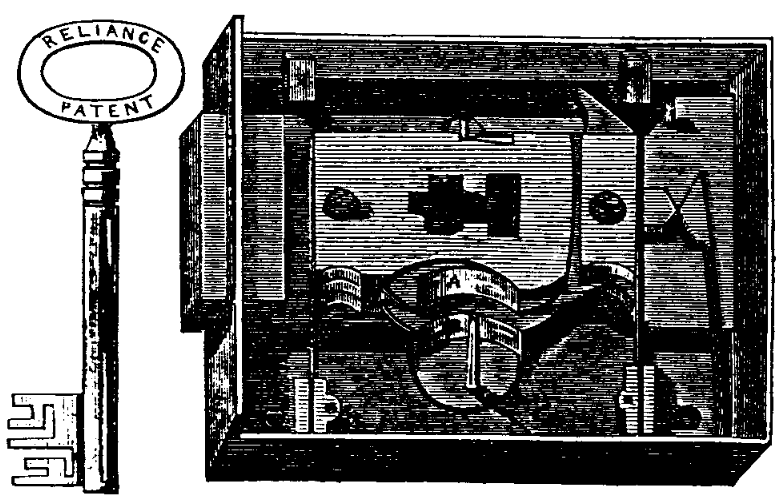


Figure 231. Tann's Reliance Guarded-lever Lock.

These guards are shown at A B, figure 231. The objection to their construction is, that the key-bit being cut to correspond thereto is very much weakened, and is thereby rendered more liable to be broken. The similarity of these "reliance guarded-levers" to the "descending-tumbler" of Somerford's second lock, invented many years before, on a comparison, will be apparent. The detecting apparatus is also identical with that of Richards'.

PITT'S IMPROVEMENT IN LATCH-BOLTS, introduced about 1844.

This improvement consisted in fixing on the latch-bolt a spring and lever, which hooked on to a stump fixed into the follow-horn. When used as a latch the follow would draw in the latch-bolt; and when required to lock, the lever (being balanced or pivotted in the middle) was lifted off by the action of the key, when it would lock, leaving the follow free; the hook-end of the lever would be moved on to another stump, and so fasten the bolt. The other parts of the lock were constructed on the common rim-lock principle.

PICKIN'S IMPROVEMENTS, introduced about 1844.

These improvements were applicable to common door locks, and consisted in drilling a small hole through the lock-case and main-bolt into the door, and at night inserting therein a pin or plug, which held the bolt, so that no key or any instrument whatever could move the bolt till the pin was withdrawn. This is a very simple and effective way of securing an inside lock, no matter upon what principle it may be constructed. The same inventor also introduced flush or secret slips to work into common locks, thereby adding further security to their construction at a trifling outlay.

CHESTERMAN'S IMPROVEMENT, introduced about 1844.

This improvement consisted in the application of curiously constructed levers to locks, so that signal wires could be carried from the internal machanism of lever locks to any required place. Some of these locks had best gun-locks fixed in them, and the action of the gun-lock combined with the levers. The tumbler of the gun-lock projected through the lock-case, to which was fixed at night a lever of about five inches in length, and the signal wire attached to the latter. The lever was then lifted up, which tightened the wire and put the gun-lock on "full cock." The action, therefore, was as follows:

Supposing the door closed and the lock fastened in the ordinary way and left (the key of course being taken out), could any false key or other instrument be forced into the lock, the instant the levers are touched (they being connected with the wire) they would act as a trigger, which would release the action of the gun-lock, thereby bringing down the lever to which was attached the signal wire, and this would set in motion an alarm bell placed in any required distant situation, so that its noise would not be heard by those tampering with the lock.

The signal being thus conveyed, there would be a chance of the thieves being detected on the spot. Window sashes, etc. could all be connected together in the above manner, if desired.

These locks were so expensive to make and fit up that few were sold, and consequently their manufacture has been abandoned.

POOLE'S LOCK, Patent dated December 4th, 1845.

The only peculiarity in the construction of this lock is the key and what the inventor calls the "follower." The screwed stem of this follower passes through a plate fixed inside the lock, and the cylindrical portion of it is screwed into a corresponding recess in the plate, and turns therein, the recess acting as a bearing for the follower.

The arm of the follower enters a notch formed in the bolt, consequently when the follower is turned on its axis of motion the bolt will be moved. Through the centre of the axis of the follower is formed a hole, and at one side a recess; and through this hole a pin passes, there being a cross-head affixed; and this cross-head is formed to fit the recess in the follower; hence, when the cross-head is in the recess, the bolt cannot be moved; and this pin, and consequently the cross-head, can be moved out of the way by means of the key, or by means of a lever constructed in the lock.

The key is formed with a female screw to fit the male screw in the follower; and the interior of the key is so formed that it will come against the pin, and push it back into a proper position to allow the bolt to slide. The bolt is at all times pressed outwards by a spring, and there is another spring which constantly presses the pin into the follower, and therefore the pin will, by its cross-head, retain the bolt from sliding till the pin is moved back; and the key, on being further turned, will receive back the bolt.

When it is desired that the bolt should be free to be acted on by its handle, then the lever before mentioned is to be folded down, by which means, owing to the form of the lever, the pin to which the lever is attached will be moved back by the lever, and as long as the lever is folded down the bolt will be free to be moved. The above improvements may be applied under different arrangements of locks, and the details may be modified.

AUBIN'S SLIDE-STUMP LOCK, invented about 1845.

This was intended as an improvement on Marr's lock. The stump, which is usually rivetted to the bolt, was in this lock fixed on a slide which worked in the bolt, and this slide threw out a detecting-bolt or slide at right angles to the other, and held a stump fixed in the plate. The other parts of the lock were constructed on the usual lever principle. It was found very expensive to make, and was consequently abandoned.

FELLOWES' IMPROVEMENT, introduced about 1845.

This improvement consisted in placing the tumbler and spring upon the main-bolt, which all moved together. The tumbler-stumps were racked or gated into the cap-plate of the lock, thereby simplifying and also adding to the strength of the lock by reducing the number of limbs.

COTTERILL'S LOCK, Patent dated March 25th, 1846.

The construction of this lock, which the inventor calls the "Patent Climax Detector Lock," is on the same principle as Bramah's, except that the sliders, with their springs, are placed in a position at right angles to that of the key, instead of in a position parallel with the key.

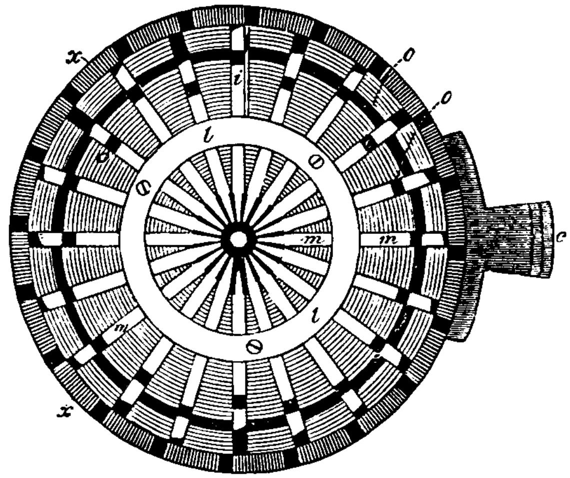
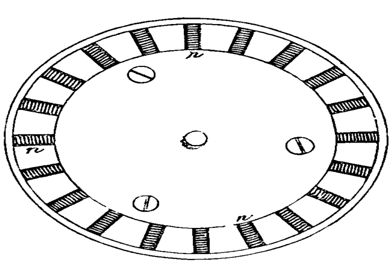
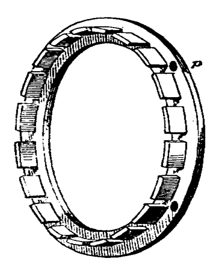


Figure 232.

Figure 232 represents a front view, showing the principle of the lock. Figure 233 is a back view of it. The cylindrical barrel, as shown in figures 232 and 233, contains a number of steel slides mm, (figures 232 and 235,) which move in radiating channels cut in the face of the barrel, and are pressed towards the centre by helical springs, nnn, figure 233, contained therein. A circular groove, oo, is cut in the face of the barrel, and also in the face of the slides, so that when the slides are forced outwards, by pressing the key into the keyhole, a continuous circular channel is formed by the coincidence of each of these with that in the barrel's face.

When the key is withdrawn, each of the slides is forced in different degrees towards the centre, so that their solid portions intercept the groove in the barrel, and in this position the barrel is held fast by a fixed circular ring p, figure 234, fitting in the groove oo, figure 232, and notched on its face so as to embrace each of the slides. The key consists of a cylindrical stem z, figure 235, having a number of inclined grooves cut in its circumference, agreeing with the number of slides in the lock.





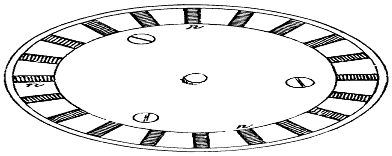


Figure 233.

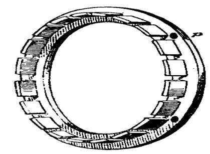


Figure 234.

These grooves are cut longitudinally in the barrel of the key, and they vary in depth, slope, and the angle formed by their bottom with the purpose of opening it; the inclined bottom of each groove forces out a slide until the openings in the latter coincide with the notched ring, figure 234, and the barrel may then be turned by the key in either direction.

Should an attempt be made to open the lock with a false key, the slides would be projected too far, and would be retained in that position by a spring-catch or detector i, figure 232, which falls into the groove, so that the true key cannot open the lock until by a peculiar backward movement the detector is disengaged; this detector is not likely to be thrown by accident. x, figures 232 and 235, is an outer ring for the purpose of preventing the slides being acted on separately. e is a thrower which works the lock-bolts underneath the disc, in a case (not shown in the cut) of the usual form. Figures 236 and 237 show another contrivance for increasing the security of the lock.

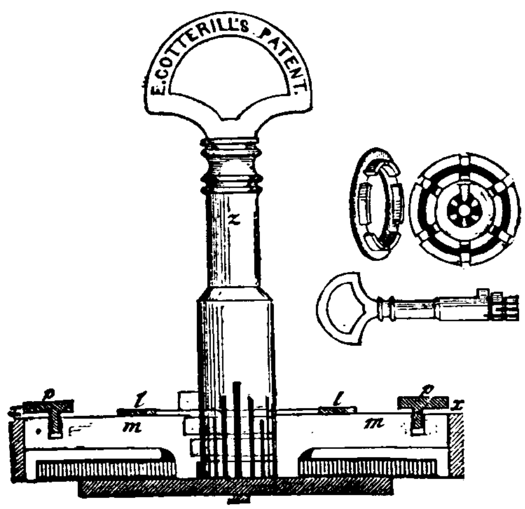
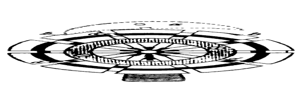
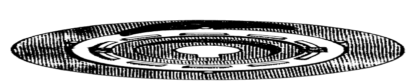
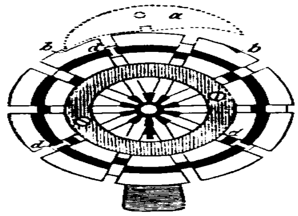
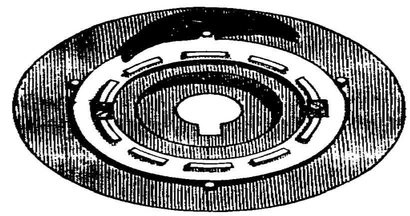


Figure 235.






a
b
b
d
d



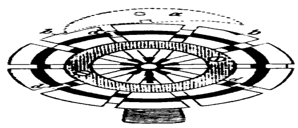


Figure 236.

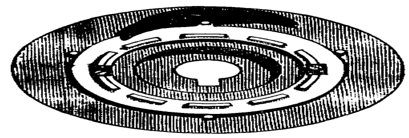


Figure 237

a is a double click, placed to prevent the possibility of a pick-lock acting upon the works, as the slightest strain applied to the lock, in either direction, would instantly oscillate the click and fasten it at b. The notches on the slides at dd will also prevent a strain being put upon the lock, for should an attempt be made to open the lock, the notched slides would come in contact with the circular notched ring, figure 234, and at once lock the action.

The inventor states that "any violent application of an opening instrument of a false key will not affect the works injuriously, owing to the slides being firmly fixed in deep grooves formed in the revolving-barrel, and secured down by a steel ring l, which precludes every approach to the movement by any other means than the legitimate key, from which, owing to its peculiar formation, it is impossible to take an impression, and advantage no other key possesses."

"The slides merely move along the grooves, under cover, and return by the pressure of the helical springs, which are equally distributed around, and these having such a very slight amount of duty to perform, are not liable to set or break; but supposing such an improbable thing could occur, it would not injure the action in the slightest degree, as the security of the lock rests solely on the exact distance the slides are forced from the centre, not in their returning to any particular place, consequently the security of the lock must remain unimpaired, even if the whole of the springs were damaged. Where the slightest friction occurs in the works, a counter one has been provided, in order to prevent derangement; in fact this lock has treble the strength and durability of any lock in the market, and possesses none of their liabilities to get out of order."

The keys are cut by a newly-invented machine, which can be varied whilst working to such an extent, that millions of keys may be cut and yet every one shall differ.

"The locks are all made to the keys, which at once removes the possibility of any but the legitimate keys opening them."

"This lock can be made to shoot any number of bolts in each

direction, and from the peculiarity of the principle gunpowder will not injure or affect the bolts in the slightest degree; neither can any instrument be applied to the key from the outside when the key is left in the door of a chamber inside. This is another peculiar advantage which no other lock possesses."

We may remark that there is nothing peculiar in the keys of this lock being made to lock, as this is the case with all best patent locks, as for instance, a six-lever lock. The key is first stepped as required, and then the levers are gated to it, which is identical with the cutting of the grooves in the slides of Cotterill's lock, after the prepared key has forced them to their true positions.

JONES' (American) LOCK, Patented in America about 1846.

This is a lever lock on the permutation principle, and very complicated. The levers are constructed with false notches, and there is a barrel and curtain combined. We have had lent to us, by Mr. Hobbs, one of these locks, which bears the date 1846, No. 184. It was sold by Mr. Jones to the United States Treasury in 1848. This identical lock Mr. Hobbs picked in 1850.

DE LA FONS' IMPROVEMENTS, Patent dated July 6th, 1846.

In the specification* of this patent various claims are set forth, the principal one being for a revolving or rotating bolt to locks in place of the ordinary straight action. The patentee also claims the use of the barrel and curtain, for the purpose of enabling the key to make an entire revolution, while the bolt made but three-fourths of a turn. The revolving forms a kind of outer ring to, and is acted on by, the curtain. The barrel and curtain, with the key, making a quarter of a turn before they move the bolt; they, of course, make a full turn while the bolt makes but three-quarters of one.

The closing up of the keyholes is spoken of in the specification merely as an incidental advantage gained by the arrangement, and although thus mentioned, was manifestly looked upon by Mr. De la Fons as of little consequence.

The other claim is for such a modification of one of his adoptions of the round bolt, as enables him to make it a tell-tale lock.

From the wording and meaning of the specification we feel

inclined to believe that Mr. De la Fons, at this period, had no real or defined conception of even the advantages supposed to be derived from the use of the combined barrel and curtain.

That Mr. De la Fons has no right to claim the barrel and curtain as his invention will be evident on a reference to the description of Mallet's lock; and we take the opportunity of here stating, that we believe the barrel and curtain combined was invented many years before the date of Mallet's patent (1820), as will be apparent from the following evidence we have obtained on this subject:

Mr. Richard Manning, keymaker, of Wolverhampton, distinctly remembers his step-father, John Roughley, of Cross Green, Coven, near Wolverhampton, maker of fluted keys and revolving barrels for the keys to work in, frequently making locks with the barrel and curtain combined, which he effected by brazing a thin disc of metal on to the top of the barrel. This was sixty years ago.

Mr. Thomas Wright, a locksmith in the employ of Mr. Duce, recollects making locks with the barrel and curtain combined sixty years ago. Mr. Yates used to make locks with the barrel and curtain combined, to order, a dozen at a time, forty years ago. Mr. Duce used to make locks with the barrel and curtain combined thirty-five years ago.

Mr. Thomas Hart, a locksmith in the employ of Mr. James Gibbons, jr., states that he recollects the barrel and curtain combined being used in locks made at Mr. David Evans', Brownlow-street, Drury Lane, London, about the year 1823; and that he used to make them there himself. Mr. Aubin used to make locks with the barrel and curtain combined, two and three at a time, to order. He used a piece of tubing for the barrel, with a thin disc of metal soldered on the top for the curtain, and this construction he states he copied from a very old lock. The last he sold, in quantity, were to a firm in Wolverhampton, January 15, 1845.

It appears that these locks were ordered principally for carpenters' tool-chests, when anything extra was required. That the barrel and curtain combined was also adopted in America previous to the date of this patent is quite evident, from the fact of Mr. Jones' lock containing it.

CHUBB'S QUADRUPLE LOCK, Patent dated December 14th, 1846.

This lock is especially intended for the fastenings of bankers'

and merchants' strong rooms, and other analogous uses. It is called 'The Quadruple Lock' (figure 238), and consists of a combination of four separate and distinct locks in one, all being acted upon at the same time by a single key with four bits. It will be seen in figure 238 that the main-bolts are attached to an eccentric wheel, throwing them each way; and to these bolts ten or twenty bolt-heads may be fitted.

The quadruple lock has six levers in each set, making altogether twenty-four levers, all of which must be acted upon simultaneously, by the motion of the proper key, before the eccentric wheel can be turned; it is thus utterly impossible, from the extensive combinations, for any attempt by a false instrument to succeed in unlocking it.

"As a further security there is a check lock, with a small key, which throws a hard steel-plate over the large keyhole. Thus, in a banking establishment, a confidential clerk may carry the quadruple key, and the principal having the smaller key, can at all times prevent the fire-proof safe or strong room from being opened, unless in his own presence."

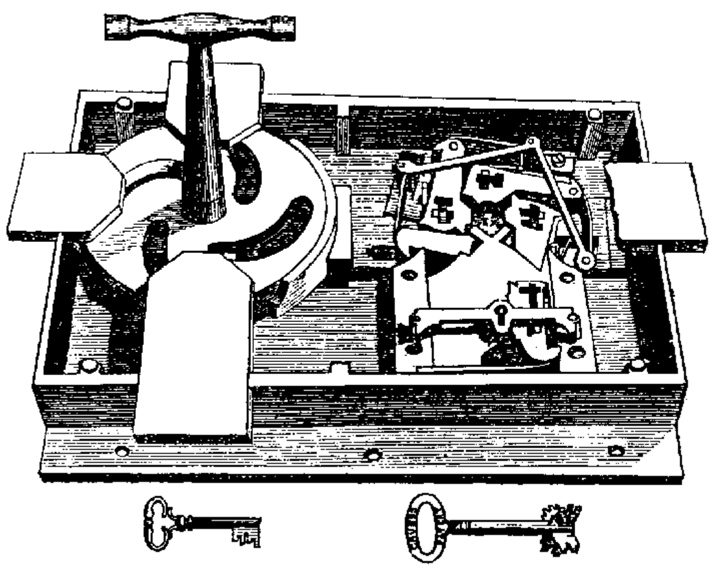


Figure 238. Chubb's Quadruple Lock.

We may observe that there is nothing new in the construction of this lock, as it is identical with the quadruple lock invented by Mr. Duce in 1823.

The use of these quadruple locks, the bolts of which are thrown

by the key, has altogether been superseded by throwing the bolts of such locks with a knob or T handle, and securing them by a small lock; and were it is desired that the principal of an establishment should lock and unlock the safe or strong room, and that the keyhole should be secure from observation, this effected by a slide lock-escutcheon, as shown in figures, 37 and 38.

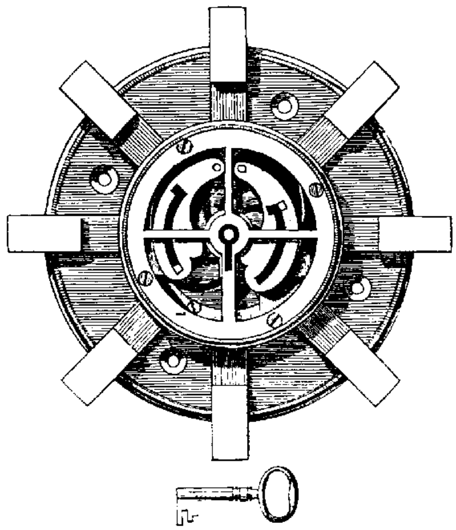


Figure 239. Multiple Lock.

Locks are also made with two or three keys, which require each key to be used successively in a certain order before the bolt can be moved, and such a plan obviates the necessity for having more than one lock.

It is convenient here to notice another kind of multiple lock.

Figure 239 represents a lock of this description, having eight bolts radiating from the centre, all of which are thrown by the small key shown in the cut, by means of eccentric wheels and levers; but in none of these multiple locks (as we have had occasion to observe before) is there any real utility, as greater security is obtained by simpler contrivances.

AUBIN'S CURTAIN-LEVER LOCK, invented about 1846.

This lock was constructed with several discs on a revolving barrel, so that the levers had a circular motion. Each of these circular levers formed a curtain to the keyhole, indeed they made a solid curtain. The barrel and curtain and levers were of the same shape, and all moved together with the key. Curious spaces

were cut out of the levers for the various steps of the key-bit to work against; there were also false notches cut in the circumference, thereby giving a great range of combination. When the true opening or path in the levers was placed in the right position by the key, a loose tongue on which was a stump passed into the levers; and the bolt was shot either out or in as required. The circular levers were kept in their proper position by check or binding springs.

BRIERLEY'S LOCK invented about 1846.

The peculiarity of the construction of this lock consists in fixing a jointed-hasp upon the face of a Bramah lock, on the underside of which is a stud that passes through lock-plate. This lock was adapted to an expanding leather folio or case, containing a number of pockets; these pockets, whether full or empty, are bound with a strap with brass eyelets, which is braced through the hasp, the stud of which passes through and secures it. During the Railway mania these folios were used as "scrip cases," and had an extensive sale. These cases are also made with indexes for letters, invoices, etc., and are extremely useful and convenient.

MORRIS'S DIRECTION PADLOCK, invented about 1846.

This padlock is constructed with a recess in front, in which are placed a dozen or more cards, with a thin piece of transparent horn placed before them. On one side of the recess which contains the cards is a lever secured in its place by the shackle. In using the lock the direction is written on one of the cards, and put into the recess under the piece of horn; the lever or bar is then put back, when it falls into a notch in the back of the shackle-joint; the key is then turned round, and the receptacle, together with the address, is safe.

This contrivance, which was quite a novelty in connection with padlocks, caused them to have an excellent sale, till the inventor reduced the quality of the article, which brought them into disrepute, eventuating their disuetude. We have heard it said that this latter circumstance led to the ruin of the inventor, who had a very large stock of them made, which no one would purchase. A more useful contrivance for the purpose designed we cannot conceive, and hope for the convenience of our commercial brethren some spirited locksmith will resume their manufacture. With a series of printed cards you may change your address as often as desired; and the cards and lock with ordinary

care would last a life-time.

PLANTE'S Lock, invented about 1846.

Plante introduced an excellent improvement into the construction of the common door lock, which he effected by affixing to the pin end of the key that projects through the back of the lock another bit which works outside the lock, and lifts up a spring that is rivetted or screwed on to the back of the lock. On the end of the spring there is a stout peg or stump, which passes through the lock-plate and into the bolt; and before the lock can be unlocked, this spring must be lifted up to release the stud which holds fast the main-bolt

TILDESLEY'S PADLOCK introduced in 1847.

This is a cast padlock, constructed with the patent tumbler of Tildesley and Sanders, invented in 1841 and is known in the market as "Tildesley's Patent Tumbler Padlock." The exterior is similar to Andrews's "American Mail-Bag Lock," from which it appears to have been copied by an individual who had visited America, and who afterwards sold the pirated invention to Mr. James Tildesley, of Willenhall. This lock has always had an extensive sale. The successors of Mr. Tildesley, Messrs. John Harper, jr. and Co., of the Albion Works, Willenhall, manufacture this and similar cast padlocks at remarkably low prices. (See chapter 19.)

NEWELL'S IMPROVEMENTS, Patent dated September 28th, 1848.

These improvements consist in the employment of two metal rings, one of which the inventor calls the key-ring, being accurately fitted and ground into the other. There are two holes bored in these rings exactly of the same size and opposite to each other, leaving a shoulder in the inner or key-ring, against which the key-bolts are pressed by a vulcanized India rubber or other suitable spring; these key-bolts are made of steel, each in two pieces, and are accurately fitted to slide in the holes bored in the rings; the thick part of them being longer than the length between the shoulder of the hole in the key-ring and the outer circumference of the ring, and the thin part projecting into the keyhole, to be acted upon by the key as hereafter described.

The key is formed with two grooves cut on the opposite side of it by a rotary cutter or other means; the grooves are large enough to admit the small ends of the key-bolts to slide along them, and

are formed with irregular or wavy bottoms, which differ from each other, the greatest depths of the grooves being at the end of the key, so that when the key is inserted into the keyhole up to its shoulder, the key-bolts shall be pressed outwards from the centre, and the thick ends of the inner pieces of the keybolts are then made to coincide exactly with the circumference of the key-ring. In this position the outer pieces of the key-bolts can offer no opposition to the key-ring, being turned round by means of the key; but when the key is withdrawn, the spring acting upon the outer pieces presses the inner pieces against the shoulder.

A "feather" on the key fits into the slot of the key-ring to take the strain off the ends of the key-bolts when the key-ring is being turned round, and a pin projecting from the key-ring moves the bolt of the lock. The ring is fixed to the box or case of the lock. When the key-ring has made half a turn, the ends of the key-bolts come exactly opposite to each other; and if the key be withdrawn from its hole, the spring will press the key-bolts against their shoulders in the holes and thrust the outer pieces into the ring, so that the key-ring cannot be turned round except by means of a key which shall press out the key-bolts to the proper distance at the same time.

The number of key-bolts may be increased. If three be used, they must be at equal distances from each other, and a third of a turn of the key-ring will lock or unlock them. If four bolts be used, they may be placed exactly at right angles, and then a quarter of a turn will lock or unlock them; or if two of them be placed opposite to each other, then the other two may be placed opposite to each other at any convenient angle with the other two, and then the key-ring must make half a turn to lock or unlock; if five or six bolts be used, they must be placed at equal distances from each other, and supposing that a pin projecting from the key-ring be used to move the lock-bolt then any number of fifth or sixth parts of a turn (together not exceeding half a turn) will lock or unlock; but if other means be used to move the lock-bolt, then it may be so arranged that any number of turns of the key will lock or unlock. The key-bolts may be arranged in sets one above the other.

YALE'S (America) LOCK invented about 1848.

The YALE lock has two cylinders, one working within the other, and they are held together by a series of pins reaching through the cylinders into the keyhole, which is in the centre. On the back of the inner cylinder is a pin that fits into a slot in the

bolt. and moves it as the cylinder is turned. The pins that hold the cylinders together and prevent the inner one from turning are cut in two at different lengths. The key is so made that by inserting it into the keyhole the pins are moved, so that the joint in the pins meets the joint between the cylinders, and allows the inner one to be turned. But as with the slides of the Bramah lock, should any one of the pins be pushed too far, the cylinder is held quite as firmly as though it had not been touched. Some of these locks have been made with as many as forty pins; and to a person unacquainted with the principles on which locks are picked, they would seem to present an insurmountable barrier.

For the purpose of picking the lock, an instrument is made that will fit between two of the pins, to that is attached a lever and weight, thereby getting a pressure on the cylinder, and causing the pins to bind; then with another instrument the pins are felt, and as they are found to bind, they are pressed in until they are relieved (as they will be when the joint comes to the right place), thereby easily opening the lock.

WINDLE and BLYTH'S LOCK invented about 1848.

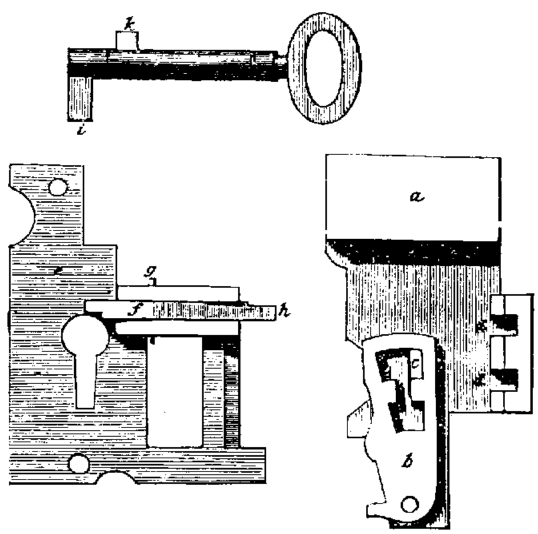


Figure 240. Windle and Blyth's Lock

Windle and Blyth's lever-bolt safety lock is of a peculiar construction. In addition to the usual double-acting levers, it has a set of "lever-bolt guards." Figure 240 represents the principal "limbs" of the lock detached. a is the bolt; b are the levers; c is the stump of the bolt; d d the escape racks for the

lever-bolt f h, which moves upon the axle g, to work in. The key is in two connected pieces, and has two bits, i, k, as shown in the cut; the upper bit, k, having a revolving motion. The bit, or the "rotary barrel-key," by its peculiar pressure, brings the lever-guards to their required position, and so retains them; whilst the key, by the usual rotary motion, acts upon the levers, and at the same time propels or withdraws the bolt at pleasure.

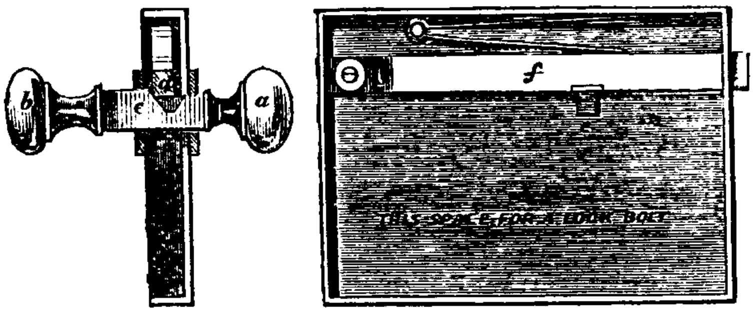


Figure 241. Windle and Blyth's Latch.

They are also the inventors of an improved action to latches, which consists in constructing the spindle with a v-formed channel on one of its squares, which works in a bevelled projecting-piece of the latch, as shown in figure 241. By pushing the knob from you on one side, or pulling it towards you on the other, it lifts the latch-bolt out of the staple or striking-plate, and so opens the door.

WILKES' LOCK, Patent dated May 8th, 1849.

This invention has for its object the use of a shield so arranged that by double locking a lock on the inside the shield will be caused to cover the keyhole, and prevent a key from being introduced from the front.

In the same specification the inventor claims certain improvements in the manufacture of knobs for door-locks and other purposes, and also improvements in the manufacture of lock-spindles.

This latter improvement consists in drilling centre holes on each square of the spindle at such a distance from each other, that by turning the spindle round. it should be certain to fit the various thicknesses of doors. It is secured in its place by a setscrew. This invention merely substitutes the centre-holes for the wormed angles of Duce's spindle.

JONES' LOCK, invented about 1849.

Jones was the inventor of a peculiar kind of stock lock, commonly called "The Drunkard's Lock," from the circumstance of the key always being in the right position to open the lock. The key is something like the figure 8, the end of the bit being as thick as the shank, and drilled out to fit the keyhole. A bolt and a tumbler are fixed on each side of the keyhole, so that let the key be put in which way you will (either up or down) you are sure to meet with the talon of one of the bolts.

If both bolts are required to be shot it is only necessary after locking out the one, to withdraw the key and put it in the reverse way and shoot the other. It is simply two locks in one, which are both worked from one keyhole. This lock will also do for either a right or a left-hand door. It has continued to have a good sale, whether front its peculiar convenience under certain circumstances to certain individuals we do not venture to say.

BRADFORD 'S LOCK, Patent dated July 22, 1850.

The improvements introduced by Mr. Bradford consist in adding to locks spring-bolts or catches, which take into the tumbler, or into the main-bolt of the lock, and are disposed in such positions that the tumbler or bolt cannot be moved with a picker or other such instrument until the spring-bolt or catch has been removed.

The spring is fixed immediately opposite to the lock-pin, which is made hollow, and has fitted into it a small rod or pin, the head of which rests upon the spring. Within the pipe of the key there is fitted another pin of the same size as the pin which is fitted into the lock-pin. The lengths of these pins are so arranged that when the key is put into the lock it causes the first pin to press against the spring, and thereby raise up the fore-end of that spring, which withdraws a third pin, which takes into a hole drilled in the main-bolt.

The withdrawing of the third pin allows the key to push over the bolt. Unless the key used for the lock were provided with arrangements for acting upon the last-named pin, the bolt could not be shifted by it. There is another hole in the bolt which receives this pin when the bolt is in its locked position. This is one of a considerable number of patented locks that have never come into general use.

AUBIN'S BALANCE-DETECTOR LOCK, invented 1850.

This lock is constructed on the principle of the scale-beam. The levers, which are double-acting, are gated at each end with a stump working in each gating. The centre of motion, a, figure 242, is in the middle of the levers; above the centre of motion is a stud or pin, e, fixed to the bottom lever; in each of the other levers is a semi-circular slot through which the pin works. This peculiar construction causes every lever to act as a detector; for if in the least moved out of their true position, the springs d or f pressing against the levers causes them to combine, and so prevents the bolt b from passing. The levers are so delicately poised that very little is required to throw them out of action; the idea was suggested by the action of the scale-beam.

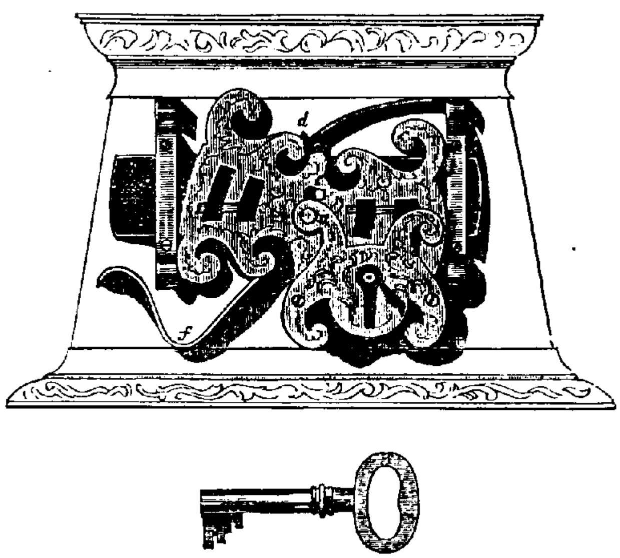


Figure 242. Aubin's Balance-Detector Lock.

AUBIN'S VIBRATING-GUARD LOCK, invented about 1850.

This lock is constructed on Bramah's principle, but with levers or vibrating-guards in the place of sliders. The levers are hung on a split ring, which fits into a groove in the barrel or cylinder b, figure 243. Each lever works in a groove in the barrel or cylinder, and when the key is pressed down it comes in contact with the pointed ends of the levers, and forces them down till the other ends rise to their true position, when the slots in the broad end of the levers are in a line and will pass the

locking-plate, as in Bramah's. If the point or inside end of the lever is pressed down but one-sixteenth of an inch it raises the other end about half-an-inch, which gives it a proportionate range of combination.

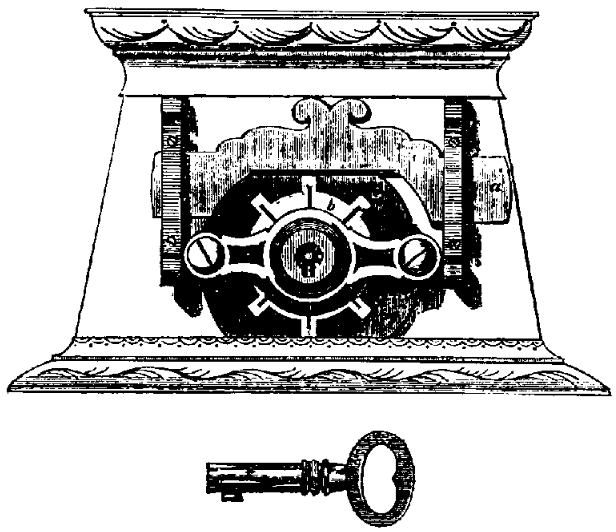


Figure 243. Aubin's Vibrating-Guard Lock.

Another peculiarity is that the key does not touch the bolta, as the latter is moved by an arm of the barrel coming in contact with a stud on the back of the bolt, and consequently the scroll of Bramah's lock is in this lock abandoned.

AUBIN'S COMPOUND-LEVER LOCK, invented 1850.

This is a compound-lever lock, the peculiarity of which consists in one set of levers, with their centre of motion at c, figure 244, acting on another set of levers, their centre of motion being at e. The key enters the lower levers b, and in turning round lifts them, which then come in contact with the necks of the upper levers d, and raises them to their true positions, so that the bolt a can move backwards and forwards. The levers on rising upwards close the keyhole, as in Parsons' change lock. The lower levers, if lifted one-sixteenth of an inch, move the upper levers one inch, thus giving a wide range of combination to the construction of the lock.

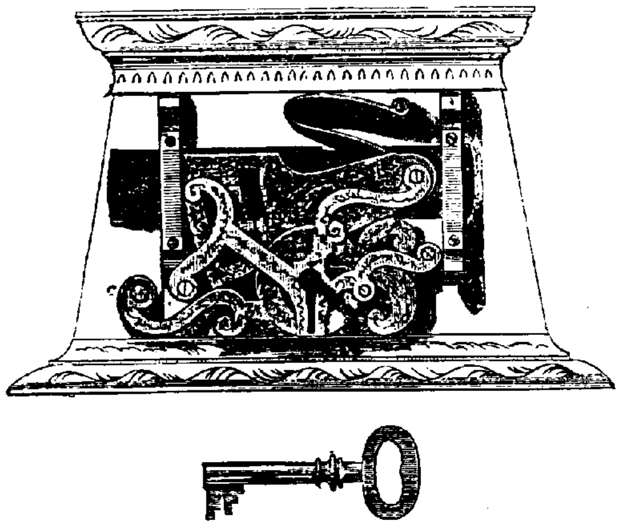


Figure 244. Aubin's Compound-Lever Lock.

This lock was found in practice to be too nicely constructed, as by heating the key in the flame of a gas-light caused sufficient expansion of the metal to prevent its opening the lock. It is undoubtedly a secure lock, but is very expensive to make.

TAYLOR'S LOCK, invented about 1850.

This is a detector lock, and is an improvement on Chubb's inasmuch as the detector acts when the levers are underlifted as well as when overlifted, and it may therefore be called a "double-action detector" lock.

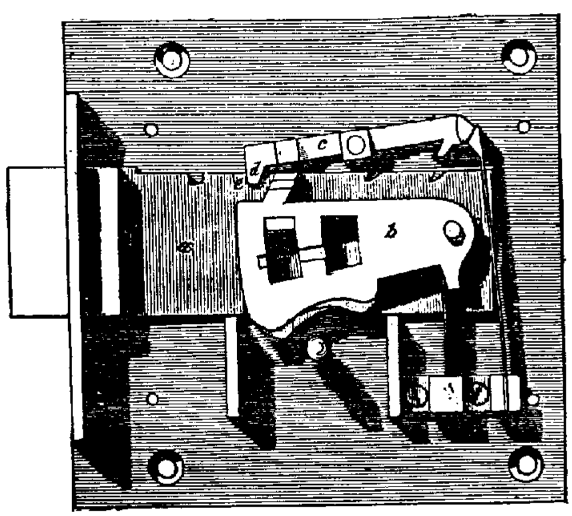


Figure 245. Taylor's Lock.

Figure 245 represents the lock with the cap removed. a the bolt; b the levers; c the detector; d the projecting nib of the detector, which falls into one of the notches in the main-bolt. The action of the lock is as follows:

When the bolt is locked out, as shown in the cut, the projecting nib, d, of the detector is in the second notch of the main-bolt, and before the bolt can be withdrawn or unlocked, this nib must be acted upon at once and equally by the arms of the levers; for if only one of the levers be overlifted, it forces the other end of the detector into the notch at the other end of the main-bolt, and thus prevents the bolt from moving. If the levers are underlifted, the nib of the detector remains in the notch, and again prevents the bolt from moving. This construction allows all the limbs of the lock to be strongly made.

BIGFORD'S LOCK, invented about 1850.

The improvement sought to be effected in this lock consists in the application of a slide or lever action on a part technically called the drill-pin, which, by inserting a false key, presses the end of a detector, thereby making the lock more secure. The advantages of this lock over the lever locks now in use consist in its being so easily detected on the introduction of a false key. The difficulties presenting themselves are:

1st. If the slide is pressed too low it detects the lock.

2nd. If the slide is not low enough the bolt will not pass.

3rd. When the lock is fixed, the proper depth of the work cannot be ascertained (the chief object in picking locks).

4th. The drill-pin and slide can be altered to such a variety of lengths that a lock with four levers is as secure as six levers on any other principle.

5th. It admits of the bolt being left much stronger than hitherto.

The inventor states that "the depth of other lever-detector locks may be easily ascertained without detecting the lock, bu in the improved detector lock this is quite impossible. The levers must be lifted to various heights by the key before the lock can be

opened or shut; and until each lever is at its proper height, the stud (which forms a part of the bolt) cannot pass through the racking in the levers; and if any of the levers are overlifted the lock will be detected, and it cannot then be opened by the proper key in the ordinary way; but notice is thus given, and the detector may be set right by turning the key in a contrary direction, as in locking. No instrument, or any but the proper key can release the detector."

TUCKER'S CLOSED KEYHOLE SEPARATING-KEY LOCK, invented 1851.

This lock, which had for its object the prevention of picking "by pressure," or by "ringing the changes," was an embodiment of that peculiar principle of security in locks, which this inventor was one of the first to apply, and which principle consists (to use his own words) "in the entire closing up of all communication with the moveable security parts of the lock, during the time that the security stump or piece is in contact with or passing through them."

In the present lock this principle was carried out as follows: Viewed externally it presented two keyholes and a knob or handle; both keyholes were perfectly cylindrical, the central or true keyhole being formed by a continuation through the lock-cap of the cylindrical tube of the drum which cantained the slides or security parts. This drum was fixed to the underside of the lock-cap, the sliders working horizontally in it, and radiating towards the centre of the tube. The handle was connected with a horizontal plate or curtain of case-hardened iron, and by its action opened or closed the central keyhole, and drew back or freed the sliders as required.

When the handle was turned so as to raise the curtain and open the keyhole, the keyhole (to the full depth of the lock) presented the appearance of an unbroken tube, affording no communication with the lock's mechanism; but if the handle were reversed, so as to bring the curtain over the keyhole, the sliders could then spring into the tube. Any attempt to raise the curtain (that is, to open the keyhole) would carry the sliders back into the drum, and fix them so that they could not be moved. The key was made in two parts, the lower or bit part being separable from the shank and bow, and requiring to be unscrewed whenever it was used in the lock; the bit of it was circular, its steps or variations being formed by a circle of sinks or recesses of varying depths in it.

The mutual action of the lock and key was as follows: the knob was first turned so as to uncover the central keyhole, the key was then placed into it, and the shank part unscrewed and removed from the lock, leaving the bit behind. The knob was then reversed so as to cover the bit entirely over, closing up the keyhole, and setting the sliders free, so as to allow their points to spring into the sinks in the key. The shank part of the key was then placed into the other keyhole and turned half round, carrying a circle of stumps (to which it gave action) through the gatings of the sliders, and throwing back the bolt.

Were a wrong key used, of course the circle of stumps could not pass the sliders, but would stop or bite against them in such a manner that if any communication with the sliders could then be obtained the lock could be picked; but as during the time such contact of the stumps and the sliders could take place the true keyhole would be hermetically sealed, and as the other keyhole at no time afforded any communication with the interior of the lock, it is clear that no skill could succeed in arranging them, as picking instruments could never reach them.

Picking by skill being thus rendered inoperative, the inventor then provided means to prevent the "changes being rung," which he effected by the use of a detector, so constructed and arranged as to come into operation only after certain of the sliders, which the security stumps must first pass, had been correctly arranged; the detector would then act so as to prevent the keyhole being opened to adjust the remainder.

The operator would in fact defeat himself, as success in his attempts to remove the first obstacles in his way would inevitably prevent any renewal of his experiments. The peculiar arrangement and formation of the key-steps in this lock were such as to throw great difficulty in the way of taking any impression of them. They could only be taken in sections, which would be a prolonged and delicate operation, requiring time, patience, and skill.

The inventor published in his circulars that "The lock placed by him in the Great Exhibition of 1851 was so made and constructed, and would long since have been brought into the market, but for an objection to which, on reflection, it was seen to be liable-that objection being that the key was made in two parts, the lower or bit portion (as it is technically termed) being separable from the shank and bow and requiring to be unscrewed whenever it was used in the lock.

The liability to accidental severance and consequent loss of the key-bit, and the manifest inconvenience attending such a mode of action, were deemed sufficient reasons to prevent its manufacture being proceeded with, although its security against fraudulent or scientific attempts at picking was such as to lead the inventor to invite Mr. Hobbs to operate upon it, conditioning to permit him to take the lock itself in pieces previous to the attempt, and then to allow him thirty days in which to make the experiment."

RESTELL'S LOCKS, invented in 1851.

The construction of Mr. Restell's two locks, which were exhibited at the Great Exhibition of 1851, and which were afterwards patented in December of the same year, we shall describe in the chapter on the modern locks. may, here observe that they were considered of sufficient merit to entitle the inventor to a prize medal.

The lever lock was the only one of a simple construction in the Exhibition that provided against picking by pressure, and was one of the first with the improvement introduced for that especial object.

WOLVERSON'S LOCK, invented about 1851.

This lock was constructed with an improved detector and an entirely new combination of levers, the principle in which seems to be that the levers communicate with three snail-like pans of metal, the effect of the key operating upon which is to throw the detector. The bolt becomes immoveable, and the combination of levers assumes such a position as to render it extremely difficult to open the lock or correct the alteration, from the ordinary position of its several parts, without the introduction of the proper key.

SUMMARY OF THE THIS CHAPTER AND THE GREAT EXHIBITION OF 1851

We have now described all the principal locks invented or known in England previous to the opening of the Great Exhibition of 1851 an exposition, which has been the means of improving the arts and manufactures of this country to an extraordinary degree. We can only form a judgment of inferiority or superiority by comparison, and at the World's Fair we were then shown in what branch of art, and in what articles of manufacture, we were

excelled by the foreign exhibitors. How far the particular manufacture of locks and keys has benefitted by the display and competition and consequent controversy of 1851 must be judged by the merits of the inventions and productions which have been introduced since that period.

Reserving our remarks on this part of our subject for the chapter on the moderns locks, we shall conclude this chapter with a description and illustration of that beautiful and ingenious piece of lock-mechanism designed and made by Mr. Aubin; a table showing the number of the Foreign and British exhibitors of locks at the Great Exhibition; a list of those who obtained prize medals or honourable mention; and the jury's report on locks.

Mr. Aubin's "Lock Trophy" was undoubtedly one of the most ingenious pieces of mechanism in the Exhibition, and we think it deserved a better notice in the Official Illustrated Catalogue than simply "Specimens to illustrate the rise and progress of the art of making Locks, containing forty-four different movements by the most celebrated inventors in the lock trade," more especially as its fabricator was a working locksmith, in humble circumstances. We may remark, too, that the one who appeared to appreciate this valuable specimen most, and who has designated it "The Trophy of Lock Ingenuity," was the American, Mr. Hobbs, who immediately purchased it from its maker.

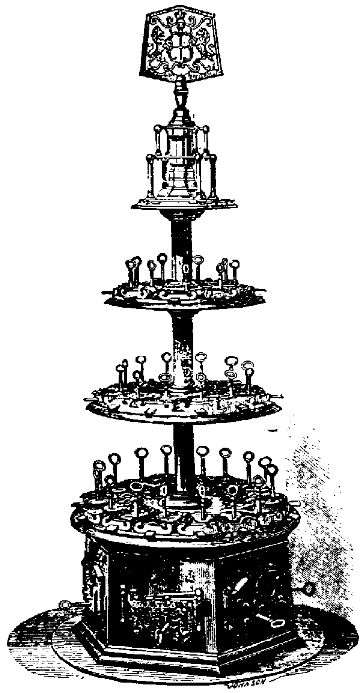


Figure 246. Aubin's Lock Trophy.

This trophy consists of a central pillar or axis about thirty inches in height, which rises from a hexagonal base-piece, the bottom supporting four horizontal circular discs, placed at different elevation from the lowest platform. On each of the vertical faces of the base-plate is constructed a lock, each being worked by its respective key. On each disc or platform there is a number of locks; sixteen on the lowest, twelve on the next above, nine on the third in height; while a Bramah lock surmounts the whole.

All the locks on the three platforms are so arranged that their bolts shoot outwards or radially from the axis or pillar. Each lock has its own proper key inserted in the keyhole; and as the locks lie horizontally, the drill-pin of each lock and the pipe of each key are of course vertical, as shown in the drawing. (Figure 246) There are delicate pieces of mechanism contained within the central axis and the chambers of the platforms, consisting of levers, racks, and pinions; and the Bramah lock is contrived so ingeniously, that its key, by acting upon that lock, acts simultaneously on all this mechanism.

The Bramah barrel, in rotating horizontally under the action of its key, gives a rotory movement to a rod passing vertically

through the centre of the whole apparatus; this rod at the levels of the several platforms acts upon racks and pinions, and these in turn act upon the key-pins rotate, each exactly in the same way as if the lock were being locked or unlocked, and the bolts shoot in or out accordingly.

All the locks are faithful representations of the several patented or other modes of construction to which they severally refer; and each exhibits the works sufficiently open to display the principle on which it is arranged. The works are finished with the utmost care; and the ornamentation and general design of the trophy exhibit a considerable amount of artistic skill highly creditable to its maker. The locks are arranged and numbered according to their similarity of construction, with a view to show how much alike some locks are, and how one inventor has copied the invention of another.

LIST OF LOCKS DESCRIBED WITHIN THIS CHAPTER AND THEIR CHRONOLOGICAL DEVELOPMENT

The following list will ill show where most of these locks have been described in the present chapter :

No. 1, Lock consists of a single bolt, with a binderspring for holding the bolt in any position in which it may be placed until a sufficient force is applied to overcome it; it embodies the simple principle on which thousands of common locks are annually made.
No. 2, Resembles the latter with the addition of a friction-roller. The bolts of either of these two locks can easily be forced back by pressing on the end of the bolt.
No. 3, Is a bolt lock copied from a lock found in an ancient building. It exhibits an improvement on both the former specimens, in so far as the bolt requires, before it can be shot, to be pressed down, in order to release it from a catch at the back end of the bolt. This release cannot be effected without the aid of a key or some other implement applied through the keyhole, and thus the bolt answers the purpose both of bolt and tumbler.
No. 4, Is a single-acting tumbler lock.
No. 5, Is an old English lock, with a double acting tumbler, being a great advance in principle on the single-acting tumbler.
No. 6, Is a modern English single-acting tumbler lock.

No. 7, By Mace, is a double-acting tumbler lock.
No. 8, Somerford's first lock.
No. 9, Has a single-acting tumbler with a pin, copied from a lock on an Indian cabinet.
No. 10, Thompson's lock.
No. 11, Daniell's lock.
No. 12, Walton's lock.
No. 13, Barron's single double-acting turnbler.
No. 14, Bickerton's first lock.
No. 15, Is a peculiar kind of tumbler lock, copied from a Dutch lock.
No. 16, By Duce, Sr.
No. 17, By Sanders, is a lock with four double acting tumblers, and is identical with the next, invented fifty years before.
No. 18, By Cornthwaite.
No. 19, By Richards.
No. 20, Somerford's second lock.
No. 21, Rowntree's lock.
No. 22, Duce's (jr.) firstlock.
No. 23, Parsons' balance-lever lock.
No. 24, Bickerton's second lock.
No. 25, Price's lock.
No. 26, Aubin's first lock.
No. 27, Barron's fly-talon lock.
No. 28, Bird's lock.
No. 29, Duce's (jr.) second lock (patented).
No. 30, Ruxton's lcok.
No. 31, Chubb's lcok 1824.
No. 32, Marr's lock.
No. 33, Tann's lock.
No. 34, Chubb's lock of 1833.
No. 35, Parsons' vertical lock.
No. 36, Young's fly-guard lock.
No. 37, Lawton's lock.
No. 38, Strutt's lock.
No. 39, Scott's lock.
No. 40, Chubb's original detector lock.
No. 41, Parsons' change lock, 1833.
No. 42, Peirce's lock.
No. 43, Ruxton's tell-tale lock.
No. 44, Bramah's lock, showing the improvements introduced by Mr. Rusell and Mr. S. Mordan.

JURY'S REPORT ON LOCKS.

"In the manufacture of locks, Wolverhampton still sustains its ancient reputation. Excellence of Workmanship, lowness of price, and an adequate degree of security characterise the contributions from that place, and prove the advantage of the peculiar division of labour which is adopted in the manufacture. The specimens of locks throughout the exhibition generally evince that the art is in a very advanced state, both here and on the continent, but still it is impossible for the jury to ignore the fact, that the present condition of lock-making is traceable to English ingenuity and invention; and they believe that, on the whole the collection of locks on the British side deserves the place of preeminence.

The lock on the very well-made safe of SOMMERMEIER, of Magdenbourg, (1 Zollv., 802, p. 1094) may be noticed honorably; and the bank lock of Messrs. Day AND NEWELL, of New York, (United States, 298 p. 1453) is remarkable for ingenuity of principle, and for combinations and arrangements which seem to render it impregnable. Locks of this description, if they could be sold at a moderate price, and made available for ordinary purposes, would no doubt be favorably received, and remumerate the inventor.

It is, however, a serious objection to any lock, notwithstanding its ingenuity and security, that the key should be so ponderous and bulky as to require for itself a separate place of deposit and safe keeping. The smallness of the key in proportion to the size and strength of the lock is particularly remarkable in the locks of Messrs. BRAMAH and of Messrs. CHUBB, besides those merits in other respects, which public opinion has so long and so amply recognized.

"On the comparative security afforded by the various locks which have come before the jury, they are not prepared to offer an opinion. They would merely express a doubt whether the circumstance that a lock has been picked under conditions which ordinarily could scarcely ever, if at all, be obtained, can be assumed as a test of its insecurity."

CHAPTER FIFTEEN: The Lock Controversy Previous to and

during the Great Exhibition of 1851

Ne craindra-t-on pas que nous ne donnons en meme temps des legons aux voleurs? Il n'y a pas grande apparence qu'ils viennent les chercher ici, on qu'ils en aient besoin; ils sont plus grands maitres que nous dans L'art d'ouvrir les portes. Apprenons done L'art d'ouvrir les portes femees, afin D'apprendre celui de les fermer D'une manicre qui ne laisse rien ou qui laisse pen a craindre. [1(502)]

PREVIOUS to the Great Exhibition the locks most in general use were Barron's, Bramah's, Chubb's, and Parsons'. These were considered to that period perfectly secure, not only against the ordinary thief, but also against the accomplished pick-lock.

The usual mode adopted by the inventors of locks to test their inviolability was to challenge the trade or other persons to pick them, and in some cases to offer a certain reward to any one who should accomplish the task. We believe Mr. Bramah was the first to do so, who about half a century ago placed in his shop window, in Piccadilly, aboard, to which was appended a padlock (see figures, **251** and **252**), and upon which board was painted the following words:

"The artist who can make an instrument that will pick or open this lock shall receive two hundred guineas the moment it is produced."

In 1817, a very ingenious mechanics attracted by the reward, and fired by the honor of opening this mysterious lock, spent upwards of a week in endeavoring to solve the problem, and eventually gave it up in despair.

In the year 1832, Mr. Chubb challenged a Mr. Thomas Hart, an ingenious locksmith of Wolverhampton, to open *his* lock, and the challenge was accepted.

The following account of this trial, together with Mr. Chubb's letter is copied from the *Wolverhampton Chronicle* of May, 1832:

"During the whole day, notwithstanding the unfavorableness of the weather (the experiment taking place in the open yard of the New Hotel), considerable interest was manifested by a crowd

of factors, manufacturers, and especially locksmiths, who constantly attended till the termination of the trial. The visitors at the inn likewise partook of the curiosity; as we observed Lord Clive, the Hon Mr. Clive, Sir J. Wrottesley, and several other gentlemen very attentive."

"We take no particular interest in any one individual, whether he be Barron, Bramah, Chubb, or any other; but we do feel a deep concern for the quality and reputation of one of the principal and most important articles of our town's manufactures; and we should much regret that, when so large a sacrifice of time, talent, and fortune is made to secure the safety and lives of the public from the midnight deprecator and other thieves, the object should not be attained, or the ingenuity of the mechanist rewarded."

"*ADVERTISMENT*"

"To the Editor of the Wolverhampton Chronicle."

"My letter, which you inserted in last Wednesday's Chronicle would inform your readers of my invitation to Mr. Thomas Hart to meet me at the New Hotel, in this town, on Thursday last, at 4:00 o'clock, to try his skill in attempting to pick my patent locks. At the appointed time I attended with several gentlemen of the town. After waiting an hour Mr. Hart did not appear. He declined to come using the pretense that I had not offered a reward in case he was successful in picking the locks."

"Being desirous of affording him an opportunity of putting his threat into execution, '*that he could pick them very easily,*' I published, early the next morning, a public challenge, and had it posted throughout the town, offering a reward of ten pounds to THOMAS HART, or any other person, who should *fairly pick* one of my improved Patent Detector Locks, that I would affix on a door of the New Hotel on Friday and Saturday, between the hours of ten o'clock and five."

"Accordingly, he came about ten O'clock on Saturday, bringing with him a vice, hammer, files, *blank keys,* and a variety of other articles, and fixed a key-pin in the door, to facilitate his cutting the blanks."

"He then commenced a vigorous and incessant attack on the lock, which he kept up until within ten minutes before five

O'clock, saving when he went to a workshop in the neighborhood, where several workmen were assisting him."

"At that time he gave up the trial, finding he could not possibly succeed. Soon after five O'clock the lock was taken off the door, sealed up by two gentlemen present, and delivered into the hands of Mr. BARTER, the proprietor of the hotel. This so that it might be opened and examined by two principal locksmiths of the town. One being appointed by myself and the other by Mr. Hart. Their job being to ascertain that the lock was made strictly according to my patent. This they did and at the conclusion I received the hearty congratulations of my friends, and repeated cheers from the multitude."

"Such has been the result of this vain boaster, his threats and his affidavits, aided by those of others."

"Since my arrival here I have been made acquainted of the various tricks and nefarious practices resorted to for the purpose of bringing my lock in to disrepute and injuring my reputation. I shall take an early opportunity of exposing the artifices and their authors to the public. Instead of HART attempting to pick the lock, all his efforts were directed to make a key, by the aid of blanks, lamp smoking, & etc., as he found it totally impossible to succeed in fairly picking it, which I required in my advertisement. He was frequently told by the bystanders the means he was trying was most unfair and untenable, but all could not succeed!!"

CHARLES CHUBB

"WOLVERHAMPTON, May 8th, 1832."

"This is to certify that we, the undersigned, having examined the Lock, No. 2,957, U, which was affixed to the door in the yard of the New Hotel, Wolverhampton, and which was attempted to be picked by THOMAS HART, on the fifth day of May, 1832; and we declare it to be strictly one of Mr. Chubb's Improved Patent Detector Locks, without any addition.

"Signed this 7th day of May, 1832.

James Mace, Lock Manufacturer
Bond Street, Wolverhampton.
John Green, Lock Manufacturer,
Stafford Street,
Wolverhampton.

Having discovered that the "Thomas Hart" was still in existence, we thought it only fair, instead of confining ourselves to the

exparte statement of Mr. Chubb, to give also the statement of Mr. Hart, and we do so in his own words.

He says:-

"In 1832, I was then in business on my own account in Wolverhampton, and was in the habit of receiving Chubb's locks to make for a manufacturer of the name of Joseph Richards, who made locks for Mr. Chubb. On one occasion some dissatisfaction was expressed by Mr. Chubb's manager at the locks having been made by me instead of Richards getting them done on his own premised. This led Mr. Chubb's manager to saying that he would not pass my work. To this I replied that he need not be so extremely particular, for that I could construct and make a lock quite as good as Chubb's in a very short time. I afterwards did so, and it was brought out by Mr. Richards. When they came into the market, Mr. Chubb published in the newspapers an advertisement with the name of Mr. Brunnel attached, to the effect that Richards' lock was good for nothing. On Mr. Richards telling me this, I retaliated by saying that I could pick Chubb's lock as easy as I could pick any common tumbler lock. This was afterwards told to Mr. Chubb, and then came the challenge. Now for my account of the said trial."

"At the time I received Mr. Chubb's challenge, I was then working for Mr. Richards as a journeyman. On the Friday the town crier went about the streets crying the challenge, and he did so more particularly before the workshop of Mr. Richards. This provocation proved too much for humanity to bear, and I at once accepted the challenge, and went on the following morning (Saturday) for the purpose of commencing operations. I then and there proposed that the lock to be operated upon should be one of those Mr. Chubb had previously been in the habit of selling as his commercial locks. About two hours were consumed in discussing this point, when it was decided that the lock which was then fixed on an outside door in the New Hotel yard was one of the same kind, but that if on examination it was proved not to be so, then Mr. Chubb would forfeit five pounds to some charitable institution."

"I then commenced operations, and soon found that the lock was not one of his regular commercial locks, for that it contained extra work. The consequence was that having brought with me only a few tin tubes, with a bit of sheet brass soft-soldered to each (with which simple instruments I had frequently opened Chubb’s locks), convinced me that I could not

operate successfully with them, and I was obliged to go to Mr. Richards's shop in the neighborhood to get a key-blank for strength. As this made-up test lock was so constructed that its own key would scarcely move the bolt backwards and forwards. I had previously offered to pick any lock that anyone would go and purchase of Chubb's make from any shop in the town, but this Mr. Chubb would not agree to. He would only consent to the trial of the lock made purposely for the occasion."

"I did not take with me any vice, but a small table-vice was brought without my request or knowledge by some other person, but such vice was not made use of by me. As soon as I inserted the tin tube in the lock, I discovered that it contained a bridge-ward which none other of Chubb's locks ever did contain before. However, not disconcerted but much annoyed, I was compelled to send for a drill and drill-string, for the purpose of drilling the blank-key to pass the bridge-ward, which no other lock required. After I had operated for some time, Mr. Chubb's manager said it was dinner-time, and that if I went to dinner I should be allowed an extra hour at night to make up for it."

"I then went to dinner, and after I returned I got the pick to pass the bridge-ward. I then first threw the detector and smoked the key-bit and applied it to the bellies of the levers, which at that time corresponded to the steps of the key, and were not flush or level-bellied, as made at the present time. I then put in the key the reverse or locking way, which gave me the true gauge for the stepping of the key-bit, which I accomplished by reducing the blank in proportion as the steps were required to be long or short."

"When I found, after stepping the brass key, that it was too weak to shoot the bolt, I went to Mr. Richards' shop, as I have before stated, and got a blank, understanding that I should have the dinner hour allowed me to operate, according as it was promised. While I was away I fitted an iron one to the shape of the brass one, and returned, feeling confident that the iron key would open it. To my surprise found that the lock was taken away, and this was some minutes before five o'clock."

"I had before this time picked eighteen of Chubb's locks, eight of which were sealed separately in papers and sent to me by the late Mr. Mordan, for the purpose of proof, and eight of them I opened at the Deanery, in this town, in the presence of the late Rev. J. Clare, a magistrate; Mr. Wynn, a factor; Mr. Perry, a factor; and Mr. Ebbels, architect."

"The first lock picked by me was ordered specially from Mr. Chubb's factory. It was placed on a block of wood six inches thick."

At this period (1832) Chubb's locks were constructed with but four levers, and these had not flush or level bellies.

It is important to state here that Mr. Hobbs, in operating upon Chubb's lock in 1851, commenced in the same manner as Mr. Hart did in the above trial, *by first throwing the detector.* From the remarks on this subject by the editor of *Herbert's Encyclopedia,* written about the same period, and printed at page 381 of this work, it is evident that this mode of operating on Chubb's locks was at that time understood.

The next account of one of these trials we here copy from a circular published by Mr. Parsons in 1834.

After describing his several other locks, he says, "THE BALANCE-TUMBLER DOOR LOCK has been and will be submitted with confidence to the man of scientific discrimination, solely with its own recommendation; and with the following testimonial in its favor to those who have not the little mechanical knowledge that would enable them to look with a discerning eye at the excellence of its construction in regard to *strength, security, and probable durability.* It consists of a *report* that was made, by the scientific persons whose names are subjoined, *of an unprecedented trial* which a small padlock, containing 26 balance-tumblers, sustained in July and August, 1834. The conclusion of which was witnessed by very many other highly respectable and intelligent persons, who also heard the declarations of the men:-

"On the 21st instant, we witnessed, at the Adelaide Rooms, the total failure of every attempt which could be made by all who applied (three most skillful and long experienced locksmiths) since the advertisement appeared, to make an instrument that would unlock PARSONS' THREE-INCH PADLOCK, for which the patentee in the beginning of last month offered, in several of the London and provincial newspapers, the unprecedented reward of ONE THOUSAND GUINEAS."

"Three candidates appeared, viz. -Thomas Cornell, WHO had been a locksmith about sixteen years and commenced his operations on the 23rd of July. William Hartill, who had been in the trade forty-four years and began on the day following. Joseph Dye, of

thirty-three years' standing, who set to work on the 1st instant. When it is known that the first successful candidate only was to have the prize, it cannot be doubted each spoke truly in saying he had used his utmost energies to succeed, until the termination, on the 21st instant, when they showed that all their efforts were in vain and acknowledged they could not unlock it, although they were in the constant practice of picking all other kinds of locks they met with in general."

"They said that every fair means and opportunity had been allowed them from day to day, and that they were well acquainted with the construction of this kind of lock, but could not even discover how many tumblers the lock contained; but when opened, to show that no deception was practiced, no less than twenty-six tumblers were found to be enclosed within its small case, of the usual size."

"This was never before found practicable by any person but the patentee, who has thus supplied the desideratum, heretofore sought in vain, of locks at moderate price, and of the regular, or even smaller dimensions, perfectly inviolable by any pick-lock or false key. We took the opportunity of examining his other kinds of locks, and feel it right to express our decided approbation; and we have had long and extensive experience in all kinds of the most ingenious patented machinery. His ne plus ultra-THE CHANGE LOCK, in which perpetual changes may be made in the lock and key, is an excellent, yet simple contrivance, to guard against the accidental loss of a key. THE BALANCE-TUMBLER LOCK, of which this trial was made, is the STRONGEST AND MOST SIMPLE TUMBLER LOCK WE HAVE EVER SEEN, AND 1S LIKELY TO BE THE MOST DURABLE."

"CHARLES PAYNE, Adelaide Rooms.
"WILLIAM CARPMAEL, Civil Engineer.
"J.R. JOBBINS, Mechanical Engineer.
"C.F. CHEFFINS, Mechanical Engineer.
"JOHN HENFREY, Engineer.

"London, 23rd August, 1834".

Such were the triumphs gained by three of the principal lock-manufacturers to the year 1851. Bramah's lock when operated upon in 1817, Chubb's in 1832, and Parson's in 1834, all successfully stood the test.

The inviolability of locks appears to have attracted more attention and to have excited much greater interest in America than the subject did here for some years previous to the time of the Great Exhibition. For particulars of the *American Lock Controversy,* we must refer our readers to a very interesting account of it in Mr. Tomlinson's *Rudimentary Treatise on the construction of locks,* which we have had so often to refer to before.

The following passage, however, we extract:-

"Soon after the inventions by Dr. Andrews and Mr. Newell, in 1841 (described in a former chapter), the rivalry between the two locks ran high; each lock being "unpickable" according to the estimate of its inventor. Mr. Newell thought the best mode of showing the superiority of his own lock would be by picking that of his competitor. After several trials, he succeeded in bringing into practical application that system of picking which we may designate the *mechanical,* as contra-distinguished from the *arithmetical.* Mr. Newell not only picked Dr. Andrews' lock, but he wound up the enterprise by picking his own! He was probably the first person who honestly confessed to having picked his own unpickable lock."

This discovery led Mr. Newell to the invention of the triple-action or parautoptic lock which we shall fully describe in the next chapter.

In America the art of lock-picking has been studied and practiced as a science in connection with lock making, while here, and especially amongst the Wolverhampton locksmiths, a distinction has been observed. A kind of opprobium used to be attached to the name of pick-lock;[2(503)] and when one maker discovered that he could pick his neighbor's lock, he usually kept it secret, on the principle that if it became generally known, the whole trade would suffer in consequence. The object was to keep the public in a state of blind security.

Although the very principle by which the American locks were picked was known and promulgated here more than a quarter of a century ago by Mr. Ainger, in the *Encyclopedia Britannica* (see page 306 *ante)*, yet it appears to have either been forgotten, or never to have been applied since that period; therefore, when Mr. Hobbs visited England in 1851, the field was as open for him as any man could have desired, and the success with which his operations were attended proved the truth of all that he had

stated and the certainty of the principle of manipulation. He found that although, as above stated, the discovery of the tentative process of picking locks had been made known, yet that no one in the trade understood it. That every lock that was then being manufactured possessed no real security, because so readily opened by any ingenious operator by applying pressure to the bolt. That all the security affected by the combinations of six levers amounted to nothing.

At the meeting of Civil Engineers in 1850, when Chubb read his paper "On the Construction of Locks and Keys," an interesting discussion ensued, and it is important to note here what was said by the several speakers on the subject of picking locks.

Mr. Farey observed that-

"Chubb's lock was a very improved modification of Barron's, containing six double-acting tumblers combined together, and also possessing the important adjunct of the 'detector,'. In no instance had one of Chubb's locks been opened by picklocks, and, indeed, with a combination of six tumblers, it became exceedingly difficult to make a false key sufficiently accurate to open a lock, because each step of the key required to be just sufficient to lift the tumbler to which that step belonged. If the step was too long the tumbler would be overlifted, and would thereby detain the bolt. If the step was too short it would not lift the tumbler high enough to release the bolt. No indication could be obtained by the trial of a false key in the lock, as to which of the steps was too long or too short."

"The lock would be secured against unlocking by any one or more of the six tumblers, being either overlifted or not lifted high enough; but it could not be ascertained which tumbler detained the bolt, or which step of the false key was incorrect. In such a state of uncertainty all attempts to rectify the inaccuracy of the false key must be directed by mere guess, and alterations were as likely to be made in the steps which were nearly correct, as in those which were wrong."

It was formerly thought that a skilful workman, furnished with impressions taken from the true key, in wax or soap, could make a false key to open any lock and in common locks with the most elaborate wards, but with only one common tumbler. Also, in Bramah's locks, there was much truth in the notion; but for a lock with six double-acting tumblers combined, a false key made ever so carefully, according to impressions, would not be likely

to open the lock for want of exactitude in the lengths of the several steps. If the key could not be made exact from the impressions, there would be no chance of rectifying it by trial in the lock, on account of the total uncertainty as to which part required alteration.

“Chubb's detector being combined with the six double-acting tumblers added very greatly to the security of the lock, for in the course of making trials with a pick-lock or false key, if any one of the tumblers was lifted too high it overset the detector detente which, by a spring action, fastened the bolt so as to secure it from being afterwards withdrawn; and although the bolt should be released from all obstruction by the other tumblers, the fastened tumbler would of itself continue to hold the bolt, as an additional detention, not capable of being removed even by an ordinary application of the true key, which would not go round in the lock after the detector was brought into action, and thus notice was given that a fraudulent attempt had been made to violate the lock."

"To set the detector free, the true key required to be first turned partially round, in a reverse direction, whereby the detector was restored to its quiescent position, and then the true key would operate in the usual manner. It was only by overlifting any one or more of the tumblers that the detector could be brought into action, and the use of the true key could never overlift any tumbler or disturb the detector."

“In making a false key the bit was usually left rather too long, being gradually reduced by trial until the proper length was attained. Though this process might succeed with a common lock, it had no chance with Chubb's lock, which would become detected by one trial with a false key, having even but one step too long, and if a step was too short at first it was not to easy to lengthen it. Hence the maker of a false key was beset with difficulty at every stage of his operations. Without tolerably accurate information respecting the true key it was scarcely possible to find out the combination of the six tumblers, or to avoid bringing the ‘detector’ into action.

Mr. Chubb said, in reply to Captain Moorsom, that if a lock had only one key and it should happen to be lost when the lock was fastened, the door would require to be forced open. Good locks generally had two keys, one of which was deposited in a place of safety. Two hundred and twenty locks might be made with one keyhole and a separate key to each, yet having one master key for

the whole. If a greater number was required it would be necessary to have two keyholes. In the event of the master key being stolen, he knew of no remedy but replacing the locks or altering their combinations.

“It was impossible to take a sufficiently correct impression in wax for the purpose of making a false key, as the locks were manufactured with such delicacy and nicety that the slightest alteration or difference in the key would prevent the lock being opened by it.”

Mr. Varley said that--

“With respect to the number of combinations Of which locks were capable it did appear to him that a certain limit should be assigned to it, in order to prevent any necessity for such close fitting**3(504)** that rust or dust on the key would prevent its opening the lock. A lock was exhibited some time back, the key of which had at first easily opened the lock. When it was warmed the slight expansion caused by the heat prevented the key from acting on the bolts."

"Mr. Hodge said that in America he had repeatedly seen impressions taken of locks having twelve or fourteen tumblers: certainly they were not made by Mr. Chubb, but were such perfect imitations of his locks, having even the detector, that there did appear to be a possibility of picking these locks; in fact, he would undertake to bring a man from New York who would be capable of doing it.”

"Mr. Stephenson, M.P., V.P., imagined that though it might be possible to take a wax impression of a warded lock, such could not be taken from a **tumbler lock(505)**, for there was nothing in a lock of the latter description which could give, by any injection of wax, a knowledge of the length of travel of the different tumblers. He therefore considered Mr. Hodge had raised a problem which did not admit of solution. He would venture to say that it was not possible to pick one of Chubb's locks by the aid of any wax impression."

"Mr. Hodge explained the system he had previously alluded to as having been employed in America for ascertaining the **range of the tumblers(506)**. The process was described to be that the operator, after thoroughly oiling the inside, and inserting two pieces of India rubber to limit the sphere of action, injected from a force-pump, a composition of glue and molasses, in a

heated state, which chilled quickly, and although extremely elastic, had the property of retaining the form and position of the lower side or bellies of the tumblers, and that after being cut out of the lock by a thin-bladed instrument, a key could be made from the impression sufficiently accurate to open the lock. This had repeatedly been done with the best tumbler locks, even on Chubb's principle, although he could not vouch for its having proved successful with any locks made by Mr. Chubb."

He thought that the locks made in New York were generally superior to those made in England, and he attributed it partly to the use of good machinery for the production of the parts of the locks, instead of the primitive tools in use at Wolverhampton and other places, and partly to the small expense of patents in America, inducing the exercise of more ingenuity and invention among practical men. At a late exhibition of the American Institute, fifty or sixty new and ingenious locks, of very superior workmanship, were produced, and he believed that nearly all were invented by practical workmen.

"Mr. Chubb regretted that what had been stated by Mr. Hodge had not happened in London instead of in New York; it must, however, be evident that such a method was totally incapable of application to a lock of Mr. Chubb's own manufacture, though he could not answer for the workmanship, or the security of those made by other persons in imitation of his locks. If a workman did not understand how to make one of his locks, he might leave a similarity between the bellies of the tumblers when at rest and the steps in the bit of the key, but he denied the possibility of this in any of the locks made by him, and in proof of this the locks then exhibited were referred to. There was no reason why the bellies of the tumblers should not be perfectly uniform and in the same plane, and it would be seen from the lock made on that principle that an impression of the inside of such a lock must be utterly useless for any felonious purpose."

"Mr. Stephenson, M.P., V.P., said he had been under the impression that the bellies of the tumblers in Mr. Chubb's lock were *always* flush, or in the same plane, when the lock was in a state of rest, and that the lift of the tumblers was entirely regulated by the notches or steps in the key. Therefore it was evident that unless the impression could be taken from the key, any attempt to make a false key must be futile, and even a facsimile of the interior of the lock would be useless. When the lower side of the tumblers were flush, as in the lock then produced by Mr. Chubb, it did not seem probable that any scheme

could be devised by which an impression of the lock, could afford any assistance for picking the lock."

"Mr. Farey coincided in Mr. Stephenson's opinion of the improbability of the American plan of taking an impression of the bellies of the tumblers being at all effective in aiding to pick a lock really made by Chubb, whatever it might do in the case of bad imitations of that kind of lock."

"Mr. Whitworth said he had much pleasure in bearing testimony to the great value of Mr. Chubb's locks. He used them almost invariably in his establishment, and never found them get out of order. The workmanship in them was of the best kind, and he thought it would be impossible to pick them by the means that had been mentioned, or by any pick-lock keys, as long as the detector was in good order. That was the main feature of the lock and distinguished it from all other tumbler locks."

"Mr. Stephenson, M.P., V.P., said it might be assumed as proved from the discussion, and therefore it was the duty of the institution to express the conviction, that no locks really made by Chubb had ever been picked, either in Great Britain or on the other side of the Atlantic. That they did, in fact, combine that strength, simplicity, easy action, and security, without which the most ingenious locks were utterly useless."

"Notwithstanding the circumstantial description of the ingenious method employed in the United States for taking an impression of the interior of a lock, it had not been proved to have been successful with one of Chubb's locks. Indeed, he must repeat that it was evident it could not be so, unless the lift of the tumblers was identical with the position of the bellies when in a state of rest, which was not the case. If the bellies of the tumblers were flush an impression of them was still more useless."

"The thanks of the institution were most justly due to Mr. Chubb, for bringing before the members so interesting a subject, which he had treated in so able a manner."

"Mr. Chubb said with respect to the locks which had been stated to have been picked, he could assure the members that they had never been issued from his manufactory, although they were very probably marked with his name. Many spurious imitations of the first expired patent, marked 'Chubb's Patent,' had been sold in large quantities, until the makers were stopped by legal

process. It was ruled, both at law and equity, that, although after the expiration of a patent, any person might manufacture the article, he had no right to pirate a peculiar trade mark, or to use a distinctive stamp, which was irrespective of any patent right."

From the statement of Mr. Hart, at page 538, and the remarks of the several speakers who took part in the before-mentioned discussion, it is quite evident that the only method then thought of by which Chubb's locks could be picked was by making a false key. This was to be effected by smoking the key-bit, or otherwise taking such an impression of the "lifts" of the levers as should enable the operator to step a blank which should open the lock.

We have now arrived at the memorable year of 1851, a period which will ever form an epoch in the progress of the arts and of manufactures.

As before intimated, Mr. Hobbs was in full possession of, and perfectly understood, the principle of picking locks by the tentative method. After declaring to a party of scientific men in the Crystal Palace, in 1851, "that all the locks made in this country up to that date admitted of being very easily picked," in order to explain and prove the truth of his assertion, he therewith commenced operating on one of Chubb's six-lever detector locks, which he picked in their presence in a few minutes.

It would appear that the fairness of the above experiment was called in question by certain persons who were not present at the time when it was made, which caused Mr. Hobbs, on the 21st of July, 1851, to write a letter to Messrs. Chubb, "simply announcing that an attempt would be made on the next following day to pick a lock manufactured by them, and which was at that time on the door of a strong room in a house named by Mr. Hobbs. Messrs. Chubb were invited to be present at the operation, but no member of the firm attended." The attempt was successful, and the following certificate relating thereto was published:

> "We, the undersigned, hereby certify that we attended, with the permission of Mr. Bell, of No. 24, Great George Street, Westminster, an invitation sent us by A. C . Hobbs, of the city of New York, to witness an attempt to open a lock throwing three bolts and having six tumblers, affixed to the iron door of a strong room or vault, built for the

depository of valuable papers, and formerly occupied by the agents of the South Eastern Railway Company. That we severally witnessed the operation, which Mr. Hobbs commenced at thirty-five minutes past eleven O'clock, a.m., and opened the lock within twenty-five minutes. Mr. Hobbs having been requested to lock it again with his instruments, accomplished it in the short space of seven minutes, without the slightest injury to the lock or door. We minutely examined the lock and door (having previously had the assurance of Mr. Bell that the keys had never been accessible to Mr. Hobbs, he having permission to examine the keyhole only). We found a plate at the back of the door with the following inscription :-' Chubb's new patent (No. 161,461), St. Paul's Churchyard, London, maker to her Majesty.'

"Mr. Hardley, 26, Great Earl Street.
"William N. Marshall, 42, Charing Cross.
"W. Armstead, 35, Belitha Villas, Barnsby Park.
"G.R. Porter, Putney Heath.
"F.W. Wenham, Effra Vale Lodge, Brixton.
"A. Shanks, Robert Street, Adelphi.
"T. Shanks, Robert Street, Adelphi.
"Colonel W. Clifton, Morley's Hotel.
"Elijah Galloway, 42, Southhampton Buildings.
"Paul R. Hodge, 9, Adam Street, Adelphi.
"Charles Peabody, 1, Norfolk Street, Strand.

This event gave rise to much newspaper controversy, and attempts were made to show that, as this was not a *test* lock prepared expressly for challenge, the picking proved nothing as regards the finest of the manufacturers' locks. Two circumstances, however, have to be noticed. The lock was of sufficient commercial importance to be placed on a door enclosing valuable papers. Also the makers had an opportunity to attend and witness, and comment on the trial, if they so chose."[4]
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The *Times* of September 4 (1851), in publishing the above certificate, made the following remarks:

"The lock controversy continues a subject of great interest at the Crystal Palace, and, indeed, is now become of general importance. We believed before the Exhibition opened that we had the best locks in the world, and among us Bramah and Chubb were reckoned quite as impregnable as Gibralter, more so, indeed, for

the key of the Mediterranean was taken by us, but none among us could penetrate into the locks and shoot the bolts of these makers. The mechanical spirit, however, is never at rest, and if it is lulled into a false state of listlessness in one branch of industry, and in one part of the world, elsewhere it springs up suddenly to admonish and reproach us with our supineness. Our descendants on the other side of the water are every now and then administering to the mother country a wholesome filial lesson upon this very text, and recently they have been "rubbing us up" with a severity which perhaps we merited for sneering at their shortcomings in the Exhibition."

"While we have been relying implicitly upon the artful arrangement of "tumblers" and such like devices, they have been carefully developing their ingenuity in picking and opening locks. A man makes a lock, and he brings it to a mechanics' institute in New York, with a certain sum of money secured by it, which sum becomes the property of the successful operator, who can shoot back the bolt of the new contrivance. Instantly astute heads and clever expert hands are engaged in solving the mechanical riddle thus propounded to them, and so far have these dexterous manipulators carried their art, that their "open sessamee" sweeps springs, tumblers, false notches, letter devices, and everything else before it."

"Mr. Hobbs is by far the most accomplished and successful of these performers, and he has come over to this country at a very opportune moment to teach our makers a very useful lesson. It is well known, however Mr. Chubb may wrestle with the statement, that Mr. Hobbs has succeeded by perfectly fair means in opening his locks as they have hitherto been made. No formal and deliberate trial has taken place between them to establish the fact, but it nevertheless remains undoubted, and the sooner Mr. Chubb improves his patent, so as to set Mr. Hobbs at defiance, the better for his own interests."

Mr. Hobbs has stated that the **principle on which the picking of locks depends(508)** to be, that "whenever the parts of a lock which come in contact with the key are affected by any pressure applied to the bolt, or to that portion of the lock by which the bolt is withdrawn, in such a manner as to indicate the points of resistance to the withdrawal of the bolt, such a lock can be picked." The first step is to produce the requisite pressure.

We may observe that during the present year Mr. Hobbs fully demonstrated to us the easy manner in which the above principle

can be successfully applied. He accomplished this by operating upon an improved patent lock in our presence and picking it in a few minutes.

The following diagrams, with the explanation, are copied from the work edited Mr. Tomlinson, before referred to, which, added to the remarks made at page 306, it is hoped will enable our 'readers to fully comprehend and understand the principle of "picking by pressure"**5(509)** as distinguished from picking by the arithmetical process, or "ringing the changes."

Mr. Tomlinson states that "if the end of the bolt were exposed, this pressure might be applied by some force tending to shoot back the bolt; but as the bolt, whenever it is shot, is buried in the jamb of the door, or otherwise concealed from view, the pressure can in general only be applied through the keyhole. In order, therefore, to apply this pressure, the operator provides himself with an **instrument(510)** capable of reaching the talon of the bolt, which in case of the Chubb lock was a pipekey of the form shown at *a b,* **figure** 247, furnished at the pipe end with that portion of the bit of the key *b c* which moves the bolt, (See **figure** 250, where the step which acts on the bolt is called the terminal step).

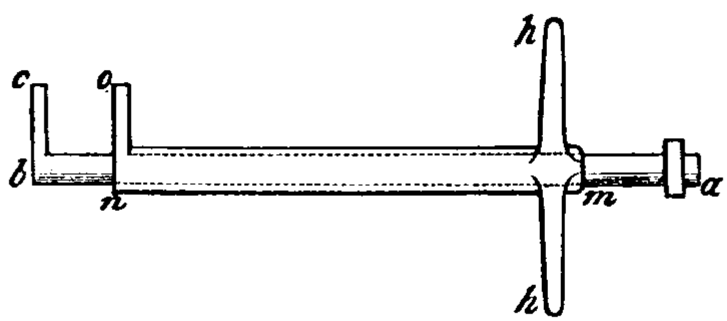


Figure 247.

The other end of the pipe-key is made square, as at *a*, for the purpose of receiving the square eye *e* of the lever *e f,* **figure 248**, to the further end of which, *f*, a weight *w* is attached by means of a string *s*. Now it is evident that if this pipe be introduced into the lock as far as it will go, and be turned round as in the act of unlocking, and the lever and weight, be attached to the end *a*, the bit *b c* of the pipe-key will maintain a permanent pressure on the bolt, which, if the weight be sufficient, will throw back the bolt as soon as the tumblers are

raised to the proper height to allow the stump to pass.

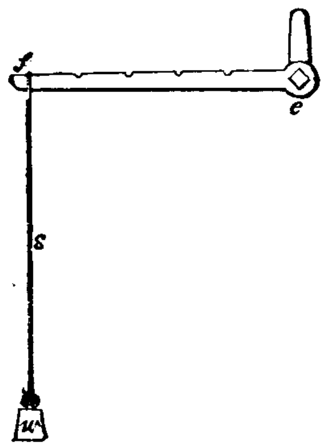
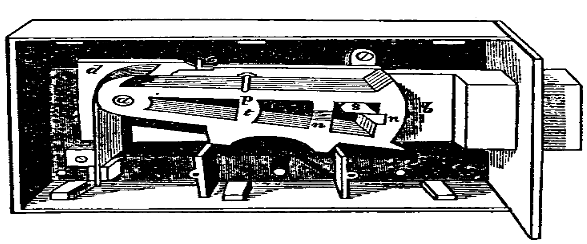
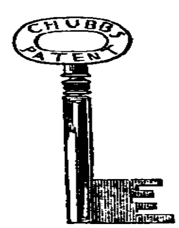


Figure 248.

The next step in the operation is to raise the tumblers to the proper height. For this purpose a second pipe, *m n*, is made to slide upon the first with an easy motion, and by means of the cross handle *h h* can be turned round or slid backwards and forwards on the tube *a b.* This tube *m n* is also furnished with a single projecting bit or step *n* o, corresponding with one of the six steps of the key, **figure 250**, and made of the proper length for entering the keyhole.

Now for the operation of opening, a tumbler lock with this simple apparatus. Referring to **figure 249**, it will be evident that if the pipe *a b, **figure 247***, be passed over the pin of the lock and turned round towards the left, and the weight be attached, there will be a tendency in the bolt to shoot back, which tendency will bring the stump ***s***, **figure 249**, up against the inner angle or shoulder of one or other of the tumblers, whichever happens to project, however slightly.





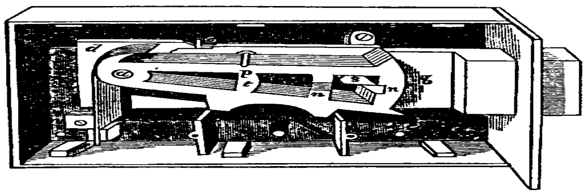


Figure 249. Chubb's Detector Lock of 1851

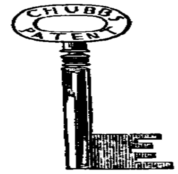


Figure 250. The Key

As Mr. Hobbs expresses it, 'one or more of the tumblers will **bind(511).**' By moving forward the pipe *m n* and turning round the bit *n o* in the lock, it is easy to ascertain, by delicate touch, which of the tumblers it is that binds. It may be found that all are free to move except one or two against which the stump is pressing with the force of the weight *w,* **figure 248.** The bit *n o* is therefore brought gently under the bellies of the tumblers which bind, and they are moved slightly upwards until they cease to bind.

As soon as they are set free another tumbler will bind; that is the bolt will move through a small space, so as to bring the stump into contact with that particular tumbler which now projects; this in its turn is relieved, another tumbler binds and is relieved, and so on until the tumblers are, one by one, raised to the proper height for the stump to pass. When the last binding tumbler is raised to the proper height, the weight *w* being no longer resisted, shoots the bolt back, and the work is done.

Now it must be evident that in this operation the detector apparatus need not come into operation. But if, as has been proposed, a detector spring be added to each tumbler, it may be converted into a friend or a foe according to the use that is made of it. If the tumblers are lifted *too high,* they will be detained or detected in that position, and the operator will have to release them by turning the bit round in the opposite direction before he can begin his work again. The same force, however, which detains the tumblers when they are lifted too high will obviously detain them when they are lifted only just high enough, and thus the detector springs would really be of great assistance to the operator in picking such a tumbler lock.

"The apparatus which we have described for picking the tumbler-lock must be varied to suit the form of the key employed in opening the lock. It is not difficult, in the case of most locks, to ascertain this form through the keyhole, without examining the key itself.[6(512)]

Soon after the picking of Chubb's lock, the friends of Mr. Hobbs were anxious he should try his skill on the Bramah lock referred to at the commencement of this chapter, which, as there stated, had been exhibited in the window of Messrs. Bramah's shop for nearly half a century, and to which was appended a challenge, and a reward of two hundred guineas was offered to any person who should make an instrument that would **pick(513)** or open it.

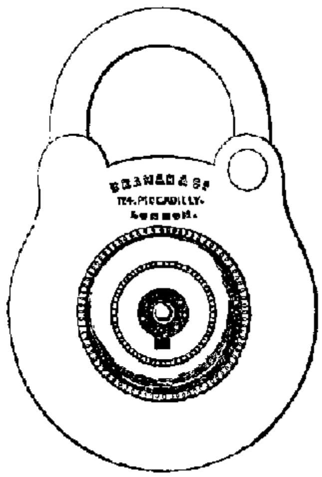


Figure 251. Front exterior view of the Bramah lock

We have received various papers both from Mr. Hobbs and Messrs. Bramah in connection with the picking of this lock, from which we shall endeavor to give an unbiased narrative of the proceedings. We will first describe the lock operated upon.

The lock was a padlock of the following outside measurement; width 4 inches; thickness, 1¼ inch; 2¾ inches over the boss; barrel, length, 2¼ inches; diameter, 1½ inch. **Figures 251** and **252** represent the front exterior and back interior views of the lock which appears to have been made in the year 1801, and had not been opened during thirty-four years, when, doubtless, the false notches introduced by Mr. Russell, in 1817 were made in the sliders and locking plate.

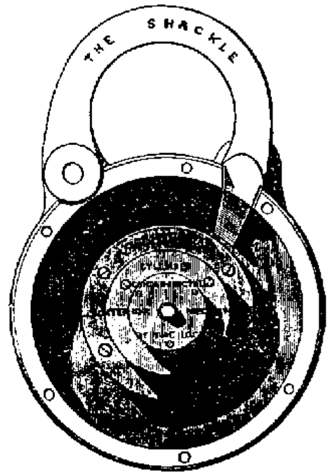


Figure 252. Back interior view of the Bramah Padlock.

It would appear that it was on the 2nd of July that Mr. Hobbs first applied to Messrs. Bramah to be allowed to **examine the lock(514)**, and to take wax impressions of the keyhole. This was complied with, and on the 9th Mr. Hobbs addressed to Messrs. Bramah the following letter;

"Gentlemen - I will call at your place of business, 124,
Piccadilly, on Thursday morning, at ten o'clock and would be
pleased to see you in relation to the offer you make on the
sign in your window for picking your lock.
Yours respectfully,

"A. C. Hobbs"

Mr. Hobbs accordingly called, and on the 19th of July an agreement was drawn up reciting the terms of the challenge upon the painted board, and provided that thirty days should be the term within which the lock was to be opened; that the lock should be secured between two pieces of wood to a wall; and that the key should be in the possession of Messrs. Bramah, who were to retain the right of using it in the lock when Mr. Hobbs was not at work. Messrs. Bramah, in order to remove any grounds of suspicion, and to secure themselves against even the possibility of a charge of interfering with the operations of Mr. Hobbs, relinquished the exercise of this right so far as they were personally concerned, and in an agreement on the 23rd of July stipulated that the key

should be sealed up, and that they would not use it until the operations were brought to a close. They also required that the keyhole should be covered by an iron band, sealed by Mr. Hobbs, when that gentleman was not engaged upon the lock.

A committee was appointed consisting of Mr. G. Rennie, the late Professor Cowper, and Dr. Black, who were to manage all the arrangements, and who were also to act as arbitrators between Mr. Hobbs on the one side, and Messrs. Bramah on the other.

The lock was in due course removed from the shop window to an upper room in Messrs. Bramah's establishment, where Mr. Hobbs commenced operations on the 24th day of July. After having worked at the lock for a week, during which period none of the arbitrators were present, Mr. Hobbs stated that he had made some progress in his labors. Upon which Messrs. Bramah addressed the following letter to Mr. G. Rennie, and similar ones to the other arbitrators:

"124 Piccadilly, July 31st, 1851.

> "Dear Sir - Mr. Hobbs states that he has made certain progress in his operation on the Bramah lock. We cannot say how this is; but as he has been at work one entire week without your inspection, we now beg your attendance before he proceeds further, and hope that you may be able to meet Professor Cowper and Dr. Black at this place tomorrow, at three o'clock.
> "We are, dear Sir, yours truly,
> "Bramah and Co.
> "To George Rennie Esq.

A reply was received from Mr. G. Rennie, who with his two other colleagues was then in Paris, to the effect that he would have liked to have seen the lock from time to time but considered that any inspection upon his part would have had little or no effect. Messrs. Bramah, however, had forbidden Mr. Hobbs proceeding with his labors until the arbitrators had met. On the 8th of August Messrs. Bramah wrote to the arbitrators to the effect that they we're disappointed in not having had an opportunity afforded them of inspecting the lock, and of having the key applied, as they entertained very strong suspicions that the lock was then so far deranged that the key would not have worked if applied.

They stated that though they had voluntarily shut themselves out from the right of using the key themselves, still they never

contemplated either an interference with the duties and discretion of the arbitrators of applying the key to the lock when they thought proper, or of being precluded from having the key used by the arbitrators upon their request. No notice, however, was taken of this application; and upon the 15th of August, at a meeting of the arbitrators, Messrs. Bramah renewed the request to have the key applied, and asked to have a person to attend during the remainder of the operations. Both requests were, however, refused, as the committee saw no reason why the key should be used till the close of the trial, or why any person should witness the further operations, as Mr. Hobbs *had the right, within the thirty days allowed him, to repair any derangement of the lock* which *he might cause during his work.* Accordingly,-

Mr. Hobbs resumed his operations as before on the next morning, the 16th of August. On the 19th of August, Messrs. Bramah addressed a letter to the arbitrators, calling their attention to the fact that the reward of 200 guineas was offered to the artist who could make an instrument that would pick or open the lock, and that he was to be paid the money on its production, and stating that, unless some person were present, it was impossible that anyone could know that the lock had been opened (should it be opened) by the instrument which might be produced.

No reply was received to this communication; and on the 23rd of August, in the presence of two of the arbitrators, Mr. Hobbs *exhibited the lock with the hasp raised, and shot the bolt backwards and forwards.* On the 29th of August, and in the presence of all the arbitrators and Messrs. Bramah, the lock was again shown with the hasp raised, having at the time a piece of *curved iron attached to it,* one end of which was screwed to the woodwork enclosing it, whilst the other, or bent end, was fitted with a *thumb-screw,* the point of which was in and pressing upon a cylindrical rod inserted in the keyhole of the lock.

Mr. Hobbs also produced a small *bent lever of steel,* with which, while the other instrument remained fixed, he turned the barrel of the lock, by which the bolt was turned back and allowed the hasp to enter the socket. Two other instruments, one like *a small stiletto,* and the other like a lady's *crochet needle,* were also produced. *A trunk of other tools* belonging to Mr. Hobbs, and a *powerful reflector* were also in the room. *Messrs. Bramah then applied to have the key used at once, but the arbitrators decided that Mr. Hobbs should have until the following day the*

opportunity of preparing the lock for the admission of the key. On the following day the key was applied, and the padlock was locked and unlocked.

We now insert the report of the arbitrators to whom the Bramah lock controversy was referred:-

> "Whereas for many years past a Padlock has been exhibited in the window of the Messrs. Bramah's shop in Piccadilly, to which was appended a label with these words, 'The artist who can make an instrument that will pick or open this lock will receive 200 guineas the moment it is produced;' and Mr. Hobbs, of America, having obtained permission from the Messrs. Bramah to make a trial of his skill in opening the said lock, Messrs. Bramah and Mr. Hobbs severally agreed that Mr. George Rennie, F.R.S., London, and Professor Cowper, of King's College; London, and Dr. Black, of Kentucky, should be the arbitrators between the said parties; that the trial should be conducted according to the rules laid down by the arbitrators, and the award of 200 guineas decided by them; in fine, that they should see fair play between the parties. On the 23rd of July it was agreed that the lock should be enclosed in a block of wood and screwed to a door, and the screws sealed, the keyhole and hasp only being accessible to Mr. Hobbs, and when he was not operating, the keyhole to be covered with a band of iron and scaled by Mr. Hobbs that no other person should have access to the keyhole.
>
> The key was also sealed up, and not to be used till Mr. Hobbs had finished his operations. If Mr. Hobbs succeeded in picking or opening the lock, the key was to be tried, and if it locked and unlocked the padlock, it should be considered a proff that Mr. Hobbs had not injured the lock, but picked and opened it, and was entitled to the 200 guineas. On the same day, July 23, Messrs. Bramah gave notice to Mr. Hobbs that the lock was ready for his operations. On July 24, Mr. Hobbs commenced his operations, and on August 23, Mr. Hobbs exhibited the lock open to Dr. Black and Professor Cowper. Mr. Rennie being out of town, Dr. Black and Professor Cowper then called in Mr. Edward Bramah and Mr. Bazalgette, and showed them the lock open. They then withdrew, and Mr. Hobbs locked and unlocked the padlock in the presence of Dr. Black and Professor Cowper. Between July 24 and August 23, Mr. Hobbs' operation were for a time suspended, so that the number of days occupied by him were sixteen, and the number

of hours spent by him in the room with the lock was fifty-one.

On Friday, August 29th, Mr. Hobbs again locked and unlocked the padlock in the presence of Mr. George Rennie (and others). On Saturday, August 30, the key was tried, and the padlock was locked and unlocked with the key by Professor Cowper (and others), thus proving that Mr. Hobbs had fairly opened the lock without injuring it. Mr. Hobbs then formally produced the instruments with which he had opened the lock.

"We are, therefore, unanimously of opinion that Messrs. Bramah have given Mr. Hobbs a fair opportunity of trying his skill, and that Mr. Hobbs has fairly picked or opened the lock, and we award that Messrs. Bramah and Co. do pay to Mr. Hobbs the 200 guineas."

"George Rennie, Chairman.
"Edward Cowper,
"J.R. Black.
"Holland Street, Blackfriars, September 2nd, 1851."

On the 2nd of September a letter was addressed by Messrs. Bramah to the arbitrators in the following terms:-

"124, Piccadilly, London, September 2.
To George Rennie, Esq., Chairman of the Bramah Lock Committee.
"Dear Sir, We beg to hand you the minutes of the meetings of the committe, and also the board from our window, on which the challenge is written. The only point to which we wish again to call the attention of the committee is that which has reference to the reward. We fully admit that, under the circumstances detailed in your minutes, Mr. Hobbs did open our lock, and has so far gained for himself much credit for his rare skill and perseverance; but beg to repeat that he has not opened it in such a manner as to entitle him, according to the terms of the challenge, to the reward of 200 guineas."

After reciting the proceedings of the various days, and alluding to the letter of the 19th of August, already refferred to, they state:

"We had at this date learnt enough to know that, whatever

might be the result of Mr. Hobbs' thirty days' operations, the reward could not be claimed; and in order to remove all doubts as to the lock not being opened by an instrument, or anything like an instrument, we wished, if Mr. Hobbs had matured his instrument, that the lock should be readjusted by the use of the key, and that he should proceed to apply them, and open the lock if he could, for which operations nineteen days out of his thirty then remained to him a feat which we did not then believe he could perform. A copy of this letter was sent on the morning it bears date to Mr. Hobbs, to Professor Cowper, and Dr. Black, but we did not receive any reply to it, nor was any meeting of the committee called till after the lock had been opened.

Mr. Hobbs' operations went on after the receipt of this letter, as they had done for the day he commenced them, viz., without inspection and without the key being once applied to the lock. We willingly admit that Mr. Hobbs was at liberty to make any number of instruments, and thus exhaust his ingenuity in finding out one that would open the lock, but we never for a moment agree that he was to be allowed to keep the spring fixed down as long as he pleased during his *thirty days' labor, and affix his apparatus to the woodwork in which the lock was enclosed, while he used at pleasure three separate and distinct instruments to assist him in his operations.* Under such circumstances we hope the committee will see fit to grant us a certificate of the whole facts, of which we take leave to enclose a sketch, mainly taken from the minutes of the committee.

"We are, Sir, your obedient Servants,
"Bramah and Co."

The following appeared in one of the daily newspapers:-

On Saturday last, being the day upon the time allotted to Mr. Hobbs would have finally expired, Messrs. Bramah proceeded to remove the **lock(515)** and take it to pieces, for the purpose of seeing whether the interior had been deranged or injured. We were surprised to find that the lock which has made so much noise in the world *is a padlock of but 4 inches in width, the body of it 1½ inch thick, and its thickness over the boss 2¾ inches. Upon opening the outer case of the lock, the actual barrel enclosing the mechanism was found to be 2¼ inches in length and 1½ inches in diameter.*[***7(516)***]

The small space in which the works were confined, and its snug,

compact appearance, was matter of astonishment to all present. The lock and key were made fifty years since by the present head**8(517)** of the eminent firm of Messrs. Maudslay and Co., Mr Maudslay being at that time a workman in the employ of Mr. Bramah, and the character of the workmanship was highly praised by several of the best hands now in the employ of Messrs. Bramah. The mechanism of the lock consists of two small spiral springs**9(518)** each of four turns of wire of ordinary thickness, and which are required to be pressed down by the key before the lock can be opened. Radiating from the center, and placed in "slits" in the barrels, are eighteen slides, each of which has a number of notches irregularly disposed, and some of which are false.

A circular steel plate is placed horizontally upon the section of the barrel, and until all the notches in the sliders have been so adjusted as to fit into the corresponding notches upon the inner edge of this circular steel plate, the resistance to opening the lock will not be removed. The chances of placing by any means, except by the true key, these notches in their proper places, amount to so enormous a number that their notation can only be expressed by some eighteen or nineteen figures. It is, in point of fact, a permutation lock, similar in its principle to those which have been recently introduced to public notice in France, and upon which Mr. Newell's lock, exhibited by Mr. Hobbs, is made.

It was found on examining the interior of the lock, that portions of the slides presented the appearance of having been considerably bent and straightened again**10(519)** and their surfaces showed marks of their having been filed a great deal; several of them, indeed, being nearly filed through. The slides, it appeared, were made of iron, which could easily be bent to any shape, and it was stated by one of the workmen that, had one of *Messrs. Bramah's present locks* with steel slides been given to Mr. Hobbs, he could never have opened it. The old familiar board, with the same challenge, will, we were informed, occupy its old place in a few days, and one of the locks now manufactured by Messrs. Bramah,**11(520)** with such improvements as have been made in up to the present time, will replace the original one made fifty years since. With the exception of the marks of the filing upon the slides, the lock did not appear to be in any way injured or deranged.**12(521)**

"It may be doubted whether these **experiments(522)** have been productive of any practical result. Mr. Hobbs has increased his fame and reputation as a clever and skilful manipulator, and Messrs. Bramah will pay the 200 pounds. Beyond this, no practical end or purpose whatever has been obtained. Messrs. Bramah are not informed of the mode in which the lock was opened, neither have they been furnished with any instrument that opens the lock, which will enable them to make such alterations as the existence of any such instrument would require, in order to give additional security to their locks. Neither has it answered any scientific purpose, or added one iota to the stock of knowledge previously existing on so important a subject as that of the mechanism of locks, for neither the arbitrators nor Messrs. Bramah saw anything of the process by which the lock was opened. The result of the experiment has simply shown that, *under a combination of the most favorable circumstance, and such as practically could never exist, Mr. Hobbs has opened the lock.*

"In the first place, no person was admitted into the room where the lock was**[13(523)]** besides the operator for sixteen days. The key was never applied to the lock during that time, as would have been the case *almost daily in any lock in ordinary use. The application of the key at any time during the operations of Mr. Hobbs would either have placed all the slides in their correct position, and thus have obliged the operator to begin de novvo after each application,**[14(524)]** or would have shown that the lock had been tampered with, and would in this case act as a "detector" lock.* The padlock, instead of swinging loosely from the staple, as in ordinary cases, was securely fixed. Instead of being fastened in or upon iron, it was secured in wood, which afforded additional facilities for screwing and securing the apparatus.**[15(525)]** He had also the undisturbed use of his trunk of instruments.

"In order to have tested the practical value of the lock, it should have been picked or opened under circumstances more in accordance with those which attend the ordinary employment and uses of locks, or similar to the plan adopted on the trial of Mr. Newell's lock at Boston, an account of which is given in the pamphlet distributed by Mr. Hobbs at the Great Exhibition. From this account it appears that the lock to be operated upon was placed on an iron chest and locked by the committee, in whose hands the key remained during the trial, and was to be used at the discretion of the committee, in unlocking and locking the door, without the knowledge of either of the other parties."

In doing so no alteration of the combination or form of the key was to be made during the process of trial. The operating party had to leave 200 dollars in the hands of the cashier, to be paid to Day and Newell's agent for the lock, in case it should be injured in the process. The lock, in such case, was to be given up to the party making the trial.[16(526)] The time allowed to the operator was one week to operate, and two days to examine the lock previous to commencing operations. Failing these tests, we think that Messrs. Bramah have no reason to regret affording to Mr. Hobbs the fullest opportunity of making trial of his skill. We cannot refrain from expressing our admiration of the great talents and abilities of the late Mr. Joseph Bramah, who, fifty years since, constructed a lock which, after undergoing sixteen days' manipulation of, confessedly, one of the most skilful mechanics of our day, yielded only to the combined action of a number of fixed and moveable instruments made and applied for that purpose.

"We have no wish, in any remarks which we have made, to appear to detract in the least degree from the merit due to the perseverance and the great ability and skill of Mr. Hobbs. The propriety and good feeling shown by him under circumstances of an exceedingly trying character have been exceedingly creditable to him. We are bound, however, to state that, in our opinion, he has done nothing calculated in the least degree to affect the reputation of Messrs. Bramah's lock. His exertions have, on the contrary, greatly confirmed the opinion that, for all practical purposes, it is impregnable."

In an article in the *Morning Chronicle* newspaper of the 10th of September (1851) is the following announcement:

The Messrs. Bramah having ascertained, by opening their lock, that it had not been materially injured by the operations Of Mr. Hobbs, yesterday forwarded to Mr. G. Rennie, one of the arbitrators, a cheque for the 200 guineas awarded by them to Mr. Hobbs. The cheque was accompanied by a letter, of which the following is a copy, and in it Messrs. Bramah state the grounds of their protest against the decision of the arbitrators:[17(527)]

"124, Piccadilly, September 9,1851.

"Dear Sirs:- We beg to acknowledge your letter of yesterday date and will not trouble you to attend here tomorrow, but beg to hand you the 210 pounds awarded by the arbitrators to Mr. Hobbs.

We need scarcely repeat that the decision at which the arbitrators have arrived has surprised us much. We owe it to ourselves and the public to protest against it, and we do so for the following reasons:

"1. Because the arbitrators having been appointed to see 'fair play', and that the lock was fairly operated upon, did not, although repeatedly requested in writing to do so, once inspect**18(528)** or allow any one to witness Mr. Hobbs' operation during the *sixteen days he had the sole custody of the lock and was engaged in the work."*

"2. Because the arbitrators did not once exercise their right of using the key, although repeatedly requested in writing to do so, till after Mr. Hobbs had completed his operations, and then, instead of applying it at once, to prove no damage had been done to the lock, allowed him twenty-four hours to repair any that might have occurred."

"3. Because the lock being opened by means of a fixed apparatus screwed to the woodwork, in which the lock was enclosed for the purpose of the experiment (which it is obvious could not have been applied to an iron door without discovery) and the addition of three or four other instruments, the spirit of the challenge has evidently not been complied with."

"4. Because, from the course adopted, an opportunity of some scientific results has been taken from us, as neither arbitrators nor anyone else saw the whole, or even the most important instruments by which it is said the lock was picked, actually applied in operation, either before or after the lock was presented open to the arbitrators."

"5. Because, during the progress of Mr. Hobbs' operations, and several days before their completion, we called the attention of the arbitrators to what we considered the interpretation of the challenge, begging at the same time that they would apply the key, and appoint someone to be present during the residue of the experiment, feeling that, whatever might be the result in a scientific point of view, the reward could not be awarded. We would add that we think that several points which appear on your minutes should have been mentioned in your award, more especially that Mr. Hobbs, on the 2nd of June, took a wax impression**19(529)** of the lock, and had made, as far as he could, instruments therefrom between that date and the commencement of his operations."

"We are, dear Sir, your obedient Servants.

Bramah and Co.

From "The Bankers' Magazine", October, 1851.

"It will be seen from the notice of the proceedings which we now publish that Mr. Hobbs was engaged on the lock from July 25th to August 23rd, and that the number of days actually employed in working at the lock, independent of those occupied in making his instruments, was sixteen. We think a lock which could stand this test is perfectly safe for all practical purposes. Very few burglars have the scientific knowledge possessed by Mr. Hobbs, and none could have the same opportunities for opening a lock which secured anything of value. Although, therefore, we regret that Mr. Hobbs has been able to show that one of the best locks in the kingdom is not impregnable, we think he has shown at the same time its excellence, and that Bramah's locks may be relied on with perfect confidence as able to defeat any attempt of the most expert thieves and burglars.

"From what we now learn of the construction of Bramah's lock, it seems that, had it been made within the last few years, and with steel slides as now employed, instead of iron slides, Mr. Hobbs would not have been able to open the lock. Without detracting from the ingenuity and industry he displayed, we think that his success was, in some degree, a matter of chance that might never happen again."

"To the Editor of the "Morning Chronicle."
"124, Piccadilly, London, October 10, 1851.

"Sir - This controversy having excited an unusual degree of public attention for some time past, perhaps you will be good enough to allow us to state in your journal that the lock on which Mr. Hobbs operated had not been taken to pieces for many years. It was only on examining it (after the award of the committee) that we discovered the startling fact, that in no less than three particulars it is inferior to those we have made for years past."

"The lock had so long remained in its resting place in

our window, that the proposal of Mr. Hobbs somewhat surprised us; after his appearance, however, no alteration could of course be made without our incurring the risk of being charged with preparing a test lock for the occasion. We were, therefore, bound in honor to let the lock remain as Mr. Hobbs found it when he accepted the challenge. No one inspected his operations during the sixteen days he had the sole custody of the lock and was engaged in the work. We are compelled to adventure another 200 hundred guineas in order that we may see the lock operated upon and opened, if it be possible, and thus gain such information as will enable us to use means that would defy even the acknowledged skill of our American friends."

"We believe the Bramah lock to be impregnable, and we cannot open it ourselves with the knowledge Mr. Hobbs has given us. We have fitted up the same lock with such improvements as we now use, and some trifling change suggested by the recent trial, and restored it with its challenge to our window.[20(530)] We have not done this in a vain boasting spirit on the contrary, we feel it rather hard that from the way in which the former trial was conducted we are driven to adopt this course. Had any one inspected Mr. Hobbs' operations during that trial it would not have been necessary.

We are your obedient Servants,
"Bramah and Co."

From the "The Times" of September 4th, 1851.

"The lock on which Mr. Hobbs operated was made fifty years ago, and had not been opened during thirty-four years. It does not contain the more recent improvements[21(531)] in at least three particulars. It had remained so long in the window of Messrs. Bramah and Co. without an experiment having been attempted, that the proposal of Mr. Hobbs somewhat surprised them. After his appearance, however, no alteration could of course be made without incurring the risk of being charged with preparing a test lock for the occasion. Messrs. Bramah and Co. have fitted up[22(532)] the same lock with such improvements as they now use, which they feel sure will effectually frustrate the attacks of persons as skilful as the celebrated American, and have restored it

> with its challenge to the place of honor it has occupied in their window, 124 Piccadilly, for half a century. Mr. Hobbs has not made a second attempt, although invited to do so.
>
> "The public, while they admire the expertness with which this mechanical feat has been performed, will not attach more importance to it than it deserves, or undervalue the merit of our best locks, because an American operator, highly accomplished in such matters, has succeeded, after an arduous struggle, in opening them. The facilities given to him were such as no thief could ever possess, even if he had the necessary ability. It is quite clear that the operation has not been one of ordinary picking."

The following is a **description(533)**, so far as can be given in words, of the mode in which Mr. Hobbs operated on the Bramah lock: "The first point to be attained was to free the sliders from the pressure of the spiral spring. The spring was very powerful, pressing with a force of between thirty and forty pounds. Until this was counteracted, the sliders could not be readily moved in their grooves. A thin steel rod, drilled at one end, and having two long projecting teeth, was introduced into the keyhole and pressed against the circular disc (see *b*, ***figure 122***), between the heads of the sliders; the disc and spring, were pressed as far as they would go. In order to retain them in this position, a curved stanchion was screwed into the side of the boards surrounding the lock, and the end brought to press upon the steel rod, a thumbscrew passing through the drilled portion of the instrument and keeping it in its place."

"The sliders being thus freed from the action of the spring, operations commenced for ascertaining their proper relative positions. A plain steel needle, with a moderately fine point, was used for pushing in the sliders; while another, with a small hook at the end, something like a crochet-needle, was used for drawing them back when pushed too far. By gently feeling among the edge of the slider the notch was found and adjusted, and its exact position was then accurately measured by means of a thin and narrow plate of brass, the measurements being recorded on the brass for future reference. The operator was thus enabled by this record to commence each morning's work at the point where he left off on the previous day."

"The lock having eighteen sliders, the process of finding the exact position of the notch in each was necessarily slow. Mr. Hobbs employed a small bent instrument to perform the part of

the small lever or bit key. With this he kept constantly pressing on the cylinder which moved the bolt. He thus knew that if ever he got the slide-notches into the right place, the cylinder would rotate and the lock open. He could feel the varying resistance to which the sliders were subjected by this tendency of the cylinder to rotate. He adjusted them one by one until the notch came opposite the steel plate. The false notches added, of course, much to his difficulty; for when he had partially rotated the cylinder by means of the false notches, he had to begin again to find out the true ones."

Mr. Hobbs, in answer to our inquiries relative to several statements in the foregoing extracts, has furnished us with the following particulars, in addition to the footnotes on previous pages: -

"TIME OCCUPIED ON THE BRAMAH LOCK."

"July 23.-In the room . .	0 hours	12 minutes	
"July 25.- " . .	0 "	35 "	
"July 27.- " . .	3 "	25 "	
"July 29.- " . .	7 "	15 "	
"July 30.- " . .	7 "	15 "	
	18 hours	42 minutes;	

Being the whole time from commencing until the cylinder was turned round. After turning the cylinder, I was in the room putting up my tools, etc., 45 minutes. When the cylinder *began* to turn I found that my instrument was not strong enough, and I then left the room and did not return till the next day, when upon calling at Messrs. Bramah's I was refused admission into the room and was excluded until the return of the arbitrators. At which time I was permitted to commence my second operation. I began by first getting back the cylinder to its original position. I was in the room on:

"August 19th	7 hours	15 minutes
"August 20th	7 "	20 "
"August 21st	1 "	10 "
"August 22nd	7 "	0 "
	22 hours	45 minutes

I then readjusted the cylinder, and on August 23rd I was in the room 1 hour and 55 minutes, and picked the lock. The time occupied in the actual operation of picking the lock was 20 hours 37 minutes. The time spent in readjusting the cylinder, an accident caused by the unusual strength of the spring, was 22 hours 45 minutes. I afterwards picked the lock three times within an hour, in the presence of the arbitrators.

We shall conclude this chapter with the following extract from *Fraser's Magazine* for November, 1852, relative to the Jury's Report on Locks:

> "This jury seems to have consisted of the only persons in England who did not hear of the famous 'lock controversy' of last year. One can hardly imagine that, if they had heard of a matter of so much consequence to the subject they were appointed to investigate, they would have altogether abstained from saying anything about it. They may be excused for not knowing, because very few did know, fortunately for our safes and strong boxes, that the mode of picking Bramah's and Chubb's locks, by which the transatlantic Hobbs gained so much glory, was suggested and explained in the *Encyclopedia Britannica nearly twenty years ago."*
>
> *"But it does seem very strange that they, or at least their reporter, should not have known, long before the report finally left his hands, that Hobbs had picked both of those locks, and taught every lock-picker in England how to do it, if he possesses the requisite tools and fingers. Of course, however, the reporter did not know it, as nobody could read any newspaper last autumn without knowing it. And this jury did exercise their judgment to the extent of declaring that Hobbs' own lock (under the name of Day and Newell) 'seems to be impregnable.' Notwithstanding all which, they express their inability to "offer any opinion on the comparative security afforded by the various locks that have come before them."*
>
> *"The only discrimination which they venture to make is that the keys of Bramah's and Chubb's locks are of convenient size, while Hobbs' is ponderous and bulky, and his lock complicated; and they might have added (without any very painful amount of investigation) enormously expensive, in consequence of its complication, and probably also more*

likely, on the same account, to get out of order and stick fast, and so become rather inconveniently impregnable - on the money-door of a bank, for instance - than the other two locks, especially Bramah's."

CHAPTER SIXTEEN: On the Modern Lock

BELLFORD'S LOCK:, Patent dated April 25, 1855.
HENDERSON'S LOCK, Patent dated May 11th, 1855
TUCKER'S HOLDFAST LOCK, Patent dated May 21st, 1855.
NETTLEFOLD S LOCK, Patent dated June 9th, 1855.
SCULLY and HEYWOOD'S LOCK, Patent dated July 15th, 1855.
BUTLER'S DIAL LOCK, Patent dated August 13th, 1855.
NEWTON'S LOCK, Patent dated November 14th, 1855.
FENTON'S LOCK, Patent dated January 21st, 1856.
TUCKER S SAFETY LOCK, Patent dated June 13th, 1856.

As was to be expected from the interest manifested in, and the excitement caused by, the *Lock Controversy* during the Great Exhibition of 1851, the subject of locks and keys has since that period assumed an importance unknown before in the connection with the arts and manufactures of this country.

Instead of the principles upon which locks in general are constructed being understood only by those immediately connected with their production, the whole subject in all its details has been studied by a considerable portion of the intellectual and intelligent classes, so much so that it is beginning to be ranked with the sister arts in importance, and is attracting the attention and drawing forth the abilities of a class of inventors which, if but little of *real* merit has been the result of their conceptions since the year 1815.

The specifications of the numerous patents taken out since that period prove that the faults in the old locks are fully understood. The determination to remedy them is evidenced by the numerous contrivances, more or less simple, which have been introduced for that purpose. The number has doubtless been augmented by the beneficial alteration in the patent laws.

We are certainly indebted to Mr. Hobbs for having initiated this spirit of emulation in improving these useful machines, as it was he who so easily proved that all our best locks constructed to the year 1851 were altogether defective in one important particular. ***That the picking by pressure had never been provided against.*** We are convinced that Mr. Hobbs could have picked any other lock invented to 1851 as easily as he opened Chubb’s.

As before stated, although this liability of locks to be picked had been not only conceived, but explained and published, yet but few, if any, of the locksmiths understood it, as the only contrivances to prevent it consisted in the false notches in Bramah’s sliders, introduce by Mr. Russell in 1817, and the false

notches in the levers and stump of Strutt's lock, patented in 1819.

From the extracts in the last chapter, it will be apparent that the only means then thought of by which the improved locks invented to the year 1851 could be picked was by making a false key. In the following lists of patented and other locks, which we shall describe as fully as their merits deserve, it will be seen that in most of these inventions the principal object has been to render the locks perfectly secure against the tentative process of manipulation.

The methods adopted are various, and in the majority of cases it has been sought to accomplish it by the most complex movements. The prevailing contrivance will be found to be the adoption of ***false* notches** in the gatings of the levers and the notches on the *ends* of the levers, as in Strutt's lock.

We shall notice these and other peculiarities of construction as we proceed, simply remarking here that nine-tenths of the patented locks are the inventions of those unconnected with their manufacture, and, with few exceptions, the movements are the very reverse of what we have before laid down as the object which all inventors should have in view and endeavor to attain: simplicity of construction.

The diagrams annexed to some of the specifications in the following list of patents are more like the drawings of a steam-engine than the illustrations of the simple piece of mechanism a lock should be. The descriptions of many of them are so long in consequence, that we have been compelled to abandon our intention of noticing them all. Had we have done so, it would have been more from their curiousness which might have acted as a caution to others not to follow in the same path of complicated constructions, which could never be made useful, than from any intrinsic merit they possess in themselves.

Inventors should always bear in mind that any article to be generally adopted must not only be useful, but of such a construction that the mechanics or artificers in the trade may readily make it. We have no hesitation in saying that with the majority of the following locks, however meritorious the improvements might be considered, and however desirable it may be to adopt them, the patentees would be utterly unable to get such locks made in quantity.

Any locksmith will easily go from one lock to another more simple in its details, but complicate the movement ever so little and he is all abroad. We have stated before that complication is too often the idea prevalent in the minds of most inventors, and that this is so in respect to locks is evidenced by the construction of most of the locks invented previous to and since the opening of the Great Exhibition of 1851.

PATENTS GRANTED FOR LOCKS AND LATCHES SINCE THE CLOSING OF THE GREAT EXHIBITION OF 1851, TO JULY, 1856, INCLUSIVE

NO. OF PATENT	YEAR	DATE	NAME OF PATENTEE
13,802	1851	NOV. 4	DISMORE, GEORGE
13,806	1851	NOV. 6	PARNELL, MICHAEL LEOPOLD
13,807	1851	NOV.13	SINCLAIR, WILLIAM
13,852	1851	DEC. 8	RESTELL, THOMAS
13,985	1852	FEB.23	HOBBS, ALFRED CHARLES

The above patents were granted under the old law.

THE FOLLOWING PATENTS HAVE BEEN GRANTED UNDER THE PATENT LAW AMENDMENT ACT, WHICH CAME INTO OPERATION IN 1852.

NO. OF PATENT	YEAR	DATE	NAME OF PATENTEE
50	1852	OCT. 1	TUCKER, WALTER HENRY
472	1852	OCT. 21	ROSE, JOSEPH
602	1852	NOV. 1	CHUBB, JOHN
808	1852	NOV. 26	REMOND AMEDE FRANCOIS
160	1853	JAN. 21	CHUBB JOHN & GOATER, JOHN
229	1853	JAN. 29	WHISHAW, FRANCIS
238	1853	JAN. 29	JENNINGS, LEWIS
367	1853	FEB. 11	CHOPPIN,WILLIAM
1074	1853	MAY 3	GOBLE, GEORGE FREDRIC
1266	1853	MAY 23	SIMSON, WILLIAM
1310	1853	MAY 27	BENTLEY, WILLIAM HENRY
1600	1853	JULY 5	TRIPE, DECIMUS JULIUS
1617	1853	JULY 6	NEWTON, WILLIAM EDWARD
1866	1853	AUG. 11	RUSHBURY, JOHN
1932	1853	AUG. 18	PIGE, ALEXIS
2076	1853	SEPT. 9	PARNELL, MICHAEL LEOPOLD
2077	1853	SEPT. 9	MARTIN, JAMES

2698	1853 NOV. 21	TUCKER, WALTER HENRY AND REEVES, WILLIAM RALEIGH
2879	1853 DEC. 10	BOST, HYPPOITE LAURENT DUE
2980	1853 DEC. 22	GIBBONS, JAMES, JUNIOR
256	1854 FEB.1	DANIEL, ALFRED
372	1854 FEB. 16	BUSH, JOHN
405	1854 FEB. 20	MILNER, WILLIAM
505	1854 MAR. 1	HOLLAND, JOHN SIMON
514	1854 MAR. 2	TANN, JOHN
1288	1854 JUNE 12	YOUNG, JOHN
1301	1854 JUNE 15	GEDGE, JOHN
1441	1854 JULY 1	JONES, ROBERT LEWIS
1514	1854 JULY 11	WOLVERSON, EDWIN
1697	1854 AUG 1	HOLLAND, JOHN SIMON
1709	1854 AUG 4	MILES, LEWIS PLAYER
1917	1854 SEPT. 2	LEWIS, GEORGE
2060	1854 SEPT. 25	McCONNEL, ROBERT
2122	1854 OCT. 3	NEWTON, WILLIAM EDWARD
2592	1854 DEC. 9	BUTTON, REUBEN
2611	1854 DEC. 12	LARKIN, RICHARD
2684	1854 DEC. 20	MILNER, WILLIAM
2712	1854 DEC. 23	GIROUX, BARTHELEMY MARTIN
218	1855 JAN. 29	IMRAY, JOHN
934	1855 APR. 25	BELLFORD, AUGUSTE EDOUARD
978	1855 APR. 25	WRIGHT, LEMUEL WELLMAN
1063	1855 MAY 11	HENDERSON, CONSTANTINE
1127	1855 MAY 21	TUCKER, WALTER HENRY
1315	1855 JUNE 9	NETTLEFOLD, JOHN SUTTON, NETTLEFOLD EDWARD AND NETTLEFOLD
1623	1855 JULY 18	SCULLY, VINCENT, AND HEYWOOD, JOHN BENNET
1837	1855 AUG. 13	BUTLER, THOMAS
1959	1855 AUG. 30	STANSBURY, CHARLES FREDERICK
2001	1855 SEPT. 4	MUELLER, CHARLES GUSTAV
2096	1855 SEPT. 17	SMITH, WILLIAM HANDASYD
2572	1855 NOV. 14	NEWTON, ALFRED VINCENT
112	1856 JAN. 16	McEVOY, HENRY
156	1856 JAN. 21	FENTON, SAMUEL
290	1856 FEB. 2	DAY, JOHN ROCK
310	1856 FEB. 5	PARNELL, MICHAEL LEOPOLD
744	1856 MAR. 27	DANIEL, ALFRED
950	1856 APR. 21	DORTET, JULES
1436	1856 JUNE 18	TUCKER, WALTER HENRY

1544	**1856 JULY 1**	**NEWTON, ALFRED VINCENT**
1690	**1856 JULY 18**	**LEUCHARS, WILLIAM**

The following is a list of locks invented since the closing of the Great Exhibition, but which have not been patented. All of these will be described in the following pages:

TITTLEY'S LOCK, Invented in 1851
LEAS LOCK, invented 1851
DISMORE LOCK, patented 1851
PARNELL'S DEFIANCE LOCK, patented dated Nov. 6th, 1851.
SINCLAIR'S LOCK, patent dated November 13, 1851.
RESTELL'S LOCK, patent dated December 8, 1851.
HOBBS' PROTECTED LOCK, patent dated February 23, 1852.
TUCKERS CLOSED-KEYHOLE DETECTOR LOCK, patent dated October 1st, 1852.
ROSE'S Lock, Patent dated October 21st, 1852.
CHUBB'S LOCKS, containing the improvements patented by John Chubb, November 1st, 1852.
WHISHAW'S MAGNETIC Lock Patent dated January 29, 1853.
JENNINGS LOCK, Patent dated January 29th, 1853.
SIMSON'S DUPLEX BANK LOCK, Patent dated May 2, 1853.
PARNELL'S SECOND LOCK, Patent dated September 9th, 1853.
TUCKER'S SAFE GUARD LOCK, Patent dated Nov. 21st, 1853.
GIBBONS' DETENT LOCK, Patent dated December 22nd, 1853.
SAXBY'S LOCK, invented 1853.
DENISON'S LOCK, Invented 1853.
GIBBONS' DOUBLE-DETECTOR LOCK, Patent dated 1853.
DANIEL'S IMPROVEMENTS, Patent dated February 1st, 1854.
TANN'S LOCK, Patent dated March 2nd 1854.
TANN'S NEW PATENT BANK LOCK.
YOUNG'S LOCK, Patent dated June 12th, 1804.
WOLVERSON'S LOCK, Patent dated July 11th, 1854.
MILES' LOCK, Patent dated August 4th, 1854
LEWIS'S LOCK, Patent dated September 2nd, 1854.
NEWTON'S LOCK, invented by L. M. Eiler, of Copenhagen, Patent dated October 3rd, 1854.
WENHAMS LETTER LOCK, invented 1854
WOLVERSON s LOCK invented about 1854.
BELLFORD'S LOCK:, Patent dated April 25, 1855.
HENDERSON'S LOCK, Patent dated May 11th, 1855
TUCKER'S HOLDFAST LOCK, Patent dated May 21st, 1855.
NETTLEFOLD S LOCK, Patent dated June 9th, 1855.

TITTLEY'S LOCK, INVENTED IN 1851.

The peculiarity of the construction of this lock consists in the introduction of a "segmental slidecap". In other respects it is an ordinary lever lock. "Its leading principle is that, immediately on the introduction of the genuine key, or any other instrument bearing upon any one of the levers or springs, for the purpose of opening the lock, a steel shield presents itself at and covers the keyhole, effectively preventing the introduction of any second instrument, or any reflector for the purpose of examining the interior of the lock."

The introduction of this "segmental slide-cap" led to the adoption of the barrel and curtain combined, by Mr. Chubb and other makers. Chubb's and other makers locks were frequently sent to Mr. Taylor, lock manufacturer, Wolverhampton, in whose employ was Mr. Tittley, to have the former invention applied to them.

LEAS' LOCK, invented 1851.

The top levers in this lock work on a pin fixed into the bottom lever, which latter with the others are placed upon another pin riveted to the main plate of the lock, as in other locks. The security consists in so gating the levers to the stump of the bolt, as that when pressure is applied to the bolt, one of the levers ***recedes*** and throws the detector, which is released in the usual way. The curtain in this lock is identical with Higginson's, described earlier in this text.

DISMORE'S LOCK, patent dated November 4, 1851.

The improvements claimed by Mr. Dismore consist, first, in forming a tube with an enlargement or boss, which rotates within a projecting cylinder, and it has fixed on it a spring, which at its bent pointed end, springs into a notch, and retains the parts in a correct position for the introduction of the key. In addition to these parts, there is a fixed plate that may be made

of steel, through which there are two openings; the one for the key to pass into the lock, and the other for it to pass out at. There is a stop to the key to prevent its passing beyond the correct position.

Secondly, in constructing a striker-plate suitable for the above arrangement, the bolt of the lock is shot by means of a spring, when permitted to do so by the catch being out of the way, and it will at all times when shutting the doors be lifted by means of an incline in the striker-plate. On the other hand, the bolt will be held back by the catch, and when the door to such a lock is fastened, is opened.

The lock is so arranged that it may be opened on one side by a key suitably formed according to the tumblers or wards, or such like parts. A lock constructed in this manner may be opened on the other side by a handle on the spindle, which by its bit acts on a lever, the face of which comes against the tail ends of the tumblers or levers. These are properly formed to be acted upon by the face of the lever, so as to move them into position to allow the bolt to come back. It will do so by means of the bit in a pin pressing against the lever, which lever acts as a fulcrum, and carries the pin which draws back the bolt.

Thirdly, in so making the key that **the bit(534)** can be separated from the stem. The patentee states in his specification that "the convenience offered by thus having the 'bit' of the key separate from the stem will readily be understood, particularly in regard to large keys, as it admits of the 'bit' end being more conveniently carried about the person, whilst the stem may be kept in any convenient place, the possession of the stem only of the key by any person giving no means of opening the lock.

PARNELL'S DEFIANCE LOCK, patented dated Nov. 6th, 1851.

This is a lever lock, with the addition of a cylinder or curtain. The key has an expanding bit. The patentee states that "the security of the lock consists in the number of the levers, and in their slots being cut and placed in an uncertain and irregular order, requiring a corresponding irregularity in the bits of the key to raise the slots or gatings to the proper height for the stump to pass. If a false instrument be used, and but one of the levers be raised either too high, or not high enough, the stump could not get out of the chamber, nor the lock by any possibility be opened."

"Viewing the lock from its exterior, it presents nothing remarkable. But upon removing the cap plate, it will be seen that all possible access to the mechanism with false or surreptitious keys is effectively prevented by a solid cylinder of hardened brass, with protecting wards extending the whole depth of the lock, and having the center of the aperture for the key, which fits to a mathematical nicety so exact as to preclude the possibility of any second instrument being used to open it."

"This protecting cylinder must revolve with the key to get to the works and the moment it passes from the keyhole, in going round to lock or unlock, the solid portion moves into its place, and so completely closes that aperture that the point of a pin, or a fine steel pen, has failed to be inserted between it and the outer plate or cap, to say nothing of the utter hopelessness of perforating the metal."

Figure 253 represents the action of the lock. **A** is the curtain, stopped by the upright bolt **F**. **B** is the bolt; **D** the levers; **E** the double-action latch.

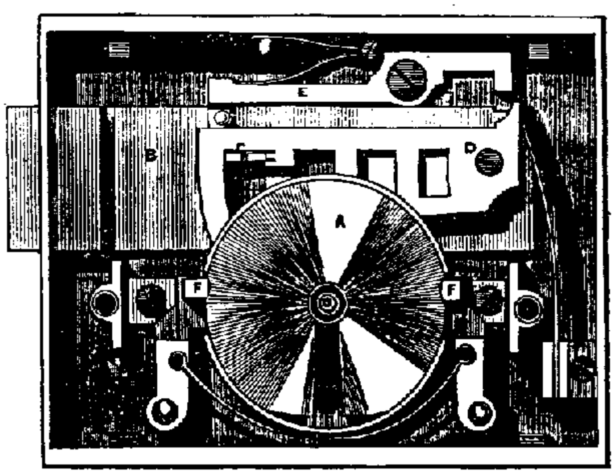


Figure 253. Parnell's Defiance Lock

Supposing the key inserted in the lock in its locked position, as shown in the cut, for the purpose of unlocking it; the key, after passing about one-third way round, meets with the forcible resistance of the upright spring-bolt or defector **F**. which is made of steel, and acts on the revolving-cylinder or curtain. The key, after passing this obstruction, arrives at the levers. In the bolt-stud, which works in the slot of the levers, there is a small deep serrated notch on one side, corresponding to similar notches on each of the levers; if, therefore, pressure be applied

to force the bolt, these notches would lock into each other.

There is also a double-action latch placed over and shooting into the main-bolt, which, when the lock is forced, bears all the strain, thus effectually rendering all attempts on the lock futile and vain. The stump shooting into the levers locks them down, which is an additional preventive against any attempt on the levers succeeding.

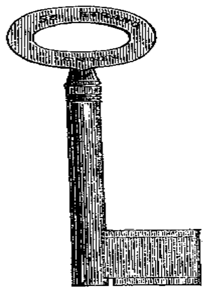
The patentee further states that "the key of the defiance lock is entirely original in its form, and, when not in the lock, appears like a highly-polished blank or key before the wards or bits are cut in it."

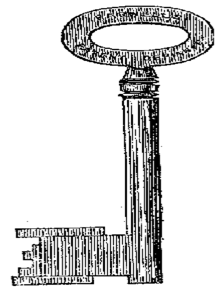
In this form it enters the lock, and fits on the edge of an eccentric steel plate at the bottom of the pin. The moment the key begins to move, the bits corresponding to the levers are gradually forced out by its action round the eccentric plate, so that when it has made a quarter of a revolution it has become slightly elongated, which enables it to pass the first impediment, the sentinel-bolt, and by the time it has arrived at the levers it has expanded about one third its whole length; then it lifts the double action latch, adjusts the levers, and shoots the bolt. In bringing it out of the lock again, a contrivance forces it back to its original shape; presenting nothing, to all appearance, when out of the lock, but a blank key.

The advantage of this sliding-bit in the key is of great importance. No attempt can be made to produce a duplicate from merely seeing it, and if an impression of the key be taken, the skeleton key made from the impression will, to be sure, get into the keyhole, but it will be arrested immediately by the sentinel-bolt **F**. and turned back; or, should the sentinel sleep at his post (steel bolts, worked by steel springs, do not sleep) nothing would be gained, for the key would but revolve on its centre pin, without having the slightest effect on the levers. On the other hand, were a key made capable of acting on the levers, it could not get in at the keyhole; the key that can get in cannot work, the key that can work cannot get in. Figures 254 and 255 show the keys in and out of the lock.









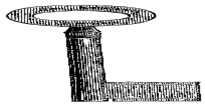


Figure 254. The Key as it appears when out of the lock.

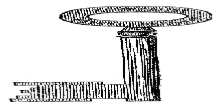


Figure 255. The Key when in the Lock acting on the Bolt and Levers.

There is but little new in the construction of this lock, and the expanding key-bit was invented by Mr. Machin in 1827, as described elsewhere in this text. When well made, this lock affords an average amount of security, but the construction of the key permits but of a very limited number of combinations. (See the chapter on K*eys and differs*)

SINCLAIR'S LOCK, patent dated November 13, 1851.

The improvements introduced by Mr. Sinclair have relation to tumbler locks, and consist of the following innovations.

First: In combining the action of two or more of the tumblers of a lock in such manner that they shall be individually incapable of being brought to the position requisite for the admission of the locking-ring, pin, or plate, or in such manner that the movement of any one of the tumblers shall produce upon the others a locking effect, which would prevent their being moved.

Secondly: In combining with wards or escutcheons a revolving-shield or plate, which will have the effect of preventing the introduction, or increasing the difficulty of, introducing picking instruments.

Thirdly: In the employment of a serpentine of zigzag gate or way for the introduction of the locking-pin, and in the application of a compound motion to the tumblers, the effect of which is, that by once turning round the key a double or triple locking may be produced.

Fourthly: In the adaptation of a dial or indicator to tumbler locks, whereby the changes of the tumbler may be varied according to the permutations of a moveable bit-key, or whereby, in combination with other apparatus, the positions of the parts of the lock may be so arranged after the act of locking, as to prevent the possibility of the lock being opened, even with the legitimate key, without the knowledge of the secret arrangement.

Fifthly: In dispensing with the shackle and eyebolt of padlocks, or either of them, and in causing the bolt of the lock

to be held, and the locking effected by means of pins or projections on, or holes or recesses formed in a plate of metal to which the lock is attached.

RESTELL'S LOCK, patent dated December 8, 1851.

The principal feature in the construction of this lock consists in constructing the keyhole in such a manner as that not more than one instrument can be introduced into the lock at one time for the purpose of picking it. Further, that if any instrument other than the proper key be introduced and turned partly round, it will meet with an obstruction, as usual in all combination locks, but cannot be withdrawn therefrom until all the internal parts have been brought back into their original position.

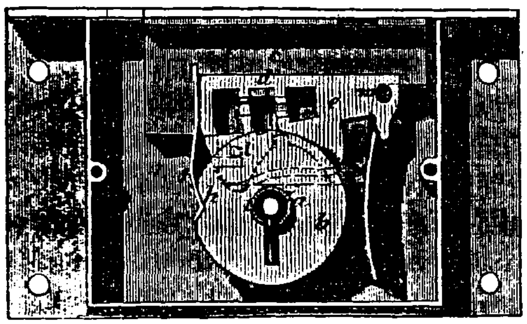


Figure 256. Restells Lock.

This objects effect is one of the *barrel and curtain combined,* as when the key or other instrument is introduced and turned round in the keyhole, the curtain or shield ***b*** (figure 256) is carried round inside the lock, and covering up the hole, thereby prevents the introduction of a second instrument.

So far there is nothing new in the invention. In order to prevent the key from being turned in the wrong direction, a projecting stud or tooth, ***f***, (figure 257) is formed on, or attached to the periphery of the curtain. When the barrel and curtain is turned around either way, this tooth or stud will be brought against one side or the other of the bit or stud on the bolt, and the key will be thereby prevented from going around any farther.

The tooth also serves to hold the barrel and curtain in the proper position to receive the key, as unless some precaution of this kind were taken, the curtain might accidentally slip round and close the keyhole.

One of the methods adopted by the patentee for preventing the curtain from slipping round accidentally consists in causing the tooth to take into a notch in a block that is attached to the upper part of the upper most lever. By this arrangement the patentee states he is enabled to relieve the shield from the friction to which it has hitherto been subjected. Sometimes he surrounds the cylindrical guard or barrel ***a*** with a small spiral spring.

A modification of the above plan of holding the barrel and curtain in its place consists in making an indentation, ***h*** (figure 256) in the periphery of the curtain, in which rests a projecting point on the front edge of the upper lever. The key is prevented from being turned in the wrong direction by the tooth on the curtain, as in the former instance. Instead of abutting against the bit or stud on the bolt, there is a moveable stop-piece, ***I***, which is secured to the plate of the lock by means of two screws, but may be moved up or down by the tooth whenever the bolt of the lock is moved up or down by the key.

Another modification of holding the curtain in its place consists in making the top lever ***e***, with a point which takes into a notch in the periphery of the curtain at ***h***, figure 256, which by abutting against one or the other of the studs or pins on the bolt, prevent the key from being turned in the wrong direction.

Another mode of preventing the curtain from moving accidentally is effected by means of a ***v***-nosed spring, represented by ***j***, figure 257, which is affixed to the inside of the cap-plate of the lock (which in the figure is removed to show the position of the spring), and bearing against the edge of the curtain as it is moved round; so that when the latter is brought into the proper position for removing the key, either when the lock is open or closed, the lower end of the spring ***j*** will enter into the notch ***h***, on the periphery of the curtain, and hold it in its proper position.

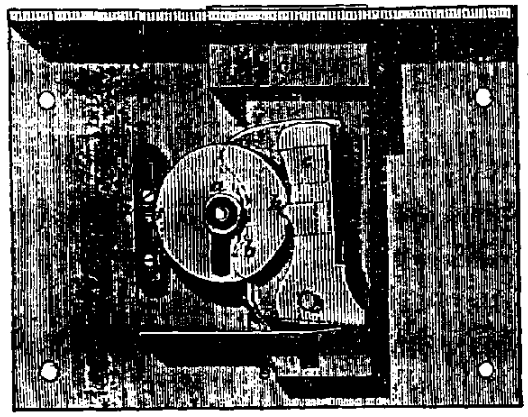


Figure 257. - Restells Lock.

All these modes of keeping the barrel and curtain in its true position are similar to, if not identical with, the notch in the collar or curtain of Mallet's lock, into which fell a lever-bolt.

Another improvement by the same inventor consists of a simple means of so altering the combinations of the levers with the bolt, that the original key, when the alteration is made, will not open the lock. This object is effected without altering the position or combination of the levers, in relation to one another, by simply making the bit or stud of the bolt moveable.

The bit or stud, instead of being fixed to the bolt in the usual way, is secured to a small moveable plate. Two holes are made in the bolt, in either of which the bit or stud may be inserted, and made to project through the levers. A recess is made in the back-plate of the lock to receive the plate, and when the bit or stud is inserted in its place in one of the holes of the bolt, the plate is secured by means of a sliding-plate or shutter.

When it is required to spoil the combination and render the original key useless, it will only be necessary to open the shutter and remove the bit from one hole to the other in the bolt. The effect of this alteration will be that, in order to allow the bit to pass freely through the gates of the levers, and thereby permit the bolt to be shot, the levers must be raised to a different height to that which was before required. Consequently, a different key must be employed to produce this effect.

In constructing locks with this improvement adapted thereto, the patentee proposes to make three keys, two for the first combination and one for the second. If one key belonging to the

first combination should be lost, the lock may be opened with the fellow key, and then the combination spoiled by raising the shutter and moving the plate and bit from one hole to the other; which being done, it will be found that the third key only will open and close the lock; and therefore the other two keys will be useless.

In order to prevent the bolt from moving while the position of the bit is being changed, a small pin may be attached to the lower part of the bolt, and made to enter a notch in the lowest lever, or that nearest the bolt, so as to prevent the bolt from shifting its position.

The same effect, that is, spoiling the combination, may be produced by mounting the pin ***m***, figure 256, on which the levers turn, on a moveable plate. The bit ***d*** will, in this case, of course be fixed to the bolt as usual. The pin ***m*** being attached to a moveable plate, such as that shown at ***k***, will be caused to project through a slot or hole in the back-plate of the lock, precisely as in the former instance. It will therefore be evident, that to alter the combination, by changing the position of the lever, it will only be necessary to shift the position of the moveable plate which carries the pin ***m.***

This patentee is also the inventor of a method of altering the combination in a Bramah lock, by means of a moveable plate.

In reference to lever locks, the patentee states that, besides preventing a person from introducing more than one instrument at a time, he further proposes to prevent any person from feeling the position of the levers by pressing the bit against them, as has usually been the case.

Hitherto the bolt has been held in its place by the levers, as the bit of the bolt was made to nearly fit the notches in the lever. Therefore by forcing the bolt back, and causing the bit to press against the face of the notches in the levers, the latter might be held in any given position, and the obstruction they would offer to opening the lock might then be felt and possibly removed.

The patentee, however, constructs the lock in such a manner that the bit cannot be brought to bear against the levers, so as to retain them in any given position. As it is not necessary that the bit should fit the notches of the levers, the notches are cut much larger than usual, so as to leave a considerable space

between the bit and the face of the notch.

In order to prevent the bolt from shifting its position, except when acted on by the key, the lower edge of the bolt is provided with a tooth or pin, which bears against the periphery of the cylindrical guard, and thereby prevents the bolt from being moved either way, until the guard is turned by the key. A notch therein is brought round, so as to permit the tooth to pass.

A modification of the latter mode is as follows: At the lower end of the barrel ***a*** (figure 256) is fixed a circular plate, which is made to fit into curved recesses cut in the lower edge of bolt ***c***. The bolt is thereby prevented from moving until the notch comes round and allows the points, which are equivalent to the tooth before mentioned, to enter the notch. The key enters the notch in the bolt, and, provided the levers are brought into a proper position, the bolt can then be shot.

Another mode of preventing anyone from feeling the position of the levers is effected by forming an additional notch in the face of the levers. One lever (say the lowermost one) is made a little longer than the others. A small pin is fixed in the side of the bolt. When the proper key is used to open the lock, the levers will be raised in such a manner as to admit this pin through the front gate of the levers.

If a false key or other instrument is introduced, and the bolt pressed back thereby, the pin will be brought against the end of the lowermost or longest lever, and retain the same. Upon discovering the obstruction, and finding all the other levers free, any person attempting to pick the lock will necessarily be obliged to move the obstruction out of the way by raising that lever. Immediately as this is done, the pressure being still on the bolt, the pin will pass into the notches of the other levers, and thereby prevent them from being raised until all are set free again.

The claims set forth in the specification are, first, the combination of the cylindrical curtain or guard ***a*** with the circular shield ***b***, and mode of applying the same, as herein shown and described, particularly the employment of a pin, tooth, notch, spring, or other analogous contrivance, adapted to the circular shield ***b***, together with the other necessary parts connected therewith, whereby the curtain or guard and circular shield may be held in their proper positions, and prevented from slipping round accidentally when the key is withdrawn from the

lock.

Secondly, the employment of pins, studs, or projecting points, adapted either to the circular shield or other part of the lock, whereby the key may be prevented from being turned in the wrong direction.

Thirdly, the use of the moveable plate ***k***, and bit or pin ***d*** or any mere modification thereof, whereby the position of the bit ***d*** in relation to the notches in the levers ***e***, or the position of the levers ***e***, in relation to the bit ***d***, may be altered when required and the combination of the several parts of the lock may be so changed as to render the original key useless for opening the lock.

Fourthly, constructing the bolt with a tooth, pin, or projecting point at its lower edge, which, by bearing against the sides of the cylindrical shield, circular plate, or other suitable part, will prevent the bolt from being shot until a suitable notch, cavity, or opening, made for the purpose in the said cylindrical shield, circular plate, or other part, is brought round, so that the tooth, pin, or projecting point on the bolt may enter therein, and allow the bolt to be moved.

Fifthly, the use of the moveable plate and its moveable bridge-piece or bracket, as applied to a Bramah lock, for the purpose of changing the relative position of certain parts of the lock.

Sixthly, constructing the levers with an additional notch at the end, into which a pin, secured to the bolt, will enter upon applying force or pressure thereto. By thus holding all the levers, will prevent any of them from being raised until the bolt is thrown back again.

Seventhly, the use of a protector-lever, which lever is by means of a pin connected to the circular shield, kept raised too high to allow the bolt to be shot, and cannot be allowed to descend until the circular plate is moved round and the keyhole closed.

Eighthly, the method of constructing a mortise lever lock, which can be opened by the key from either side, the keyhole being protected with double shields.

Ninthly, the method of constructing tumbler latches, as shown in the drawings attached to the specifications.

HOBBS' PROTECTED LOCK, patent dated February 23, 1852.

The patentee, in his specifications, states that, "My invention relates to a novel mode of constructing certain parts of locks, by means of which the possibility of feeling the position of the gating of the levers by applying pressure to the bolt is prevented."

"Another part of my invention consists in a novel arrangement or construction of parts, whereby the key or instrument which operates upon the levers to bring them into a proper position, preparatory to throwing the bolt, is carried into the lock, and the keyhole is effectively closed while the key or other instrument is so acting upon the levers."

"This lock in its general appearance resembles the usual lever locks. It has the same form of key and the same moveable parts.

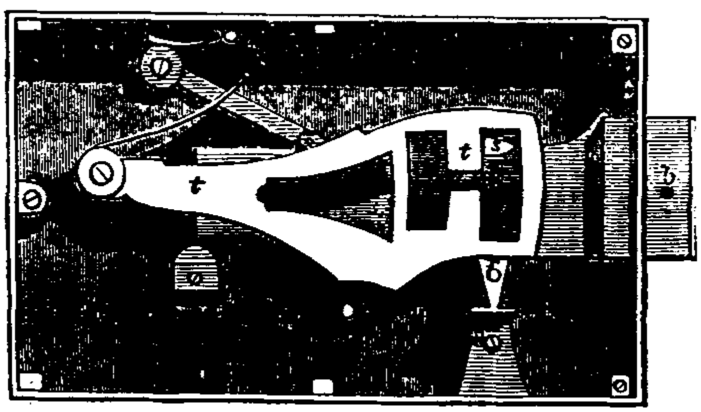


Figure 256. Hobbs' Protector Lock.

The only addition being attached to the ***tumbler stump***, which addition works under the bolt of the lock. Figure 258 represents the mechanism of this lock. "**bb**" is the bolt. "**tt**" the levers, with the usual slots or gatings, through which a tumbler stump **s** must necessarily pass when the bolt is being locked or unlocked.

In all other locks this ***stump*** is riveted into the bolt. Consequently any pressure being applied, or an attempt made to withdraw the bolt, brings the ***stump*** against the face of the levers, causing them to bind, by which means the gatings are easily found. In this lock, on the contrary, the stump ***s*** is

riveted into a piece shown detached in figure 259.

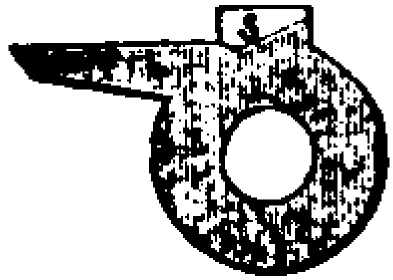


Figure 259.

The hole ***h*** is fitted on a center pin in a recess formed at the back of the bolt. The stump passing through a slot in the bolt, stands in its usual position. There is a small binding-spring to prevent the piece from turning of itself.

When the key is applied to the lock and the levers properly adjusted, the stump, meeting with no obstruction, passes through the gating of the levers. But should an attempt be made to withdraw the bolt before the levers are all properly raised, the stump, meeting with the slightest resistance, turns the piece to which it is attached on its center and raises the portion of the piece ***p*** so that it comes into contact with a stud, riveted into the case of the lock, thereby preventing the possibility of withdrawing the bolt, and at the same time releasing the levers from any pressure, so that it is impossible to ascertain their proper position.

D is a dog, or lever, catching into the top of the bolt, serving as an additional security against its being forced back. **K** is the 'drill pin' on which the key, figure 260, turns.

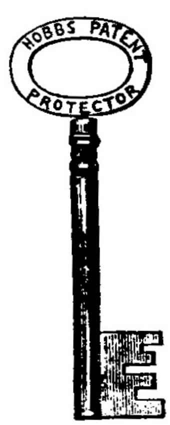


Figure 260.

R is a piece on which the levers rest. Although, by this simple addition, and without adding materially to the cost, locks are rendered perfectly secure against picking, or being opened by any instrument except the true key or its duplicates, yet as with all other locks where the key is not susceptible of change, any person having had the key in his possession may, by taking an impression, become master of the lock. For purposes of absolute security this danger is effectively guarded against by the ***permutating or changeable key locks."***

The claims set forth in the specification are:

First, the use and application of a moveable stump to the bolt, or attaching a moveable piece to the stump, or the stump to a moveable piece, for the purpose above described, and shown in the several figures in sheet No. 1.[1]

(535)

Secondly, the use of a compound or double lever, as shown in figures 9 and 10, sheet No. 1, for the purpose above described.

Thirdly, the arrangement shown in sheet No. 2, figures 1 and 2, or any modification thereof, either by circular parallel motion, by which the bit of the key is carried into the lock and made to operate upon the levers. This will bring them into a suitable position, preparatory to shooting back the bolt, the keyhole being completely closed while the key-bit is operating upon the levers.

Fourthly, the constructing of a lock, with a bolt having a series of right angular slots, moving both vertically and horizontally, operating with a single set of slides or levers, as shown in sheet No. 2, figures 6,7,8, or any modification of the same for the purposes before named.

Mr. Hobbs is also the inventor of a "flush-bolt portable or camp-desk lock." The specification states in reference thereto that, "The advantages of this lock over those in general use are these; that the bolt descends flush with the selvage when the lock is unlocked and when in the act of locking first ascends vertically from out of the selvage, until it arrives at the proper height of the link, then, with a horizontal motion, slides under the link, as in the ordinary method of the common link-plate lock."

The movement in this latter lock is precisely the same as that in Perry's. Numerous efforts have been made to construct a ***simple flush-bolt lock,*** and the most successful of any we have seen is one to be described hereafter, and is the invention of Mr. Aubin, Nettlefold's patent of 1855.

TUCKERS CLOSED-KEYHOLE DETECTOR LOCK, patent dated October 1st, 1852.

The separating-key lock of this inventor (previously described) was found to be objectionable, from the possibility of the accidental severance and consequent loss of the key-bit. The present lock was produced as possessing equal advantages in point of security, while at any rate free from that special objection to the key which had tended mainly to nullify the commercial value of his previous invention. The same principle of "closing up all communication with the security parts" while "pressure" can be produced against them is also eliminated in this lock, and is carried into operation as follows:

The lock presents two ***external*** key openings, through one of which, ***F*** (figure 263) the ***true or grated keyhole*** can be seen. This grated keyhole is situated in a drum, ***H***, placed close behind the front-plate **J**, and rotating parallel with it, and forms the sole inlet to the interior mechanism. The keyhole ***E*** leads to a central sink or chamber in the drum, into which the key must be inserted, or in which a handle may be fixed, in order to give the requisite rotation to the drum, but which chamber offers no communication with the internal mechanism of the lock.



Figure 261.

By this arrangement, and by the manner in which the sliders **D** (the action of which is from front to back, as in a Bramah lock) are situated relatively to the locking-plate **G**, the effect of non-communication with them from the keyhole, while they are in

contact with the locking-plate, is produced.

These sliders are placed in two chambers in, and slide parallel with, the axis of the drum, immediately behind the true keyhole, the locking-plate being fixed at such a distance from them when the bolt is thrown that they, together with the keyhole, must be carried behind the front plate and *covered over entirely,* before they can be brought into contact with it, access to them being then impossible.

The tentative process of picking being thus rendered inoperative, security against "ringing the changes" was next provided for (to use the words of his specification) as follows:

By the adoption of a new principle of detection, whereby all further attempts to pick the lock are entirely prevented, should previous trials to effect it have been to a certain point successful, and this is carried into effect by a pin or bolt (**I**, figure 262) springing from the circumference of the drum, which flies into a hole in the lock-frame so soon as certain of the combination sliders have been sufficiently advanced to pass the face of the opposing (locking) plate, when, should the remaining sliders be incorrectly adjusted, the drum can neither be advanced nor retrograded, so that no further attempts to pick the lock can be made.

As in this lock the key-steps only impinge on the *ends* of the sliders, there is no *difference* in the impressions made by *long* and *short* steps, consequently "mapping" the sliders is impossible. It was equally impossible with the previous lock.

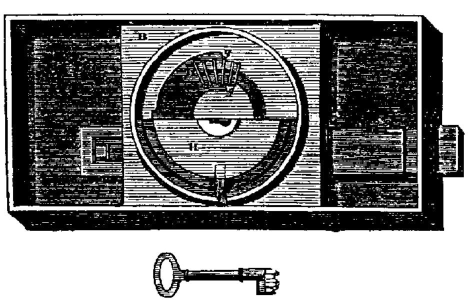


Figure 262.

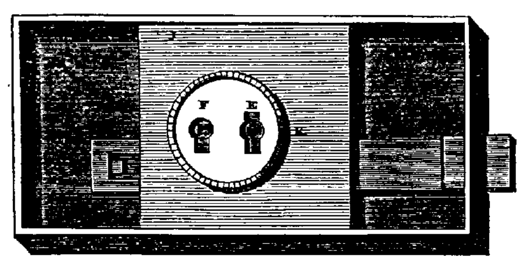


figure 263.

The remaining feature of importance in this lock consisted in the mode of making the frame or case, the body of which was cast *solid,* leaving only sufficient space in it for the revolution of the drum and the passage of the bolt; the front and back plates

being screwed to the solid body.

The purposes contemplated by this mode of making the case were strength and cheapness of manufacture, and security from injury by gunpowder. The idea of a *"solid* powder-proof lock" was indeed so effectively carried out in it, that in a full-size bank lock on this plan there was not sufficient vacant room for half-of-powder, and for that little, even a vent was provided at the back of the lock.

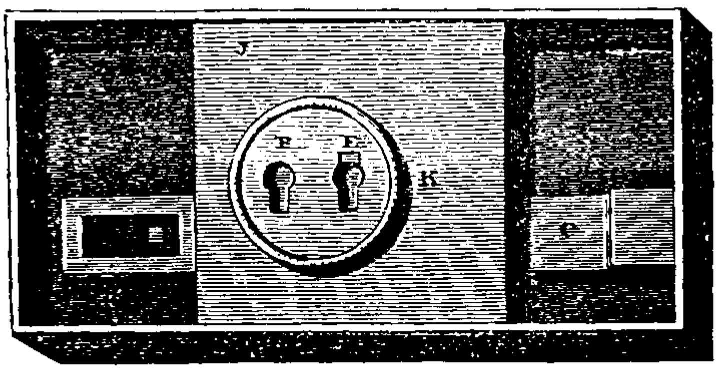


Figure. 264

This mode of making the lock-case has been since patented by Mr. Milner, and so closely imitated him that with the exception of the vacant space for the insertion of powder in his lock, being many times greater than in the original lock, and that Mr. Milner's contains no vent for the escape of the powder. it would puzzle a nice observer to find the difference between them.

ROSE'S Lock, Patent dated October 21st, 1852.

The object of the inventor of this lock was to produce a lock which could not be picked, and he sought to effect it as follows:

The lock is of the ordinary lever kind, and at the back of the levers are two strong springs, one spring for each lever. The pin upon which the back-ends of the levers work is inserted into the short arm of a bell crank, whose fulcrum is fitted to the frame of the lock, immediately above the pin on which the back-ends of the levers work; the long arm of the lever is prolonged parallel with the bolt, and terminates in a projecting piece corresponding with a slot made in the top of the bolt of the lock.

On any attempt being made to force back the bolt, the short arm of the bell-crank lever would be carried back, and the long arm

with its projecting piece would be brought down, and would effectively prevent the bolt being pressed back by the projecting piece fitting into the slot or aperture made for its reception in the bolt.

On pressure being withdrawn from the bolt, the springs would force back the levers, and with them the short arm of the lever, and consequently raise the projecting piece on its long arm out of the slot in the bolt, and thus leave it in a fit state to be opened by the proper key of the lock.

The claim is for "improvements in locks, whereby the bolt is prevented from being forced back, as herein-before described."

CHUBB'S LOCKS, containing the improvements patented by John Chubb, November 1st, 1852; and John Chubb and John Goater, January 21st, 1853.

The following description of Chubb's *modern* locks we here copy from Mr. Tomlinson's book, it having been furnished by Mr. Chubb to the editor of that work for insertion therein. We applied to Mr. Chubb for a similar description, but did not receive any reply:

Lock No. 1. "The first of the improvements introduced consists of a barrel, to which a circular curtain is attached, revolving round the drill-pin in the lock; so that if any instrument is introduced to attempt to pick it, the curtain immediately closes up the keyhole and prevents the introduction of any auxiliary instruments, there being several required in action at once to produce any effect."

"If by any means these several instruments can be introduced simultaneously, the barrel keeps them all confined in a very small space, preventing their expansion, and renders it impossible to work them independently of each other; therefore they are of no avail, being incapable of acting as more than a single pick, which is perfectly useless. The barrel and curtain have each been previously used *separately* in locks, but until patented by Mr. De la Fons in 1848 they had not been used in *combination.*"

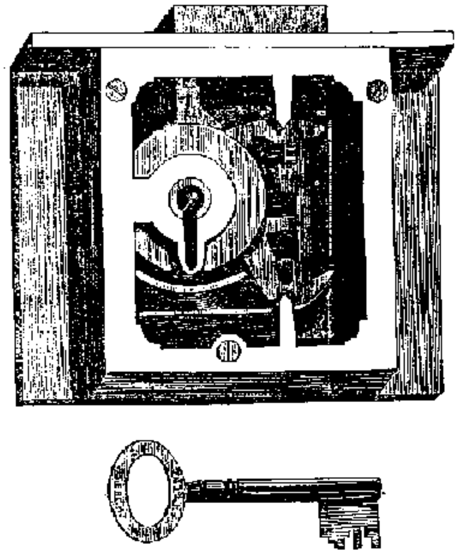


Figure 265.—Chubb's Detector Lock of 1856.

Neither of them used separately is of much use, but when combined they afford a very great security. Locks have been, and still are shown containing either the barrel or curtain *singly;* and as these have been picked, it has been asserted that the improvement now introduced in Chubb's lock is equally insecure, but a slight examination of the difference in their construction will prove the contrary. Mr. Chubb has *purchased* the patent-right of this part of Mr. De la Fons' invention, and applies it to all his locks.

Lock No. 2. "The next improvement, recently patented by Mr. Chubb, is based upon the assumption the security of the barrel and curtain as already described (although this assumption is not in the slightest degree admitted), and consists in applying what is called a 'tumbler-bolt,' working on a hinge connected with the main-bolt. The web of the key does not in any case touch the main-bolt in unlocking, but acts only on the tumbler-bolt.

All the tumblers must first be lifted, each to its proper position, before the tumbler-bolt will act. Should any pressure be applied to either bolt before the tumblers are all at their exact position, the effect would be to throw the bolts out of gear, and thus effectively to stop the stump of the main-bolt from passing through the racks of the tumblers. None of the many plans of picking which have been suggested, such as smoked key-blanks, thin key-bits, etc. would be of the least avail against a lock made on this principle.

Different kinds of detectors may be applied to these locks. It is submitted that this lock, retaining all the simplicity and durability which have distinguished Chubb's lock for so many years, and combining with them these important improvements, affords a complete security against all surreptitious attempts of any nature. Locks on the same principle are being made on the permutation plan, with any number of tumblers, and any number of changes in combination that may be desired.

"It has been suggested that the 'detector,' instead of giving additional security to Chubb's lock, affords a partial guidance to a person attempting to pick it. This objection holds good to a certain extent in these locks as originally made, in which all the tumblers had an *equal* bearing against the detector-stump; but in the locks as now constructed, this objection is entirely obviated by giving the tumblers an *unequal* bearing, whereby, if an operator feels the obstruction of the detector-stump, he cannot tell whether the tumbler which he is lifting is raised too high, or not high enough."

"**Lock No. 3**. For banks, Mr. Chubb has introduced what he particularly calls his 'bank lock.' It contains a barrel with a series of curtains. While the keyhole is open, all access to the tumblers from the keyhole is completely cut off by two sliding-pieces of solid metal, which fit closely on either side of the barrel. These pieces are acted upon by an eccentric motion, so that when the key is applied to the lock and turned in it, the keyhole is shut up by the revolution of the curtains, and then only do the sliding-pieces of metal move aside **I**, to allow the key to act upon on the tumblers."

These pieces return to their position when the key has passed; therefore, while the key is lifting the tumblers, all communication is cut off from the exterior of the lock by these sliding-pieces and the series of curtains. The bolt is made in two pieces, the main-bolt never being in contact with the key, which acts only on the talon-bolt, and by it transmits the motion to the main-bolt.

After the action of locking, the talon-bolt is partly repelled, and a lever or 'dog' connected with it locks into a series of combinations arranged upon the front parts of the tumblers, and holds them securely down, so that none of them can be lifted in the least degree until the talon-bolt is thrown forward to release them. If, therefore, any pressure be applied to this

talon, to endeavor by its help to ascertain the combinations of the tumblers, it will only the more tightly lock them down, and render the attempt ineffectual.

By another contrivance, it is rendered impracticable to move a pick or picks round in the lock more than a small distance, unless the tumblers could previously be all lifted to their right positions, which can only be done by the right key. Should one or more of the tumblers be surrepitiously raised by any possible means, they cannot be detained in this uplifted position, for the action of turning back the pick to try to raise another tumbler sets in motion a lever which allows the tumblers already raised to drop to their former position, leaving the operator just as far from the attainment of his object as at the outset."

From the foregoing description of Mr. Chubb's *modern* locks, it would appear that he places great reliance upon the security against picking when the barrel and curtain combined forms part of the construction of a lock; but it must always be borne in mind that wherever the key can go, there also can a picking instrument. We attach the same amount of importance to the adoption of the barrel and curtain combined as we do to the use of the various kinds of detectors; and we recommend all future inventors of locks to aim at constructing them in such a manner that they may be perfectly secure without the aid of such questionable friends.

An objection has been made by some against the use of those lever locks, the keys of which are stepped, and the lowest of which steps usually moves the bolt. They say that by grinding or rubbing off a portion of the step in question, whilst the proprietor's back is turned only for a few moments, a dishonest *employee* may open his master's safe or other depository and commit a robbery, and the employer not know in what manner the robbery has been effected, for no marks of violence are necessary to the successful operation. We admit the thing is just possible; at the same time no thief would attempt a robbery by such means when he could effect his object more certainly and in less time by taking an impression of the key.

The *rationale* of the above plan is as follows: From what we have previously stated in former chapters, it will be understood that in lever and tumbler locks the lowest or bottom step on the key-bit usually moves the bolt by coming in contact with its talon. Now if to throw the bolt quite out, that is to lock the lock, requires the step to be, say, 5/8” long, it follows that if

1/8” were rubbed off and the same key applied, the **bolt** would not be shot in the same proportion, although the key performed its revolution.

The consequence would be that the stump of the bolt would remain in the main-gating of the levers instead of in the rack nearest their center of motion, the true position; and it will therefore be apparent that if when in such a position the operator went to the lock with a key having only the bottom step on its shank, it would move back the bolt without the slightest difficulty, because the levers could not offer any obstruction to its motion.

We have never heard of a robbery having been effected by this means, neither do we think a *thief* would ever adopt it. It must also be borne in mind that with a *hardened* key, it is not an easy matter to reduce a step of the bit even the sixteenth of an inch by rubbing it with oil and emery.

In the Chubb's lock shown in figure 265, a contrivance has been introduced for the purpose of preventing a lock being tampered with in the manner above described, which consists in placing a guard on the bolt, so that the next longest step of the key-bit will move the bolt, instead of the terminal step coming in contact with the talon in the ordinary way; but we do not consider this plan by any means effective or desirable.

WHISHAW'S MAGNETIC Lock Patent dated January 29, 1853.

The patentee states in his specification that his invention to consist in locking the locks of doors, safes, etc. by means of electromagnetism. To the door-frame or casing, as the case may be, is attached an electromagnet of sufficient power, which, as is well known, is produced by passing a current of electricity by means of properly insulated wires (coiled round the soft iron) in connection with a galvanic battery.

The electromagnet is let flush into the frame or casing of the door, so as not to be visible externally; the poles of such magnet are made perfectly smooth and even throughout, so as to admit of a uniform surface for the end of the iron bolt (or any suitable lock which may be fixed on the door, or a simple iron bolt alone will answer the purpose) to abut against, in order that when the surface of the end of the bolt is in contact with the poles of the magnet, (provided the electric circuit is complete,) the electromagnetic locking is perfected; but immediately on the circuit being broken the electromagnetic lock

is unfastened, and, in the case of an ordinary lock, the security will then depend simply on the bolt being shot into its keeper. As many locks as there are electromagnets and ordinary locks included in the circuit can be secured by this invention.

JENNINGS LOCK, Patent dated January 29th, 1853.

This invention has reference to a new construction of lock, in which a series of permutation plates, each pierced with a central hole to receive the key, are arranged within a cylinder or other case furnished with a projection to receive the action of the key, and with a recess or recesses in the outer periphery to receive a lever when all of them have been brought round to the proper point.

The key is made of a series of plates corresponding in number with the permutation plates, and each having a recess of different length to act in succession on the permutation plates to bring them to the proper position for the reception of the levers, one of the series of plates being cam-formed for the purpose of operating the lever.

The permutation plates and lever are arranged within a rotary cylinder or other case, surrounded by a permanent flanch or case properly recessed for the reception of the lever when held out by the permutation plates, to prevent the said rotating case from turning when locked. Combined with the rotating cylinder or case which contains the permutation plates and lever is an eccentric fitted to a yoke on the bolt for the purpose of throwing the bolt, the eccentric being at the dead point when the bolt is thrown out, so that any pressure applied directly to the bolt to force it in may have no tendency to turn the eccentric.

It will be obvious that the key, instead of being made of separate plates, may be cut out of a solid piece of metal, but this will not present the advantage of changing the combination.

SIMSON'S DUPLEX BANK LOCK, Patent dated May 2, 1853.

This lock, which is the invention of Mr. Willlam Simson, banker, Edinburgh, has combined with it the "detainer" claimed by Mr. Gibbons in his patent, dated December 22nd, 1853.

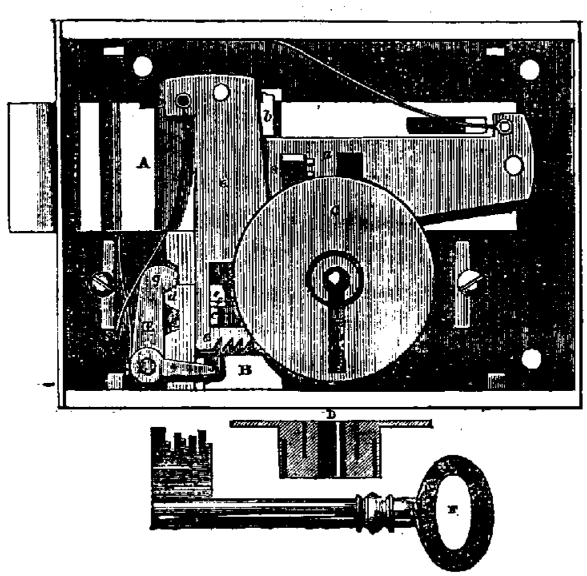


Figure 266. Simson's Duplex Bank Lock.

Figure 266 represents the combined lock, and the following description is taken from the published prospectus of it.

"Into this lock are introduced the following new parts or mechanism:

1. Simson's patent double set of bolts, each with its separate springs and levers. The ordinary horizontal-bolt, **A**, is crossed beneath at a right angle by another bolt, **B**, with its own set of levers, **e**. The vertical-bolt, **B**, is not shot beyond the case of the lock. It is brought down with a lateral projection, **b**, fitted to a notch in the horizontal bolt to hold it fast, and to shut down the horizontal-levers, **a**. This combination renders it impossible either to lift the latter or to force back the former until the vertical bolt has been raised again. The two sets of bolts and levers vary, each having its own notch in the bit of the key.

Each set consists of four levers: there are thus in every lock eight levers, giving upwards of 2,400,000 different combinations. The key cannot be taken out of the lock until the vertical-bolt has secured the horizontal-bolt. The horizontal-levers being shut down by the vertical-bolt, their range or lift cannot be felt from the keyhole. The required liberation of both bolts is effected by one turn of the key. In locking, also, one turn of the key first throws out the horizontal-bolt, and then brings the vertical-bolt down upon it.

2. Simson's patent curtain or block, **c**, adapted to the circuit of the key, acting as a protector to the wards, levers, and bolts of the lock, and moving round with the key when turned.

"The sides are grooved to fit the wards, as shown in Section **D**, and the edge overlaps to some extent the bolts and levers, thereby more than fully closing up the keyhole as soon as the key is slightly turned. The wards, by this arrangement, are vastly elevated in importance, and lose their character of an easily destructible security; and in proportion as the protector fills up space, which is usually left vacant, it prevents the application of gunpowder to destroy the lock; and it excludes dust, thereby keeping the works for a longer time unclogged."

3. Gibbons' patent detainer, **E**, applied to the vertical-levers, rendering it necessary to lift them all simultaneously to their true position, and effectively securing them against having that position ascertained by raising them one by one.

"The vertical-bolt **B** is retained in its proper place, when locked, by the lowest lever, **f**, which has its face close to the stump, **c**, of that bolt. The other levers, **c**, have a series of notches cut in their ends, and have their faces, **e**, set back, so that when the lowest lever, **f**, is adjusted, the bolt can be moved a little distance before the stump, **c**, reaches them."

Upon the adjustment of the lowest lever, **f**, a slight motion given to the bolt, **B**, causes the beveled edge, **d**, of it to act upon the detainer, by pushing up its beveled end, **g**, thereby bringing down the other end, **h**, which is pointed, into the notches cut in the ends of the levers, thus fixing them firmly in whatever position they may be at the time such motion is given to the bolt.

The true key forms the complete combination, by lifting every one of the levers correctly before it begins to move the bolt; but should any one of the levers, **e**, be put out of its proper position by a false key or picker, the act of moving the bolt carrying its stump from the face of the lowest lever, **f**, to the faces of the other levers, **i**, causes the detainer to fix such lever in that wrong position, and it will be impossible for the operator to tell which lever it is that prevents the opening of the lock, or whether it does so by being above or below its true lift.

"He can pretty accurately ascertain the difficulties he has to overcome in attempting to open an ordinary lever lock without its proper key, and he is able to adjust his instruments accordingly; but this detainer shuts out from him the means of arriving at an opinion as to the requisite lift of the levers, and leaves him quite at fault."

We are sorry we cannot compliment Mr. Simson on the originality of his invention, as the double set of levers was introduced by Mr. Duce, in 1824, as described earlier; and the "curtain or block," as we have before shown, has been reinvented over and over again. The size of the lock allows the limbs to be made very strong, and the number of combinations obtained by the number of levers presents a great obstacle to its being picked either by the tentative process or by ringing the changes. Like all other bank locks, its high price will prevent its being adopted for general purposes. The locks we have seen, which were made by Mr. Gibbons, are thoroughly well made.

PARNELL'S SECOND LOCK, Patent dated September 9th, 1853.

This lock is constructed with levers, supported on a pin or fulcrum placed at or near the center of the levers instead of the end, as in the ordinary lever locks. There is a notch at the outer end of the levers to receive the lock-stop, and another notch at the opposite end of the lever to receive the detector-stop. Upon the outer end of each of the levers (or it may be in any other convenient part) are formed two inclined planes, and springs are placed in such a position as to be capable of acting upon either incline, so as to move the levers in opposite directions.

When the bolt is shot, the springs pressing upon the inclines force the levers against the locking-stop, so as to retain it in the notch; but if an attempt be made to pick the lock, the moment any of the levers are lifted too high, the pressure of the corresponding spring becomes transferred to the incline of that lever, and the lever is thereby forced into contact with the detector-stop, which enters the notch in the lever, and is retained therein by the pressure of the spring upon the incline. There is also a horizontal-stop acting against the butt end of the levers when the bolt is shot out.

The claim is for supporting the tumblers or levers upon a central axis, the arrangement for maintaining a tumbler in contact with the detector-stop after the withdrawal of a false key, and the

horizontal-stop.

TUCKER'S SAFE GUARD LOCK, Patent dated Nov. 21st, 1853.

Mr. Tucker, finding that his *closed keyhole lock;* described subsequently in this text, was still open to the objection of requiring a two-fold operation of the key to unlock it, the present lock was invented to supply its place. The same *principle* of security is adopted in this as in the former lock, it being equally impossible to obtain access to the security parts while pressure could be maintained upon them as in the closed keyhole lock, but the mechanical construction of this lock is very dissimilar.

The security parts are here formed as circular or wheel-shaped levers, arranged upon a central pin; these levers are surrounded or enclosed in a moveable box or barrel with an opening in its side, which opening is the *true* or *internal* keyhole (there being but one *external* keyhole) through which alone can communication with the levers be obtained.

As it is only when this internal keyhole is carried behind a fixed shield or safe-guard in the lock (so that no communication with it from the external is possible) that the bolt or security-stump can be brought into contact with the levers. It is manifest, therefore, that all attempts at picking by the pressure or tentative process must prove abortive.

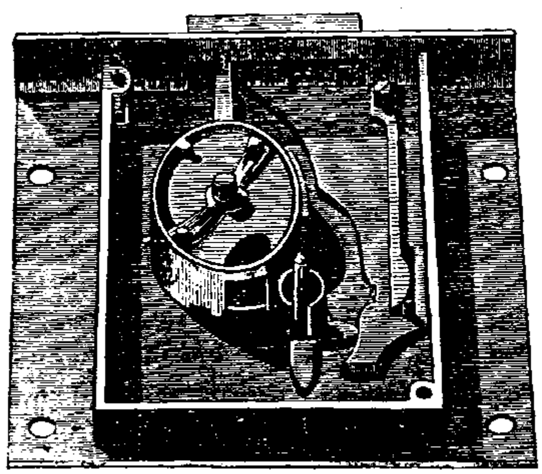


Figure 267. Tucker's Safe-Guard Lock.

The requisite motion is given to the surrounding box by an auxiliary key-bit attached to a socket (surrounding the

drill-pin, and reaching the whole depth of the lock), into which the key fits, and carries with it the socket and auxiliary-bit in its revolution. The drill-pin or axis of the key is fixed beyond or without the line of action of the moveable box, the talon of the bolt upon which the bit operates being still further beyond it.

The action is thus: The key is placed into the outer keyhole and turned round, carrying the auxiliary-bit with it; the key-bit first passes into the internal keyhole in the side of the box, adjusting the levers to their true position, whilst a simultaneous movement is being given to the box; the action of the key being pursued, it then passes out *of the internal keyhole,* the auxiliary-bit continuing the movement of the box and carrying the internal keyhole behind the fixed safe-guard or shield, so that no communication with the levers can be effected; by which time, and not until then, a gating in the side of the box being brought into a line with the bolt-stump, the bolt can be drawn back.

In the reverse or locking action, the first effect of the action of the key, when put in motion, is to lock out the bolt, carrying the bolt-stump out from the box; by continuing the action, the auxiliary-bit operates on the box, reopening the internal keyhole and forcing the levers back into their normal positions, so that neither dirt nor viscid oil can prevent their action.

The part of the levers on which the key-bit impinges is so shaped that the key-steps can only impinge on a projecting point or nib, by which means, *be the steps of the key acting on the levers either long or short, the amount of smoke they remove shall in each case be the same.* This peculiar formation of the lever is claimed by the inventor as a means of preventing the possibility of " mapping" the levers. Another advantage claimed by him also as arising from the use of the auxiliary-bit to throw the bolt is that no fraudulent shortening of the terminal of the key-bit can prevent the bolt from being fully thrown, or the levers being restored to their correct locked positions behind the stump.

GIBBONS' DETENT LOCK, Patent dated December 22nd, 1853.

The improvement effected in this lock consists in the introduction of a *detainer* or *lever-fixer* the use of which is to fix the levers in one position before the stump of the bolt comes in contact with them. The lever next to the bolt is made with its face to project beyond the other levers, so that when the bolt is

locked out, the stump of the bolt is retained in its proper position by this lever, which the inventor calls the "locking-lever."

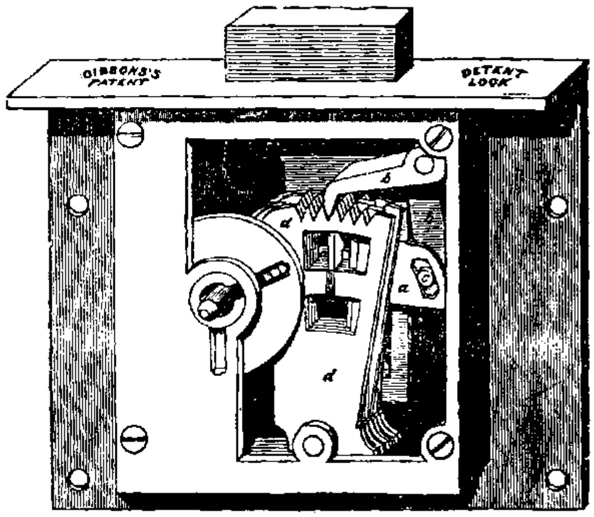


Figure 268. Gibbons' Detent Lock.

Figure 268 represents the lock. ***a*** *is* the locking lever; ***d*** the other levers, which are set back, so that in unlocking, the lever ***a*** must be raised to allow the stump of the bolt to enter its gating, when it moves along some distance before it comes to the face of the levers ***d.*** The act of lifting the lever ***a*** causes it to raise the arm of the detainer **b**, which is connected with it by the pin **c** and this brings the point of the detainer into the notches formed in the ends of the levers ***d,*** as shown in the cut.

By this means, the levers ***d*** become firmly fixed or detained in their position, and are incapable of any further adjustment until the stump of the bolt comes in contact with them. The true key lifts all the notched levers **d** to their true position before it acts upon the locking-lever **a**; the detainer **b** is then brought into action, and the levers as represented in the cut offer no obstruction to the passage of the bolt.

Should any one of the levers **d** be either **above or below** the true lift, at the time the lever ***a*** *is* lifted, the detainer will fix it in that particular position; the face of the lever will oppose the passage of the stump of the bolt, which renders it impossible to open the lock, or even to tell which lever it is that causes the obstruction, and whether it arises from its being above or below its true position. This lock is constructed with a curtain

and one deep ward or wheel, as shown in the key, figure 269.

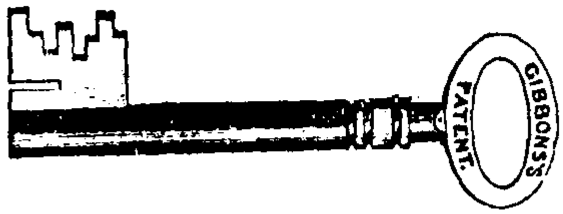


Figure 269. The Key.

The above construction makes it impossible to pick the lock by applying pressure to the bolt, and the true lift of the levers cannot be ascertained by raising them separately. The lock can only be opened by simultaneously raising all the levers to their true position, which can only be done by the true key.

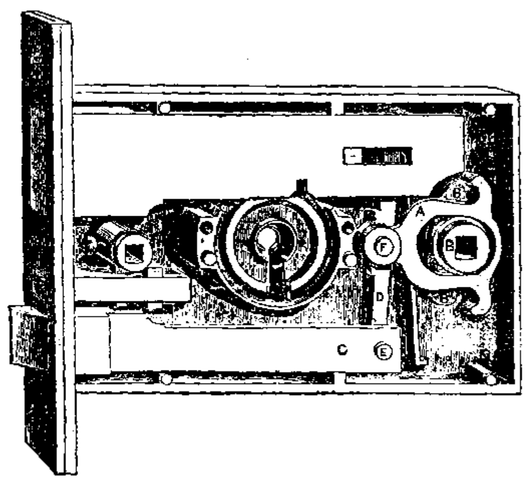


Figure 270. Gibbons ANTI-FRICTION LATCH-BOLT

Another improvement by the same inventor is shown in figure 270, which represents a mortise lock. The improvement consists in using a loose tail-piece, **A**, to connect the follow **B** with the latch-bolt **C** by means of a guide **D**. The guide **D** works at its upper end upon a circular pin or axis affixed to the plate of the lock, its lower end being connected with the latch-bolt **C** by a pin **E**, and with the tail-piece **A** by a center-pin **F**. The upper and lower extremities of the follows, as well as their corresponding recesses in the horns of the tail-piece **A**, are of a semi-circular form, the consequence of which is, that on turning the knob in either direction, a rolling action takes place between the surfaces in contact with it; the ordinary friction is thus avoided, and a perfectly smooth, easy, and durable action is

obtained.

When turned to its full extent, the follow is stopped by the tail-piece coming in contact with the end of the lock, thus making it impossible to strain the guide or to bend the tail of the bolt, defects to which the common latch-bolt is well known to be liable. The position of the follow, which is placed very near to the end of the lock, allows the greatest possible space between the knob and the keyhole, which in small-sized locks is a most important advantage.

SAXBY'S LOCK, invented 1853.

The interior of this lock consists of a cylinder with four pins or slides radiating from the center, and pressed into the keyhole by means of spiral springs. The pins project beyond the periphery of the wheel or cylinder, and into slots in a ring which is affixed to the case of the lock, thereby preventing the cylinder from being turned. On each pin is a notch, so placed that when the proper key is inserted into the keyhole, the notches on the several pins will be brought into a position such as will allow the cylinder to turn. The turning of the cylinder in this, as in the Bramah lock, shoots the bolt.

This lock is the same in principle, but not so secure in its construction, as the Yale lock described at earlier.. The inventor was rewarded by the Society of Arts with the Society's medal and the sum of ten guineas; and shortly afterwards the lock was picked by Mr. Hobbs, "in the presence of parties connected with the Society, in the short space of three minutes." We shall refer to this circumstance again in the next chapter.

DENISON'S LOCK, Invented 1853.

This lock is the invention of E. B. Denison, Esq., Q.C., (whose name is better known in connection with clock-making), and was exhibited at the Society of Arts with others, when the Society made the unlucky mistake of selecting for its premium a lock which, as above stated, Mr. Hobbs picked in three minutes, and which was also proved to contain nothing new in its construction.

Figure 271 represents Mr. Denison's lock with the bolt shot and the levers **t t** thrown, so that the bolt evidently cannot be drawn back until they are moved into the proper position for the stump to enter the gating.

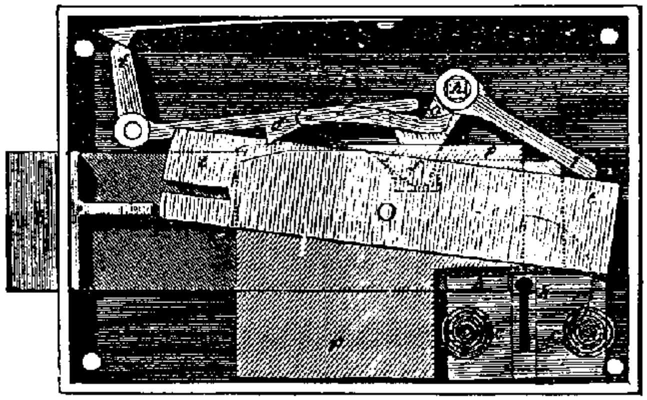


Figure 271. Denison Lock

One of its peculiarities is that there are no lever springs. The levers turn on a pin near the middle, so that they will stand indifferently in any position, especially as they are separated by thin plates, **p p**, which cannot turn. In this lock, therefore, the friction, which is usually an impediment, and sometimes obstructs the action of the springs, is an advantage. The first plate should be between the bolt and the first lever, and no plate is required between the last lever and the cap of the lock.

The plates should slip easily onto the lever-pin, and one or two of them should be bent a little, so that when the cap is on, they will act as friction springs, and increase the steadiness of the levers. It is easy to see that when a proper key is put into the keyhole **k** and turned half round, it will raise the levers into the position in which the stump of the bolt can enter them, and the bolt can be drawn back.

But the bolt is never acted on by the key, which may consequently be very thin and light, as it has nothing to do except raising the levers. The bolt is worked by a handle, **h**, which has a fantail projection, **f**, working in a notch in the bolt, and also another broad lever, **L**, which pushes down the ends of the levers nearest the keyhole as soon as it has shot the bolt.

The key, therefore, is not required at all to lock the lock, but only to open it; differing therein from the large safe locks, in which the bolts are shot by a handle, which are locked by the key afterwards. At the same time it is more secure than any of the self-shutting or spring locks, which are, moreover, apt to get shut accidentally when not intended.

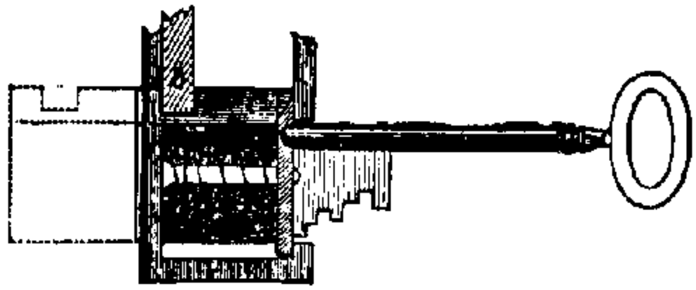


Figure 272. The Key.

It is admitted in the *Rudimentary Treatise an Locks,* edited by Mr. Tomlinson, and published in 1853, that this lock cannot be picked by any known method, for the following reason: when the bolt is fully shot the stump is a little beyond the end of the levers, as is shown in the figure, and the keyhole is completely closed by a steel curtain, **c c**, which cannot be pushed in by the key or any other instrument, except when the bolt is fully shot and the stump removed beyond the possibility of contact with the levers; and therefore the tentative method, before described, of feeling the pressure of the stump on the levers cannot be used.

The curtain **c c** (shown also in figure 272) slides on two pins with spiral-springs behind it, and has a square plug which pushes through the back of the lock, as dotted in figure 272. This plug has a notch in it which exactly coincides with the bolt **b** when the curtain is up against the keyhole, so that the curtain cannot be pushed in except when the bolt is fully shot (as in figure 271); and then, when the curtain-plug is pushed down by the key ever so little, the bolt cannot be drawn back at all so as to feel the stump against the levers.

One of the levers has its end above the gating elongated a little to keep the bolt steady when shot, and in advance of the curtain-plug. The key is solid without a pipe, which further diminishes its size; the key of a large lock with seven levers weighs not much more than a quarter of an ounce.

There is a further provision to guard against the bolt being shot, either carelessly by the owner or intentionally by somebody else, without turning the handle far enough to depress the levers and fix the bolt. **d i** is a lever turning on a pin just above the bolt, and working on a spring at **s** like Chubb's detector, or what is called a jumper in clock-work.

For convenience this may also be called the detector; and it will

be seen that when the corner **i** is on the right hand of the jumper **s**, the tooth **d** will fall into one of the notches of the bolt as soon as it is shot about three-quarters of the full distance; and then the bolt cannot be drawn back again until it has been fully shot and the handle turned far enough to depress the levers, when a projecting corner of the fantail **f** will raise the detector and make it pass the jumper, which will hold it up as now shown in the drawing. As the bolt is drawn back again in unlocking, a pin in the fantail catches hold of a piece set on the top of the detector, and brings it down again to be ready for action.

The advantages of this lock are therefore these:

First: Perfect security, at least against any known method of picking;

Secondly: A keyhole so small that no forcing instrument strong enough to do any mischief can be got in;

Thirdly: Protection of the lock by the curtain from the effects of the atmosphere upon the works;

Fourthly: Impossibility of getting deranged by the levers sticking together, or by failure of lever springs, there being none;

Fifthly: Cheapness of construction compared with any other lock equally secure and strong;

Sixthly: Lightness and smallness of the key;

Seventhly: The convenience and safety of not having to use the key for shutting the lock.

This invention is not patented, Mr. Denison being one of those who disapprove of patents. A somewhat different form of it for small locks is described in the *Rudimentary Treatise* before mentioned; but it does not appear likely to come into use for furniture or small articles, where the handle would probably be objected to; and the difference in the size of the key and the price of the lock, compared with other locks, is not so great as in large and strong locks for safes and articles of that kind.

GIBBONS' DOUBLE-DETECTOR LOCK, Patent dated 1853.

This lock contains a new element of security, it being so

constructed that not only will the over-lifting of any one of the levers throw the detector; but should any attempt be made to move the bolt without having first sufficiently raised all the levers, the detector will be brought into action by the under-lift as well as the over-lift of any one of the levers.

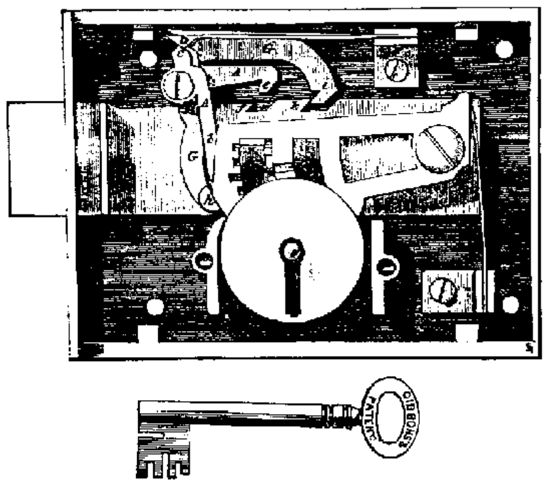


Figure 273. Gibbons' Double-Detector Lock.

When any of the levers are raised above their true position, the arm **b** of the detector **A** is brought forward, and the arm **e** hooks into the bolt at **f**; the v-nosed spring **D**, acting upon the point **c**, keeps it in that position.

The under-lift detector **G** has its arm **i** slightly hooked into the bolt at **k**. When the levers are lifted by the true key the point **i** rises out of the bolt; but should any attempt be made to move the bolt when any of the levers are below their true position, the levers will keep down the detector by pressing upon it at **h**, and the beveled edge of the bolt at **k** will draw down the detector at **i**, where it will be *fixed* by the spring **D.** In cases where a detector lock is required, these locks will be found very superior to the ordinary detector locks, which act by the over-lift only.

DANIEL'S IMPROVEMENTS, Patent dated February 1st, 1854.

These improvements, consist, first, in applying to one-bolted locks a slide, on which the follow acts, and on which is fixed the tumbler and tumbler spring, connecting the slide with a bolt answering as lock and latch-bolt, and which bolt will act by being placed under, upon, by the side, or end to end with the

slide, or in other positions, as different forms of locks may require it to be placed.

By means of this slide the double action of the latch is obtained, that is, admits of the handles turning either way, and allows the same bolt to be locked out with the key, dispensing with the use of a second lever or tumbler, and other complicated parts hitherto applied to attain the double action in one-bolted locks; it has also the advantage of being very durable.

Secondly: In casting the cases of locks with suitable bearings and holes for the bolts, tumblers, and other parts to act in, in the construction of locks containing one, two, or more bolts;

Thirdly: In applying a certain method in the formation of the patterns used for casting lock cases, which dispenses with the laying in of cores for forming the bolt-holes;

Fourthly: In employing a click inserted into the neck of the knob, which acts into racks formed in the spindle by tightening or slackening a screw in the neck of the knob; the neck consisting of an inner and outer neck, the inner neck being of cast iron or other suitable metal.

TANN'S LOCK, Patent dated March 2nd 1854.

The patentee, in his specification, states that, “This invention consists in an improved mode of constructing certain parts of locks, for the purpose of rendering such instruments more secure than the locks as heretofore constructed, and in known and common use; and this invention relates more particularly to those descriptions of locks known and distinguished as 'tumbler locks.'

The mode heretofore practiced in constructing locks of the most modern, and, up to the present time, allowed to be of the most improved construction, namely, those known as Hobbs' patent, has been to make the 'stump' or that part which is employed to hold the bolt of the lock (when shot outwards) in such a position as to prevent or to render difficult the drawing back of such said bolt with any pick or instrument other than the key designed and specially intended to be employed for such purpose; and further, a peculiar feature in the construction of the aforesaid locks has been to arrange and dispose the aforesaid stump with respect to the other parts of the lock in such manner as that it is independent of the bolt of the lock, instead of being affixed to such said bolt, as heretofore generally practiced in the

construction of locks, and particularly those known and distinguished as Barron's, Chubb's, and other patent locks.

The object and intention of making such said stump independent of the bolt has been to take the end pressure off the bolt, and thereby to render ineffectual any attempt to force back the bolt for the purpose of causing the aforesaid stump to press against the tumblers of the lock, and by which such said tumblers would hang, and thereby facilitate the raising thereof, and the ultimate unlocking or picking of the lock by instruments other than the key thereof.

Now, it is to be particularly understood that the principle of construction of this invention consists in, and is entirely dependent upon, and will only act, so as to afford additional security to the lock when end-pressure is exerted upon the bolt, instead of the pressure being required to be taken off the bolt, as before stated, with reference to Hobbs' locks.

This I effect by constructing locks in the following manner, that is to say: I employ a bolt, in which a stump is fixed, which works in the 'gates' of the several tumblers in the manner commonly practiced, excepting that (for the purposes of this invention) I construct and arrange that tumbler which is in immediate contact with the bolt (and which I call a locking or holding-tumbler) in such manner that this tumbler only receives the pressure from the stump of the bolt, by which I take off the pressure from the other tumblers, and thus prevent them from hanging when raised by any instrument other than the key of the lock.

I employ a separate spring, acting upon the tail-end of the said locking or holding-tumbler, for the purpose of raising the front end of such said tumbler when the other tumblers are raised by the action of the key thereon, and when there is no end pressure upon the bolt, observing that the aforesaid locking or holding-tumbler, by being acted on by the aforesaid spring only, is entirely self-acting, and is not in any way operated upon by the key of the lock.

It is only when end-pressure is exerted upon the bolt (as commonly practiced in picking locks) that this tumbler becomes locked or held, and does not therefore rise with the other tumblers, and the locking or holding of this one tumbler in particular: arises from the pressure of the stump against the edge of the gate of this tumbler being greater than the pressure

of the spring upon the tail end of such said tumbler.

Thus it will be seen that so long as the end-pressure remains upon the bolt of the lock, such bolt cannot be drawn back, but immediately such pressure is removed the spring acts, and the locking or holding-tumbler then rises; and I protect this tumbler from being acted upon by a pick or other like instrument, by forming a rebate upon the bolt of the lock, below the edge of the said tumbler; and I also place a shield beneath the under-edges of most of the other tumblers, so as to present an obstruction to the introduction of a pick or other like instrument.

I declare this invention to consist in so constructing certain parts of locks as that I render available the end pressure upon the bolt for the purpose of attaining greater security in locks than heretofore; whereas the principle of construction of the modern locks, before mentioned, consists in removing the pressure from the bolt for the purpose of affording such security.

TANN’S NEW PATENT BANK LOCK.

Figure 274 represents “'Tann’s’ New Patent Bank lock," which, with the following description, are taken from the patentee's published prospectus. The figure shows the lock with the cap-plate and nozzle or chamber removed:

First: The tail end of the bolt is formed of two plates, placed one over the other, the upper or rising-plate forming the talon. These are hinged together at one end, with a slot at the other, so that if any force or pressure is applied to the talon before the tumblers are raised, the effect of any such pressure causing the top-plate to rise, immediately detecting the lock; and the slot catching against the back-stump entirely takes off the pressure of the levers from the tumbler-stump, so that the levers will not hang or indicate the height of the gating;

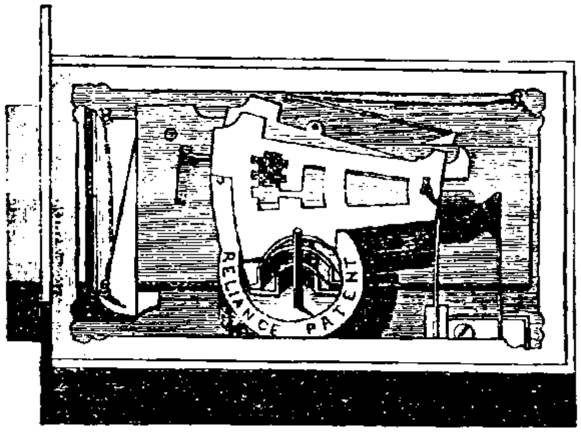


Figure 274. Tann's "New Patent Bank Lock."

Secondly: Relieving the main-stump from the pressure of the levers, so that if force is applied to the bolt, the levers will not hang or indicate the height of the gating, through which the main-stump passes; and this is effected by a self-acting lever, working in the bolt and not operated on by the key.

Supposing force was applied to the bolt for the purpose of picking or opening the lock by any other instrument than the key, the effect of such force would be to cause the self-acting lever to hold in the bolt, and thus take the pressure of the stump from the levers, and it remains fixed until such force is removed; consequently the very pressure, so fatal to other locks, in this affords additional security, and prevents the possibility of its being opened.

Thirdly: Protecting the levers by guards. (From the many thousands of lever locks that have been made, all of similar construction, it follows of necessity that many of them must be alike, and consequently pass each other).

The guards form an entirely new feature both in the arrangement of the lock and key, and effectively shut out the keys of all other patent locks. The guards are placed on several of the levers, and protect the levers either above or below them, so that even if a false key or pick succeeded in lifting the levers with unprotected fronts, it could not possibly raise those behind the guards, and the slightest extra lift at once fixes the detector, and then the proper key only can regulate it.

Fourthly: The cylindrical nozzle affixed to the outside of the face-plate of the lock, in which is a solid circular piece of

hardened metal, with a keyhole cut at right angles with the keyhole in the face-plate of the lock, so that when the key is inserted the keyhole in the nozzle is opposite to the one cut in the metal.

The keyhole in the faceplate being closed, the revolving metal in the nozzle is then turned by the action of the key, and brought opposite the keyhole in the face-plate, at the same time closing up the aperture by which the key entered the nozzle, so as to always present a closed keyhole, whether the key is in or out of the lock. Thus it will be seen that the keyholes in the face-plate of the lock and the nozzle not being opposite to each other, both can never be uncovered at the same tine, and thus render impossible the introduction of any picking instruments.

We may remark that the nozzle forms a distinct chamber, and in consequence doubles the thickness of the lock, which makes it look clumsy. This nozzle or chamber is for other reasons very objectionable. The construction is similar to the chambered locks described in chapter 15, and therefore possesses no novelty.

YOUNG'S LOCK, Patent dated June 12th, 1804.

This invention consists of an improved detector lock, and a latch to be applied to the same and other locks. Figure 275 is a representation of the lock. **a a a** are the levers, which differ from ordinary levers in having teeth, ***b,*** on their ends, by which the picking of the lock, by forcing back the bolt so as to feel the levers, is prevented; the end **c**^{1} of the slide **c**, on the lever ***d,*** which is fixed on the bolt, engaging in such case in the teeth ***b,*** and frustrating the attempt.

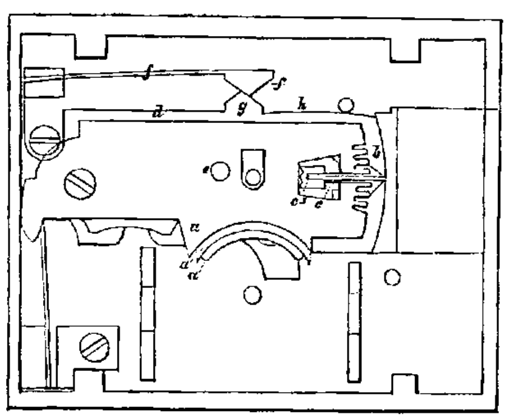


Figure 275-Young s Lock.

The lever ***d*** *is* in two parts, the part carrying the slide **c** turning upon a point **e**, shown in dotted lines upon the other part. When the bolt is shot, the spring **f** pressing upon the part **g**, causes the end **h** of the lever ***d*** to rise, and until it is brought down again by the action of the key into a horizontal position the bolt cannot be withdrawn.

If a false key be introduced, and it brings the lever **d** past the horizontal position, the point **g** of the said lever passes to the side **f** of the spring, which no longer tends to bring back the lever **d**, but to keep it in its displaced condition.

The introduction of the true key detects the displacement of the lever **d**, and corrects it in a way the patentee does not consider it necessary to describe.

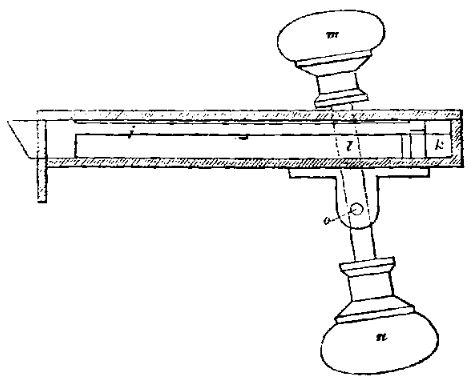


Figure 276. Young's Latch.

The improved latch to be used with the above or any other lock is shown in the horizontal section, figure 276, **i** is the latch-bolt, urged forward by the spring **k**, the said latch is withdrawn by a lever 1, turning upon the point **o**. The knobs **m n** are moved by a sliding motion, instead of the usual rotary motion.

Mr. Young is also the inventor of what he calls the "Palace Motion" to locks and latches. Figure 277 represents a three-bolt mortise lock, with steel follow, brass collar, wards, etc. **A** is the lock-bolt; **B** the private bolt; **C** the latch or spring-bolt; **D** the follow; **E** the latch-lever; **F** its center-pin; **G** a pin on which is suspended the latch; **H** the spring. The latch is drawn into the lock by the crank of the follow bearing against the lever at **I**.

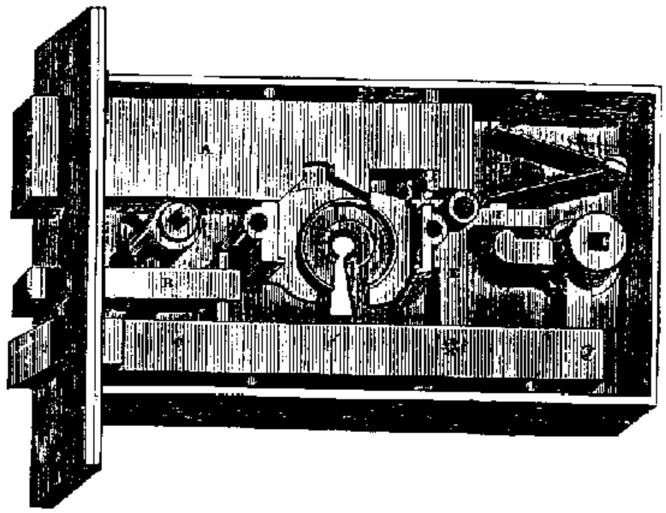


Figure 277. Young's Palace Motion Three-Bolt Mortise Lock.

Reverse the turn of the follow, and the latch will be drawn into the lock by the straight-arm of the follow pressing against the pin on the latch at **J**.

WOLVERSON'S LOCK, Patent dated July 11th, 1854.

This lock is constructed with a series of plates on the end of the bolt, which are capable of sliding vertically; these plates are pressed downwards by springs. There is a slot made in a horizontal direction in each of the said plates; and after the bolt of the lock has been shot, it can only be withdrawn by the said plates being made to slide vertically to the several heights required to bring their respective slots opposite each; for a plate situated at the back of the lock prevents the slot being withdrawn, unless the said plate can enter the said slots.

The several plates on the bolt are raised to the necessary heights in the following manner: Immediately over the keyhole in the interior of the lock are a series of slides, which by the motion of the key are raised to different heights; these slides have projections on their sides, which, when the bolt is shot, engage under projections on the sides of the first mentioned sliding-plates.

The first action of the key is to raise the slides, these raise the plates on the bolt to the necessary height to permit of the bolt being withdrawn; the plates on the bolt are held in their position during the motion of the bolt by clicks engaging in

teeth on their edges. When the bolt is shot, the said clicks coming against a fixed obstacle are disengaged from the plates, which are pressed down by their springs.

MILES' LOCK, Patent dated August 4th, 1854

The patentee, in his specification, states that in the construction of this lock, any number of levers may be used according to circumstances, *each combined with its own spring,* for which purpose brass will be found suitable, so that for marine and other similar purposes the objectionable use of steel or iron in any portion of the lock can be avoided.

A lever, called 'the regulator,' is also introduced, which has a different motion from the others, being without a spring attached to it. It receives the pressure from the springs of the other levers, and in case of any attempt at picking, it reacts upon them, and produces such a combination of difficulties as must insure the highest amount of safety in the lock.

This inventor is one of the few who have taken the right course with respect to the improving of locks, but he did not go far enough. He evidently understood the desirability of making the springs of a metal that would not rust; and this idea has since been fully and successfully carried out by Mr. Aubin in not only making the spring of the lever of brass, but also making it *out of one and the same piece of metal.*

LEWIS'S LOCK, Patent dated September 2nd, 1854.

This lock is constructed with two knife-edged stumps attached to the head of the bolt of the lock, with one knife-edged or flat stump fixed to the lock-case at the tail-end of the bolt. There are also double-acting levers, having notches at the ends, corresponding with the stumps just described. When any other key than the proper one is used to open the lock, or pressure is applied for the purpose of picking it, the stumps drop into their corresponding notches, and at the same time the lever closes the keyhole.

NEWTON'S LOCK, invented by L. M. Eiler, of Copenhagen, Patent dated October 3rd, 1854.

The object of this invention of improvements in the construction of locks, is to dispense with the use of a key and consequently obviate the necessity of having any keyhole, or other opening,

whereby access may be obtained to the interior of the lock with any instrument whatever.

Instead of employing a key or other analogous instrument provided with wards, pins, or other equivalent contrivances for bringing the several internal and moveable parts of the lock into their proper position for shooting the bolt back for opening the lock; this object is effected by means of the power of a magnet. The foundation-plate of the lock must of course be made of some metal, such as brass or copper, which is not capable of affecting or being affected by the magnetic influence of a permanent or other magnet.

On the inner side of this plate are made a series of grooves or channels, arranged and combined in any arbitrary manner. In these grooves or channels are made to work a series of iron or steel slides, which must be capable of moving within the grooves, and should be so arranged that they cannot be moved except in a given and prearranged order and succession.

When the bolt of the lock is shot forward, one of these slides or pieces is brought up behind it in such a position that it cannot be moved back until the slide has been first removed, and this cannot be done until all the other moveable pieces are brought in succession into their proper positions.

These moveable pieces or slides must be moved by the power of a magnet applied at the back of the copper or brass plate, and which will be sufficiently powerful to attract and move the small slides inside when it is applied immediately above them. As three, four, or any number of these small pieces or slides may be combined and arranged in any preconceived manner, it follows that unless a person wishing to open the lock knows precisely the position, arrangement, and combination of the parts, he cannot bring these parts into their proper places, and consequently will not be able to open the lock.

The proprietor must provide himself with a plan, showing the position of the pieces, and with this before him he will have no difficulty, by the aid of a powerful magnet, to draw back the slides in their proper order, so as to leave the bolt free to move back.

In locks where a trifling additional expense is not an object, and great security is required, this may be obtained by the application of one or more permutation-plates, whereby the

combination or arrangement of the internal parts may be changed at any time with facility. Several bolts may be adapted to the lock, if required, and these may be so arranged that they must be moved in some prearranged order. For instance, they may be marked letters to form a particular word, and unless moved in their proper order the lock will not open.

WENHAMS LETTER LOCK, invented 1854

This is an improved letter lock constructed on a new detached principle, and is the invention of Mr. F. H. Wenham, of Effra Vale Lodge, Brixton, Surrey. It can only be picked by ringing the changes.

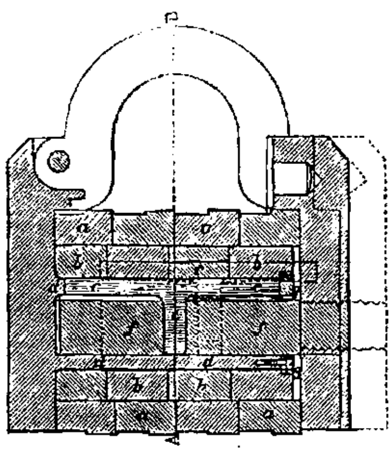


Figure 278--Wenham's Letter lock.

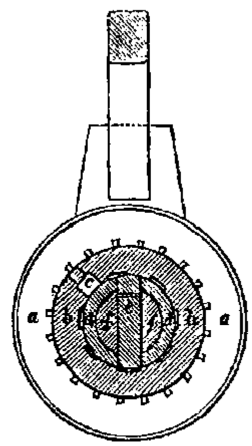


Figure 279.—Section at A 11.

In the following drawings the same letters of reference apply to each of the figures: **a a**, figures 278, 279 and 280, are letter-rings; **b b** under or stud-rings, having one deep notch shown at **c c**, and several very shallow false notches seen in the transverse section, figure 279. **d d**, is the central tube upon which the rings turn. This is cut through on one side with a longitudinal groove to admit the T piece **e e**. The stem of this slides in a hole at right angles in the draw-bolt **f f** and is forced upwards by two springs or elastic strips, cut from its own material, as seen on its under side.

When the T-piece is down in its groove, it abuts against the collar **g**, and holds the bolt back in its place; but when the deep notches (indicated by the selected letters on the outer shifting rings) are brought in a line over the T-piece, it springs up so that its end can pass above the edge of the collar **g**, and allow the bolt to be drawn.

If a force is put upon the bolt, it is *impossible* to open the lock, even if the right letters are hit upon, for the T-piece in this case becomes jammed against the collar and held as if in a vice, and consequently cannot rise unless the pressure is removed.

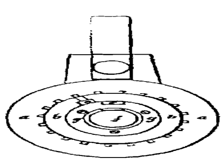
It is therefore evident that in opening this lock, no attempt must be made to draw the bolt *before* the proper letters are placed in a line, thus at once removing all possibility of picking by what is known as the "pressure principle."

So long as a pressure is maintained upon the bolt it remains *absolutely impregnable,* as even the proper letters will not be available; and as the usual method of picking by feeling cannot be brought into operation, the only chance is to attempt to work through the permutations, which no one conversant with the subject would think of doing.

The use of the shallow false notches in the stud-rings is to prevent the possibility of opening the lock by hearing, for if the stud-rings had but only one or two notches, the cessation of sound (caused by the slight friction of the T-piece) when it arrived at the gap or notch, might indicate the proper letters; but the interruption of sound caused by the shallow notches quite remedies this objection.

Figure 281 represents the center stud-ring. This has its notch cut away in an inclined direction, as shown; this is for the purpose of forcing the T-piece down again into its groove when the lock is to be closed, by means of the inclined plane being carried round by turning the ring. If all the notches were square, the rings could not be made to turn when the T-piece was up and the lock could not be shut.

This lock was exhibited at the Society of Arts in 1854, and obtained for its inventor the Society's bronze medal.



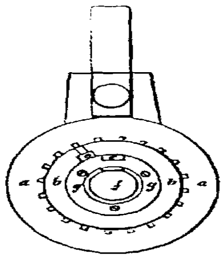


Figure 280.—End View, with the cap unscrewed from the bolt and removed.

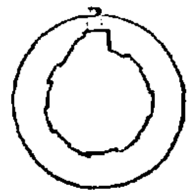


Figure 281.Centre-Stud Ring.

WOLVERSON s LOCK invented about 1854.

The peculiarity in the construction of this lock consists in the delicate poising of the detector, by which it is rendered very susceptible of motion. Also the curves of the steps of the key-bit are made irregularly, some almost flat, others elliptical. There are also two sets of levers; the key when turned round in the lock touches the first set, which gives motion to the second or compound levers, until they reach the point of unlocking, but they do not then stand in the same *relative position* as at starting, a certain distance having been gained by some, in consequence of the irregularity of the curves.

In restoring the detector to its place, the levers assume a new form or motion, and are at a different elevation from that required to unlock; hence all information gained after the detector has been thrown, which would probably take place at the first touch, would be of no use whatsoever.

The delicate poising of the detector and the compounding of the levers in this lock is identical with Aubin's compound-lever lock, invented in 1851, and described earlier.

BELLFORD'S LOCK:, Patent dated April 25, 1855.

This lock is for sliding doors; the peculiarity of the construction consists in combining a catch with a sliding bolt. The inventor, in his specification, states that the casing of the lock may be of rectangular form, in which there is a sliding bolt working on a stump, the said stump passing through a slot in the bolt. Between the bolt and the casing there is a guard-tumbler; one end of this tumbler works on the said stump, and the opposite end is provided with a projection, against the back side of which a pin on the bolt catches when the bolt is thrown forward.

There are two springs fixed on the casing, one of which acts upon

the bolt and the other upon the guard-tumbler. Just below the bolt there is a catch, the inner end of which works on a pivot; the outer end passes through a slot or opening in the side of the casing, the said slot being sufficiently long to allow the outer end of the sliding bolt to pass through. To one side of the framing of the door there is secured a slotted bar, and a mortise is made in the framing over which the bar is secured, the lower edge of the slot in the bar being some distance above the lower edge of the mortise.

When the door is closed, the lower or inclined edge at the outer end of the catch strikes against the lower edge of the slot in the bar, and the catch passes through the slot, and is forced down over the lower edge of the said slot by the spring, which acts upon both the bolt and catch.

The key is then inserted in the keyhole and turned, and the guard-tumbler is first raised, so that the projection will be raised from the pin attached to the bolt; the key then throws the outer end of the bolt through the slot in the bar, and the catch is thereby prevented from being raised until the bar is thrown back. The catch is operated upon by a knob in the usual manner.

HENDERSON'S LOCK, Patent dated May 11th, 1855

This invention relates to a peculiar construction and arrangement of certain parts of locks, whereby they are rendered less liable to be opened with a pick or false key. The improvements consist in adapting to the outside of the face-plate a species of auxiliary lock, which requires to be first opened before the keyhole of the main lock can be entered by the key.

This auxiliary lock is composed of a number of concentric wards and concentric split rings, which work around the pipe of the lock in the spaces between the concentric wards. The whole is covered by a shield and outside casing, so that when the key is out, the keyhole is perfectly closed. An additional ward is fitted inside the main lock round the pipe, a sufficient amount of space only being allowed between the outside of the pipe and the inside of the ward equal to the thickness of the metal of the pipe of the key.

In opening this lock by the proper key, the key is first inserted into the auxiliary lock in a reversed position to that which it must assume before it can enter the main lock, the keyhole of which is suitably situated, and entirely concealed by the

concentric rings before mentioned. The splits in each of these rings are all brought around to correspond to the main keyhole by turning the key, whereupon the key is at liberty to enter the main lock, and having entered therein all the concentric rings will be held fixed by a suitable catch until the key is withdrawn again, whereupon on the key coming in contact with the holding-catch, the rings will be released again, and free to turn round with the key before its withdrawal from the auxiliary lock.

The internal concentric ward serves to prevent the possibility of acting upon the main-bolt for the purpose of shooting it whilst the tumblers are held up to the required elevation by other implements.

TUCKER'S HOLDFAST LOCK, Patent dated May 21st, 1855.

This lock was designed by the inventor for the purpose of providing a lock that should offer the same security against picking and fraudulent tampering as the "safe-guard" lock, described earlier, while it should at the same time be more simply and cheaply constructed. The same principle of security is adhered to in this lock also, the ordinary revolving-barrel and curtain being so applied as to prevent the bolt-stump being brought into contact with the slides until the key itself has passed beyond them.

The manner in which this is effected is simply by causing the upper part of the stump or some other pin or projection in the bolt to bear upon the circumference of the curtain in such a way that the stump cannot reach the security-slides until the key (the bit of which is confined in the barrel) is carried so far around as to leave the slides behind it, by which time and not until then, an opening in the curtain presents itself opposite to the stump and allows it to come in contact with the slides, when, if the real key has been used, it will pass into their gatings and the bolt can be upshot.

If, however, a wrong key or false instrument is used, the stump will stop against the slides and "pressure" be produced; but as during the time of such pressure the instrument is carried beyond the slides, and cannot be brought again into contact with them without first driving away the stump and relieving the pressure, it is clear that the tentative process of picking can have no effect upon them. The curtain in this lock serves also to throw the bolt and to force the slides into their correct positions in locking. The slides **b**, figure 282, are horizontal flat pieces of

metal, made to surround the drill-pin entirely, the openings, **c** in them for the revolution of the key being so small as to admit but a very small quantity of gunpowder, by which means in conjunction with spaces in the rim of the cap for its escape on explosion, the lock is rendered powder-proof.

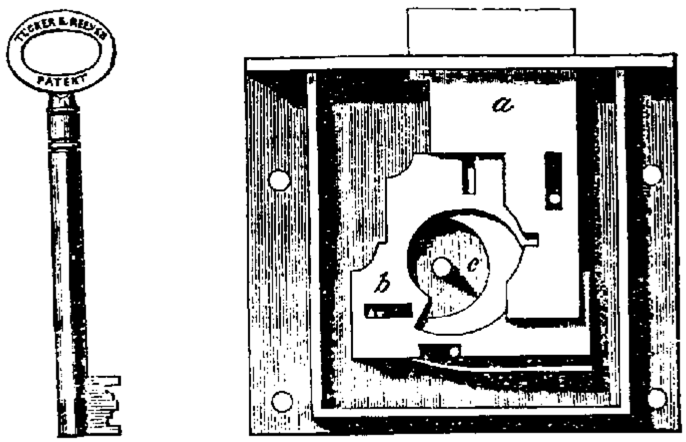


Figure 282--Tucker s Holdfast Lock, with the cap and curtain removed. The Key represents the kind used for iron safe door locks.

The inventor modifies his modes of using the curtain to prevent pressure for various descriptions of locks and latches; for instance, in trunk, portfolio, book-edge, and padlocks, and in all kinds of spring locks and latches, he attaches the stump to the curtain, and causes it to revolve with it, the key being in such cases carried considerably past the action parts of the slides before the stump has traveled far enough to reach their gating-edges. The stump is also in all these kinds of locks made to restore the slides into their proper positions before the key can be removed from the lock.

He also claims a peculiar mode of locking the shackles of padlocks, by which they are rendered much stronger than in the ordinary way. It consists in forming the shackle with a continuation, or tail beyond the joint, such tail being carried into the body of the lock, and in causing the locking of such shackle to be effected at the inner or tail end of it, in place of locking it at the outer or spoon end, as is customary, by which means the usual weakening locking-slot in the spoon end of the shackle is entirely done away with. The curtain itself also forms the bolt in the padlocks under this patent, which still further simplifies the work and lessens the cost of production.

NETTLEFOLD S LOCK, Patent dated June 9th, 1855.

The principal feature in this lock, which is the invention of Mr. Aubin, consists in simplifying the general construction, and by making the levers answer the double purpose of spring and lever. This latter object is effected by making the lever *figure 283 and* ***c****,* figure 284 with its spring, out of one and the same piece of hard metal. The stump, which is usually fixed in the bolt in other locks, in this is fixed into the bottom lever **b**, and this lever when end pressure is applied to the bolt **a**, for the purpose of picking the lock, rises in an *inclined slot,* cut in the lever or in the bolt, as the maker may choose. A hook on the end of this bottom lever grasps a stump fixed in the lock-case.

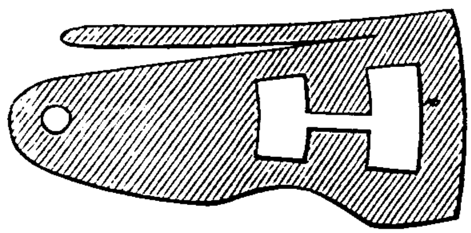


Figure 283. Nettlefold's Lever.

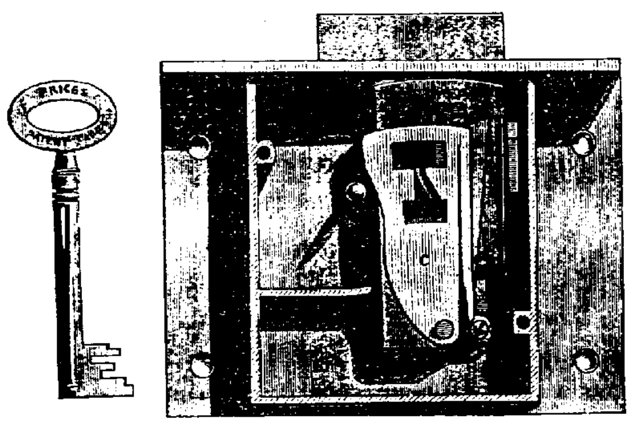


Figure 284--Nettlefold s Lock.

When the bolt is released from pressure, the lever being self-adjusting it regulates itself. The construction of the lock allows the internal parts to be made very strong; and as it cannot be picked by pressure, the security it affords is undoubted. It car, be made into a change or permutating lock at a small additional cost. Another way of constructing it is with an expanding stump, or a stump in two parts, so that when end

pressure is applied to the bolt, the stump opens or expands, and becomes too wide to pass the gating of the levers.

Another improvement consists in constructing the lock with an expanding key chamber, which entirely closes up the keyhole when the key is out of the lock, thus preserving the interior from dust. It makes it also powder-proof.

The great evil in all lever locks hitherto invented has been the tendency of the levers and springs to separate from each other, or the prong of the spring working on to different levers as soon as the lock receives a slight jar. The springs in other locks are made of thin steel; and if from any cause a small speck of rust is produced on any one of them, it is rendered very liable to break, especially in frosty weather. These steel springs, even in the workman's hands, are difficult to keep in their true position, each spring to its own lever, and chamfering the springs and the levers is too often resorted to in order to make them work better, but which in reality renders the lock still more liable to get out of order when fixed.

Mr. Aubin's simple but meritorious lock may be considered to comprise but three moveable pieces or limbs, namely, the key, the bolt, and the bottom lever. False notches, serrated stumps, curtains, deep wheels or wards, and all such like contrivances are altogether unnecessary in this lock, **and where such exist it is an evidence of doubt** as to the real security of the lock on the part of the particular inventors.

Aubin's **pianoforte** lock, constructed on the same principle as the former, is the simplest flush-lock of any yet invented. It requires only one limb to work the bolt, ***a a,*** (figure 285) and is locked and unlocked by an inclined slot working on a pin fixed in the bolt, and which thus forms bolt, lever, and spring made out of one and the same piece of metal. This lock, when fixed on a pianoforte, is perfectly free from any noise or jar incidental to some other locks caused by the vibration of their several parts.

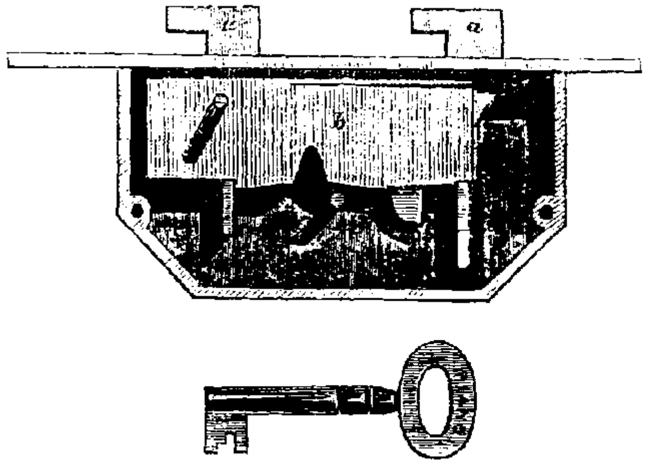


Figure 285. Nettlefold's Flush-bolt Lock.

The claims set forth in the specification are:

First: The moving of the bolt by means of a diagonal slot, or two inclined planes in a sliding-plate acting upon a stud or studs in the bolt.

Secondly: The application to locks of an oscillating-tumbler for moving the bolt.

Thirdly: The forming the levers and their springs in one and the same piece of metal.

Fourthly: The application to locks of an expanding stump.

Fifthly: The application to the bolts of locks of a hanging-plate, carrying a stump, and also a stud which enters an inclined notch in the bolt, so that when end-pressure is applied to the bolt, the inclined face of the notch acting upon the stud throws up the hanging-plate, and prevents the stump from entering the notch in the lever.

Sixthly: The application to locks of two discs carrying two stumps acting upon the bolt, so as to prevent the stump on one of the discs from entering the notch in the lever when end pressure is applied to the bolt.

Seventhly: The application of a sliding-shield operating to prevent access to the levers by means of false keys.

Eighthly: The application to locks of two swinging-pieces,

forming an expanding-chamber.

SCULLY and HEYWOOD'S LOCK, Patent dated July 15th, 1855.

This invention relates to the application to locks and latches of a novel construction of guard for protecting the internal mechanism of the lock or latch from being tampered with, for the purpose of throwing the bolt or lifting the latch. In place of the ordinary keyhole a cylindrical-chamber is formed, through which the key is inserted, and in this chamber is placed and secured a swivel-pin, which is provided with a helical rib or feather, or other lateral projection, which will offer an obstacle to the insertion of a key other than that of a given construction.

BUTLER'S DIAL LOCK, Patent dated August 13th, 1855.

This invention consists in affixing a number of stumps to the bolt of a lock, which stumps bear against circular pieces of metal revolving on centers connected with the upper plate of the lock; these circular pieces form stops against which the stumps bear. In the revolving stops are found grooves, through which the stumps pass when the bolt is shot in or out. Thus it will be seen that the bolt cannot be moved until each of the stops is arranged with its groove opposite to the stump on the bolt which is to pass through it.

The stops may be turned by hand from the exterior of the lock, but the patentee prefers so to arrange them that they can only be turned by a key introduced through keyholes arranged round the main keyhole on the face of the lock. On the front plate of the lock are arranged hooks, which catch into the bolt, so that the plate of the lock can only be removed when the bolt is half shot, or in some other previously arranged position.

NEWTON'S LOCK, Patent dated November 14th, 1855.

The first part of this invention consists of a method of impressing the form of the key upon inert tumblers, which are then removed from reach or influence through the keyhole before they reach the fence, which permits them, if properly arranged, to be moved far enough to permit the bolt to be thrown, but which cheeks them if not perfectly arranged. This part of the invention also consists in restoring or bringing back the tumblers to their original relative position as they are brought back within reach of the key, so that they can in no manner indicate what key has

been used.

The invention also consists in so cutting the edges of that portion of the key-tumblers on which the key acts as to prevent the long bits of the key from marking their length upon the tumblers, and thereby avoiding all chance of taking an impression of them. And this part of the invention also consists in the employment of a wiper, to pass over the surface of the tumblers which have been acted on by the short bits of the key to remove any print or tract which might have been left by the short bits in acting upon them, and thereby avoiding all chance of taking an impression of any of the bits of the key.

FENTON'S LOCK, Patent dated January 21st, 1856.

The inventor constructs a mortise lock, in which one bolt is made to serve all the purposes of the three bolts in the ordinary mortise lock. The bolt is pressed forward by a double, or elliptical, or curved spring or springs, and is drawn back by turning a spindle with a knob at each side of the door, like the first bolt of the ordinary lock above mentioned.

The lower part of the bolt is for being acted upon by the key, so that the bolt may be shot farther, and for locking the door. The bolt is kept out by a tumbler, which drops into a notch in the bolt. The bolt has another long notch, in which the stud of the tumbler lies when the bolt is unlocked. The bolt is secured from one side of the door without using the key, by means of a piece of metal or lever, moved by a spindle and knob, and locking into a notch, or behind a projection on the bolt; thus paralyzing the bolt, and answering the same purpose as the third bolt in the ordinary lock above mentioned.

TUCKER S SAFETY LOCK, Patent dated June 13th, 1856.

In all the previously patented locks of this inventor it will have been observed that no tumblers or levers acted on by springs have been used, except in the locks under the present patent he has availed himself of the ordinary levers used by other makers, and has simply endeavored so to modify the construction as to render such locks secure against picking by pressure, without diminishing their strength or materially increasing their cost.

The manner in which such security against picking by pressure is effected in the present lock is as follows: Proceeding upon his characteristic idea, "that the reason ordinary lever locks can be

picked is, that communication with the levers can be obtained while the tumbler-stump is in contact with them," he has here introduced what he terms a "tumbler-guard," so constructed and disposed as to *stand* between the tumbler-stump and the *gating faces* of the levers when the bolt is locked out, and which tumbler-guard must first pass into the gatings of the levers before the tumbler-stump can reach them.

By this means the tumbler stump can *never be made to touch the levers until the whole of them have been correctly adjusted for its passage through their gatings.* The tumbler-guard is a horizontal plate, with a return or vertical projection rising from it; this plate runs upon guide or *lanket* pins fixed in the plate of the lock, and is in no way pivoted or attached to the bolt, and it is its vertical projection which stands between the levers and the tumbler stump, (which latter is riveted to the bolt in the ordinary; way).

The action of the guard is such, that when pressure is applied to the bolt, the vertical projection is brought against the faces of the levers, and a slot in the horizontal plate is made to fasten itself to a guide pin in the plate; its backward action being thus retarded, the tumbler-stump then reaches the horizontal plate, which is thus made to sustain the pressure of the tumbler-stump and prevent it from being brought into contact with the levers, so as to enable the gatings to be felt.

By this arrangement, and by the use of a guard to the levers, all the advantages afforded by a *loose or moveable stump* are obtained, without in any way impairing the strength and durability of the lock; on the contrary, the resistance to violence afforded by this lock is considerably greater than in an ordinary lever lock, as the pressure of the tumbler-stump against the tumbler-guard must *always* be at the *base* of the stump, *altogether irrespective of the particular levers* which may be incorrectly arranged, whereas in locks made with a loose tumbler-stump, the resistance afforded against violence is materially less than in an ordinary lever lock.

It is this specific purpose of affording security against picking by pressure without detraction from the strength of the lock which has caused the production of this lock, and such purpose is expressly specified by him in his specification. Other contrivances are specified under the same patent, but not being yet commercially introduced, no description of them can be given here.

In reviewing the various *modern locks* which we have now described, our readers will doubtless be tempted to put the question: Are there any amongst them combining the true principles upon which locks should be constructed, viz., perfect security, strength, simplicity, and durability; or possessing the qualities enumerated by Mr. Chubb in his paper before referred to, namely:

First: Perfect security is the principal point to be attended to, as without it no lock can be considered as answering the intended purposes.

Second: The works of a lock should in all cases possess strength, and be well adapted, especially in the larger ones, to resist all attempts to force them open; and both in the larger and the smaller kinds, the works should not be susceptible of injury or derangement from attempts with pick or false keys.

Third: Simplicity of action is requisite, so that any person having the key, and being unacquainted with the mechanism of the lock, should not be able to put it out of order.

Fourth: The workmanship, materials, and interior arrangement of a lock should be so combined as to insure the permanent and perfect action of all its parts, and its durability under all ordinary circumstances.

To this question we answer, **Yes**. There are some possessing all the latter qualities, whilst there are others not only combining all these excellencies, but which would successfully compete for another medal and premium if the Society of Arts were again to offer such a reward "for the invention of a good and cheap lock, combining strength and great security from fraudulent attempts; cheapness, freedom from disarrangement by dirt, and requiring only a small key."

To name them here would be invidious; but we believe our description of them cannot fail to point out those we refer to. The *real* improvements introduced into the construction of locks since 1851 are certainly not numerous, but they are effective and to the purpose; and if inventors and lock manufacturers will only keep in view the principle upon which all machines should be constructed, namely, simplicity, we do not despair of seeing at no distant time a lock possessing all the before-named qualities, and of such a simple character, that it shall be minus those

bugbears in every lock, and the most troublesome limbs to all locksmiths—viz., SPRINGS.

CHAPTER SEVENTEEN: The Lock Controversy since the Closing of the Great Exhibition

In resuming the lock controversy, we shall continue it in the same chronological order, and shall reserve our remarks on the subject generally till the close of the chapter.

After Mr. Hobbs had succeeded in picking the Chubb and Bramah locks, it was natural for the English locksmiths to desire to pick the American locks, and several attempts to pick the Parautoptic Bank Lock were accordingly made. A challenge was affixed to one of these latter locks in the Great Exhibition, offering a reward of two hundred pounds to any one who succeeded in picking it. Mr. Garbutt, an engineer, accepted the challenge, and on September 10th, 1981, Mr. A.H. Renton, Mr. E.H. Thomson, and Mr. W.F. Shuttock were appointed arbitrators to superintend the arrangements.

These gentlemen met Mr. Garbutt at the house, No. 20, Knightsbridge, when the following conditions were agreed to:

-"That a Newell lock should be selected, and should be screwed to a wooden box; that Mr. Garbutt should have access only to the keyhole of the lock, through which keyhole all his operations for picking the lock should be conducted; that Mr. Garbutt should have uninterrupted and exclusive access to the box between the hours of nine in the morning and nine in the evening, for thirty days, beginning on the 11th of September, he having during that time the privilege of introducing one associate, and the arbitrators reserving to themselves the right of inspecting the seals placed by them on the box; that in order to afford every information concerning the internal arrangement of the lock, the trial lock should be taken to pieces in the presence of all the parties; that it should be examined by Mr. Garbutt; that it should be locked and unlocked with the proper key by him and Mr. Hobbs; that it should be fastened to a box and the fastenings sealed by the arbitrators; that the key, when the lock was

finally locked, should be sealed up by the arbitrators and delivered to Mr. Hobbs, who would retain it until required by the arbitrators to hand it over to them. That at the expiration of the thirty days, or earlier in case either of the success or the abandonment of the attempt, the arbitrators should examine the lock. And, finally, that if Mr. Garbutt should have succeeded in picking the lock (that is, in withdrawing the bolt without injuring the lock), the sum of £200 should be paid to him by Mr. Hobbs."

In accordance with the above agreement, Mr. Hobbs produced a parautoptic lock with ten levers, No. 8560, which with the key were examined by Mr. Garbutt. The lock was afterwards fixed to a box and sealed. Mr. Hobbs then set the ten bits of the key, corresponding to the ten levers, to an arrangement chose by himself; the lock was then locked and unlocked by all parties in succession, and the key, after the final locking, was sealed up and give to Mr. Hobbs, who at the same time delivered to Mr. Garbutt a similar but smaller lock, which he was to be allowed to retain during the whole period of the trial. This was intended to make him familiar with the construction of the lock to be operated upon.

The prescribed period having expired on the 11th of October, the arbitrators met at the before-mentioned house, when Mr. Garbutt delivered up to them the lock in its locked condition and perfectly uninjured. The arbitrators then gave the following award:

-"We therefore hereby certify that Mr. Garbutt, having had uninterrupted and exclusive access to the lock during the period of thirty days, and availing himself of the conditions of the agreement, had every facility for opening the lock that could be obtained without possession of the true key, has delivered up the same into our hands unopened and uninjured; and the said lock has been delivered by us to Mr. Hobbs."

This brings us to the year 1852, when another attempt was made to pick the parautoptic lock. The following account of it is taken from the Observer of that period: -

'Hobbs' American Lock Again

"It will be remembered that, in The Observer of the 28th of March, a challenge appeared from Jeremiah Smith, offering to pick Hobbs' celebrated lock, an opportunity of attempting which he

complained had not been afforded him at the Great Exhibition. On the 11th of April we published a reply from Mr. Hobbs, in which he expressed his readiness to afford Mr. Smith every facility for making the attempt, and appointed a certain hour at his warehouse in Cheapside, on the 14th of April, to make the necessary arrangements. Mr. Hobbs proposed the appointment of three arbitrators to decide the time, place, and terms for the trial to be made, and named, as two of them, Mr. Hensman, engineer to the Bank of England, and Mr. J. G. Apphold, of Finsbury Square, requesting Mr. Smith, the challenger, to name a third party to be present and to act with them. Mr. Smith attended the meeting, but brought no friend with him to act as the third arbitrator, stating that he did not understand from the terms of the challenge that he was to bring anybody.

The Exhibition Lock, which excited so much wonder and admiration at the Crystal Palace, was then produced, and in the presence of Messrs. Hensman and Apphold, Mr. Smith was asked if he would undertake to pick the lock? He replied in the affirmative, but would prefer having one that was fixed upon a door in the ordinary way. It was observed that these were not the terms of the challenge, and it was shown further that this was impossible, as there were only one or two public offices in which the locks had yet been fixed, and that there would be both inconvenience and objection in such a course. The Exhibition Lock is one of the largest size, and contains no less than fifteen bits, or tumblers, being susceptible of we cannot venture to say how many thousands of millions of changes, and is altogether so formidable and complicated-looking a piece of mechanism, that we are not much surprised at the challenger, on a little reflection, hesitating about undertaking the task.

He observed that he did not want to attempt a test lock, which had been produced for the purposes of the Exhibition, but would have no objection to undertake an ordinary commercial lock, and Mr. Hobbs accordingly produced one of the Commercial Bank locks, containing ten tumblers, stating that although the terms of the challenge were that a sum of £200 would be paid to any person would pick the “Exhibition Lock,” he would substitute the smaller and less complicated one, to meet Mr. Smith’s views, and put the matter out of dispute. It being found very difficult to bring Mr. Smith to any decisive terms, a suggestion was made for a subsequent meeting, when Mr. Smith was to come prepared with a friend to enter into the necessary arrangements.

On Tuesday last, a friend of Mr. Hobbs called upon Mr. Smith

appointing the following day (Wednesday), at three o'clock, at the offices in Cheapside, and Mr. Smith undertook to be there with a friend. Mr. Hobbs was in attendance with the two arbitrators, Messrs. Hensman and Apphold, and remained in waiting from three till a quarter past four o'clock, but Mr. Smith did not appear, nor any friend on his behalf, nor was any letter or message sent to explain the cause of his absence.

Under all the circumstances we cannot come to any other conclusion than that Mr. Smith has thought better of his challenge, and has, by withdrawing form the ordeal, given a tacit admission of the invulnerability of the American lock. As The Observer was the means in the first instance of giving circulation to the report that one of these locks had been picked, which, on subsequent inquiry, turned out not to be the case, the feat having been achieved by making a facsimile key from the original, and going through the 720 permutations of a six-bit lock til the right combination was hit upon, we have thought it but fair to Mr. Hobbs to give this narrative of the circumstances connected with Mr. Smith's rather confident challenge and its inconclusive termination.

Mr. Hobbs has, in every instance in which any person came forward to attempt to pick his lock, acted with the greatest fairness and liberality, and has at the present moment no less than seven of his locks in the hands of adventurous experimenters who wish to make themselves acquainted with the principle before attempting a task the successful accomplishment of which would be attended with so much glory and so much pecuniary advantage. The lock, however, has up the present time remained invulnerable; and although we do not hesitate to say that we should feel extremely proud if any ingenious mechanic of this country could be found to turn Brother Jonathan's flank and establish our mechanical and scientific superiority in this particular, we are bound to say that hitherto the American lock has maintained the reputation its proprietors claim for it as one of the most perfect combinations for security yet invented."

About this time Mr. Hobbs read a paper before the Society of Arts on locks and keys, when a discussion arose, in which it was stated that the parautoptic lock had been picked in London, the truth of which statement Mr. Hobbs thought it was his duty to deny. It appears the report was published in the Observer, and many of the other London journals, which called forth from Mr. Hobbs a letter, dated April 2nd, 1852, addressed to the editor of the above paper, and containing the following paragraph:

–"Early last autumn I lent to Mr. Potter, of South Molton Street, one of my locks, for the purpose of giving him an opportunity to make himself acquainted with its principle and construction. After he had had the lock in his possession several weeks, a report reached me that one of Mr. Potter's workmen had picked my lock. I immediately called on Mr. Potter to ascertain the fact. Mr. Potter informed me that for the purpose of testing the possibility of opening the lock by means of an impression taken, or a copy being made of the true key, Mr. Smith had made a copy of the key by means of a transfer instrument, which instrument he showed me at the time. After the key was made, it was tried, and found to lock and unlock the locks as readily as the original key. Mr. Potter then sealed the screws of the lock, and with the key that he had made by copying the original, hit the combination and unlocked it. The lock was of the smallest size, having but six levers; the number of changes that could possibly be made were 720. The time occupied by Mr. Smith, according to his own statement, was six hours and fifty-five minutes; this, allowing one minute for each change, would give him time to have made 415 out of the 720 changes before hitting the right one. I asked Mr. Smith why he did not use the original key instead of making a copy? His answer was, that 'he could change the one he made faster, as he did not have to screw the bits in.' Any person will readily understand the difference between **ringing the combination(536)** of a key and picking a lock.."

This lock was evidently opened by ringing the changes; but this was certainly not picking it. We have before alluded to the difference between picking a lock by instruments and opening it by ringing the changes with a permutating key, and we shall further explain and illustrate this important difference in the chapter on keys.

We now come to the unfortunate affair of the Society of Arts in connection with this subject. It had been customary with the Society from its first establishment to offer premiums for various inventions, and not unfrequently for a lock, and on the 1st of November, 1852, the Society offered a premium "For the invention of a good and cheap lock, combining strength and great security from fraudulent attempts; cheapness, freedom from disarrangement by dirt, and requiring only a small key."

Various locks were sent to the Society for competition for the premium, and the committee, of which Mr. Chubb was the chairman, gave their award in favour of the lock invented and exhibited by

Mr. Saxby, who received the Society's medal and a bounty of ten guineas. This lock (which from the description of it, contained nothing new either in principle or construction) Mr. Hobbs picked "in the presence of parties connected with the Society, in the short space of three minutes."

This circumstances led to much newspaper correspondence, and the committee were so much censured for their want of discrimination and judgment in choosing that lock which was so soon and so easily proved not to possess any qualities justly entitling its fabricator to the honour of receiving the Society's medal and the premium of ten guineas.

The question raised by the Society's award will be best understood from the following letters before referred to. The first was from Mr. Hobbs, and appeared in the Journal of the Society of Arts, June 25th, 1853, and is as follows:-

"Sir, – As the recognition of merit, and the encouragement of improved manufactures and inventions by a body like the Society of Arts is a matter which ought to be as far removed from suspicion of any gross error as the fallibility of human judgment will admit, it will not be considered intrusive, perhaps, if I submit the following cases to your judgment:--

"On the 1st of November, 1852, the Society issued their usual circular containing an offer of premiums for various articles, and amongst others (No. 83), 'For the invention of a good and cheap lock, combining strength and great security from fraudulent attempts; cheapness, freedom from disarrangement by dirt, and requiring only a small key.'

"Being engaged in the manufacture of locks I considered the subject with some attention, but perceiving that the conditions were not perfectly consistent with each other, I gave up all hopes of obtaining the prize, and looked forward with more curiosity than anxiety for the new productions of lockmaking ingenuity that might be called forth by the liberal offer of the Society of Arts. At length your journal of the 11th instant informed me that the medal of the Society, and a premium of £10 had been awarded to Mr. Saxby, of Sheerness, for a lock that answered all the requisitions.

On calling at the society's rooms to inspect this piece of mechanism, I was surprised to discover that it was constructed

precisely the same principle as the 'Yale Lock,' described in a paper read before the society in January, 1852, and of the same construction as locks manufactured and sold by Mr. Cotterill, of Birmingham; in short, that it had no claim whatsoever to be regarded as a new invention by the committee of the Society, however honestly it might have been submitted as one by the maker. The want originality in the lock, supposing that it answered all the conditions named in the circular, might have been passed over as a venial offense. This unhappily was not the case. That the essential requisite of security –'great security,' as it is expressed in the circular, did not belong to it, was proved by a very simple experiment. To be brief, I picked this prize lock in the presence of parties connected with the Society, in the short space of three minutes!

"I do not mean to insinuate that there is any general carelessness in the selection of parties to determine the merits of competitors, or in their competency to form an opinion upon the worth and utility of the articles submitted to them. It is simply with the committee on locks, and with this particular case, that I have to deal; and it must be self-evident from the above statement tat they have betrayed their incapacity in the most flagrant manner. The case is still more surprising when I observe that Mr. Chubb, of St. Paul's Churchyard, was a member of the committee by which this award was made. This singular fact exonerates the Society indeed from which a gentleman of Mr. Chubb's repute, as a mechanic in that particular branch of art, was a member, should be implicitly trusted.

"Respectfully yours,

"A. C. HOBBS.
"79, Cheapside, June 21st, 1983"

The above letter attracted the notice of the editor of the Bank's Circular, in which the following notice appeared on July 2nd, and was copied into the Times of the 7th;--

"Mr. Hobbs and the English Locksmiths.

"It is now pretty generally known that until the year of the Great Exhibition nobody had succeeded in obtaining the '200 guineas' offered by Messrs. Bramah to any person who could pick their celebrated lock. This piece of mechanical ingenuity was at last performed by Mr. Hobbs, from America, who was not a

lockmaker, but a lockpicker. Since then the art of picking locks has become somewhat elevated, and has attracted the attention of several of our first-rate engineers.

"The Society of Arts in John Street, Adelphi, desirous of promoting the skill of English locksmiths, issued a circular last year for premiums on various articles of manufacture, amongst which was one 'for the invention of a good lock, combining strength and great security from fraudulent attempts, cheapness, freedom from disarrangement by dirt, and requiring only a small key.'

"The condition upon which the prize of £10 was to be awarded seemed to be somewhat inconsistent with the object required; but nevertheless the offer commanded attention, and the successful competitor was Mr. Saxby, of Sheerness; and to him the prize was awarded by the committee, the chairman being Mr. Chubb, the lockmaker in St. Paul's Churchyard.

"By a letter from Mr. Hobbs, which appeared in the Journal of the Society of Arts of the 24th of June, we find that Mr. Hobbs' curiosity, which was only equaled by his modestly in not competing for the prize, induced him to inspect this piece of mechanism which the committee, presided over by Mr. Chubb, had pronounced to be the one most in accordance with the prescribed rules of the society; when, so far from its possessing that 'great security' required, he discovered that it ws constructed on the principle of the 'Yale lock,' such as are manufactured by Mr. Cotterill, of Birmingham; and to prove to the parties present that is possessed no 'security,' Mr. Hobbs, taking a small straight iron wire from his pocket, and a thin strip of steel, opened it in the presence of several members of the society in three minutes!

"Without offering anything of a personal insult to Mr. Chubb, it is impossible not to question the accuracy of his judgment on this branch of mechanical art. There can be no doubt that the first requisite in a lock is perfect security; but if the public are misled by the mistaken judgment of men who decide upon the merits of the question, it will undoubtedly throw great suspicion upon the character of public scientific institutions."

The above remarks as well as the following are worthy of special notice, as coming from independent commentators on the question involved in this controversy.

"Love (Hobbs?) laughs at locksmiths."

"In the month of November last the Society of Arts, in its praise-worthy efforts to promote mechanical and scientific ingenuity in this country, issued their usual circular, offering premiums for inventions and improvements in various departments of industry; and among the rest, one for the invention of a good and cheap lock, combining strength and great security from fraudulent attempts, cheapness, freedom from disarrangement by dirt, and requiring only a small key. Now this was, no doubt, a great desideratum; but the amount of mechanical ingenuity, and the quantity of skilled mechanical labor, which were requisite to produce a lock combining great strength and security from fraudulent attempts, were evidently inconsistent with the element of cheapness, which was also stipulated for by the society.

If appears, however, that the stimulus of honorary distinction and pecuniary reward, induced several of our mechanicians to compete; and a lock was produced by MR. Saxby, of Sheerness, which, it was alleged, answered all of the requirements of the circular. A committee was appointed to investigate the merits of the various inventions, and Mr. Chubb, of St. Paul's Churchyard, the eminent lock manufacturer, was appointed the chairman, and a report was drawn up, in which, for the reasons therein alleged, the Society's medal and a sum of £10 was awarded to Mr. Saxby for his invention. We have not had an opportunity of seeing the report, but we must presume that the committee were satisfied that the conditions of the Society's circular were complied with, otherwise, the conferring the honorary and pecuniary rewards was a mere farce, and by no means calculated to raise the character of the Society of Arts in the estimation of the public.

"It turns out, however, that the lock submitted by Mr. Saxby has no claim whatever to originality; it is constructed on precisely the same principle as the 'Yale lock,; which was described in a paper before the same society so lately as January, 1852. It is also the same in character and principle as the locks manufactured and sold by Mr. Cotterill, of Birmingham, without their security or complication. It can scarcely be supposed that a scientific body like the Society of Arts could have been ignorant of these facts; and even if they were, we cannot understand how they could have escaped the penetration and judgment of the chairman, himself a practical mechanician. We acquit Mr. Saxby of all complicity in the affair; he may have honestly and ignorantly believed that his lock was an original invention, or such an improvement and simplification of the model

as entitled him to the reward; the committee may likewise have made their adjudication in good faith, but it is certainly calculated to lessen the pubic confidence in the decisions or recommendations of the society, when we find that besides the total absence of originality, the other and more important element of security is entirely wanting.

"It appears that as soon as the announcement of the award was made public, Mr. A. C. Hobbs, the patentee of the celebrated American Lock, who obtained no inconsiderable amount of celebrity, such as it was, during the Great Exhibition, by picking the patent locks of some of the most eminent firms, and who had so little hope himself of being able to meet the contradictory requirements of the Society's circular, that he had abstained from entering the lists as a candidate, went to the Society of Arts on the 16th instant, for the purpose of examining the prize lock.

After some little difficulty of delicacy, arising probably from the unwillingness of the parties to put him out of countenance, the lock was produced and Mr. Hobbs, taking out of his picket a thin slip of steel, and a straight iron wire, picked the lock in the presence of some members of the society in three minutes! The lock was then examined by Mr. Hobbs, and found to be an exact copy of Cotterill's Birmingham lock, but of course much more indifferently constructed.

The principle of the lock, it may be stated, is the same as the patent Bramah lock, with this difference in its application: the slides in the Bramah lock are pressed onto the barrel parallel with the motion of the key, while in 'the prize lock' of Mr. Saxby, and in the Cotterill lock, the motion of the slides is from the centre to the circumference of a disc.

With instruments properly constructed, Mr. Hobbs says, 'the prize lock' might e picked in less than a minute, and we have been given to understand that it does not meet the conditions of the Society's circular, either as regards originality, cheapness, security, or non-liability to derangement from dirt. There is certainly in this statement of facts, which we believe will be found substantially correct, evident proofs of incapacity, carelessness, or favoritism on the part of the committee of the Society. The Society were, doubtless, fully justified in placing confidence in a committee so constituted, and the latter will probably be able to explain how they arrived at a decision which speaks little for their mechanical acquirements, or for their

investigation of the merits of the article submitted to them. They may be certain of this, that the indiscriminate distribution of the honours and rewards of the Society is not calculated either to stimulate the inventive genius of our artisans or to elevate their own character in public estimation."

The following anonymous[1(537)] reply to the letter of Mr. Hobbs appeared in the succeeding number of the Journal of the Society of Arts, namely, July 1st:--

"Sir, –I observe in last week's Journal a letter from Mr. Hobbs on the subject of Mr. Saxby's lock, recently rewarded by the Society, which I think needs a few words of explanation and reply, as your acute correspondent appears to be somewhat in error as to the circumstances of the case.

"The remarks of Mr. Hobbs appear to amount to this; first, that Saxby's lock is not new, the principle being the same as the Yale lock, and as Cotterill's lock; secondly, that it is not very secure, because he picked it.

"Now, unquestionably, Saxby's lock is constructed on the same general principle as Cotterill's and Yale's, and both of them in turn are derived from the Bramah; but this does not prove the locks to be the same; an did Saxby, by ever so slight a modification, produced a lock for half-a-crown as good as Cotterill's lock for ten shillings, then Saxby certainly deserved the Society's prize.

"In seeking for a 'cheap and very secure lock,' it is evident that the Society desired a good common lock, one which could be made and sold for a few shillings, and yet be much more secure than the locks commonly to be had for such a price, which in fact are too often no locks at all, being easily opened and locked again with a bit of wire or a bent nail.

"The term 'great security,' as set forth in the prize list, mean, I imagine, great security against the attempts of the idle and mischievous; but it certainly never aspired to defy the systematic ingenuity of a professional lock-picker like Mr. Hobbs. The great security of the storeroom or apple loft is not to be compared with that of the banker's safe or deed box; and a lock intended for the former, and perfectly secure against all trials to which it might be put, would no doubt be set aside as valueless for the latter.

"I think that no one expected, as the result of the Society's premium, an unpickable banker's safe lock for five shillings.

"Whether Mr. Saxby's lock is quite new in principle, or whether it is in fact merely a modification of some older lock, is not the question; neither is it important to inquire in how many minutes Mr. Hobbs picked the lock. The real point is, that Saxby's lock is much more secure than common locks are, and that it costs much less than really good locks commonly do.

"I am, Sir, yours faithfully,
"P.L.O."

Mr. Hobbs replied as follows, (Journal of the Society of Arts, July the 8th):--

"Faith! Here's an equivocator!" –Shaekspeares

"Sir, –Had your correspondent, P.L.., really afforded the 'explanation and reply' promised in his opening paragraph, I should hardly have troubled you with a rejoinder to his observations. Either I am not so 'acute' as his flattering designation would lead me to suppose, or his 'explanation' must be deficient in point and clearness; for I can neither see that it justifies the committee on locks, by whom the premium was awarded to Mr. Saxby, or that it corrects my opinion concerning the requisitions of the Society.

"Not to occupy your space unnecessarily, I will simply repeat the words of the proposal made by the Society, and submit my own understanding of them for comparison with the judgment of P.L.O. The offer was made for 'the invention of a good and cheap lock, combining strength and great security from fraudulent attempts; cheapness, freedom from derangement by dirt, and requiring only a small key.' I supposed the above to mean that a lock was to be produced either on a new principle or by the arrangement of some principle already known, which should combine, with as much strength as any lock now in the use, as great or greater security, and yet be capable of manufacture at a lower price for the various purposes of which locks are required, and should require only a small key.

If I am not mistaken in the plain import of the language, I may venture to repeat that the lock for which the committee have awarded the premium of the Society does not in the most distant

manner come up to the requisitions. Instead of its being either a new principle or a new arrangement, it is precisely the same both in principle and arrangement as the Cotterill lock, without the slightest modification; in fact, only differing from it in the inferiority of its workmanship. It is less secure than either a Bramah or tumbler lock of the same cost, and is quite liable to be deranged by dirt. It requires a key of the same size as the Bramah and other locks.

"I make no comment upon the wisdom of supposing that the Society intended to award a premium for the means of securing P.L.O.'s 'apple loft' from the pilfering propensities of his naughty boys; the words are for great security from fraudulent attempts, and they need no commentary to make them plainer.

"In conclusion, it would give me great pleasure to be afforded an opportunity of proving the correctness of my statement to the Society by a comparison of the different kinds of locks now in use. I am prepared to prove also that as good a lock cannot be produced by Mr. Saxby for half-a-crown as by Mr. Cotterill for ten shillings. In regard to 'professional lock-picking,' I will undertake to show that Mr. Saxby's lock can be easily opened and locked again, not by the application of extraordinary skill or anything so profound as 'systematic ingenuity, but by a bent nail and a bit of wire, or by a key made of a piece of pine woods; in a word, that the principle of Mr. Saxby's lock is neither secure for the 'storeroom, the apple loft, nor the banker's safe;' that it is not 'much more secure than common locks;' and that it cannot be produced at a lower price than 'really good locks.' This proposition being distinctly understood, your correspondent P.L.O. will have some difficulty in satisfying either the Society of Arts or the public that the committee on locks have not committed a very ridiculous blunder.

"Respectfully yours,
"A. C. HOBBS.
"97, Cheapside, July 5th, 19853."

In the same number were also the following letters from other correspondents:--

"Tiverton, July 2nd, 1853.

"Sir,-I should be sorry unnecessarily to trespass upon your

columns; but the fact of the lock of Mr. Saxby, for which the medal was awarded by the Council of our Society, having been proved by the successful experiment of Mr. Hobbs to be even ludicrously unsafe, renders it imperative on me, having been a competitor with Mr. Saxby for the prize, to take this public means of disabusing the minds of the many persons at present cognisant of, or who may hereafter be acquainted with, the fact of my having so competed, of an opinion they must naturally form from the premises: –That the lock considered by the committee to be the most deserving of the prize having been shown to be utterly untrustworthy, mine consequently was in all likelihood equally, or supposing such a circumstance possible, still more insecure. That such is not the case, and that in this instance the committee have in their desire to introduce a cheap lock attached too little importance to the still more requisite element of perfect security, I will (in order to vindicate the reputation of my lock from the stigma which must otherwise, in consequence of this error on the part of the committee, rest upon it) venture to demonstrate in a manner at once conclusive and unquestionable, and which, under the present circumstances, cannot I think be considered objectionable.

I submitted it to the decision and criticism of the Society in the full confidence, not only that it would prove to be a 'cheap lock,' but that it was not possible, by any amount of skill or perseverance, to succeed in picking it. In such belief I still continue; and in order to convince my friends and the public that the decision in Mr. Saxby's favour was not owing to any want of security in mine, I herewith publish my intention of placing the sum of £100 in the hands of a banker, to be handed by him over to Mr. Hobbs, should be succeed within the next three months in picking the patented lock of my construction, which was placed before your Society in competition for the prize.

On receiving notice from Mr. Hobbs, through your journal, of his intention to make the attempt, I will at once commence fixing it in a manner suitable for experiment; on the completion of which, he shall be at liberty to examine a lock constructed on the same principle, that he may acquaint himself with its peculiarities, after which I will allow him ten days in which to effect his purpose; conditioning solely, that either myself or some person appointed by me, shall, if I shall so require it, be present during the operations to prevent violence or injury to the lock. No other sufficient means being open to me but the present of removing whatever prejudice may have been created against my invention, by the erroneous decision of the lock committee, must

be my excuse for thus occupying your space.

"I am, Sir, yours respectfully,

"W.H. TUCKER."

"Sir,–I have never seen a more unfortunate attempt at getting out of a scrape, than the anonymous letter in the Journal last week written almost avowedly by some member of that sagacious committee which gave a medal and something more to the inventor of a lock, which Mr. Hobbs has shown to possess the two qualities of antiquity and good-for-nothingness in an eminent degree.

"They now pretend, at least their advocate does for them, that they understood–nay, that 'it is evident that what the Society desired was a good common lock.' If so, do they think the Society could not have said so? If so, why did the Society say something as different as possible? If it is so evident, why does P.L.O. take so much pains to explain that the expression 'great security' in the premium list just be understood to mean only as great security as you can expect for half-a-crown? The prize list said nothing about half-a-crown, and did specify 'great strength and security from fraudulent attempts,' and also from 'disarrangement by dirt,' and that the lock was only to require a small key.

"To anybody but Mr. Chubb and his committee this rather particular description must have suggested anything rather than a cheap common lock; but it did not to them–at least so they assure us now. The fraudulent attempts, we are told, could not be supposed to have any reference to bankers' safes, because you cannot expect a good bank lock for the price of a good common lock; and a common lock, we know, is the thing the Society meant to ask for. And therefore it is evident that the fraudulent attempts the Society had in view were the attempts of the 'idle and mischievous' on the 'storeroom or apple loft.'

"The freedom from 'disarrangement by dirt' required by the Society's conditions could not possibly suggest to the intelligent minds of Mr. Chubb's committee the idea of one of Mr. Chubb's locks having to be broken open on account of two of the tumblers having got stuck together, Mr. Chubb, of course, never heard of such a thing. The expression, no doubt, suggested to them only the idea of a mischievous boy stuffing dirt into the lock of the aforesaid storeroom or apple loft, by way of paying

off the owner for being so ill-natured as not to leave it open.

"'No one expected, as the result of the Society's premium, they say, 'an unpickable bank lock for five shillings.' Probably not: but there is a widish margin left between an unpickable bank lock for five shillings, and Mr. Chubb's pickable one for five pounds or thereabouts. If the committee had no lock presented to them, which (as far as they could judge) did 'possess great strength and security from fraudulent attempts, freedom from disarrangement by dirt, requiring only a small (that is, of course, alight) key, and cheap, for a lock possessing those qualities, which is the only rational meaning of the word, they had nothing to do but so to report to the Council. Or, if Mr. Chubb's committee did not chose to give any encouragement to a lock which might be likely to interfere with Mr. Chubb's locks, they might have given no premium at all with at least as much credit to themselves as they have obtained by what they have done. Or, if they really meant to reward Mr. Saxby for cheapening the construction of an old lock, they might have done so, taking care to inform the public what their reward was for.

"They did none of these things, but committed the gross blunder so properly and promptly exposed by Mr. Hobbs. And they now add to it the much grosser and more discreditable blunder of attempting to disguise it, by an excuse which everybody can see is a pure ex post facto invention from beginning to end. I think it due to the credit of the Society to expose such a proceeding as it deserves. If P.L.O. had put his name to his defence of himself and his colleagues, he should have had mine to this answer to it. As he has not, I take leave to subscribe myself,

O.P.Q."

"Sir, -On perusing in the Society's Journal a letter from Mr. Hobbs, who has obtained notoriety for his mechanical skill in opening or picking locks, manufactured by those who have hitherto been allowed to occupy the highest position in that branch of mechanism, I beg to state that I was not aware (until I saw the above) that a premium had been offered for a good and cheap lock, or I should have been a competitor or the honour.

"I have invented and patented a lock, which I do not hesitate to say is the strongest, the simplest, and yet the most secure, and least liable to become injured by dirt, &c., of any others ever made. It is sold for 5s. and less; and although so low in price, I have no objection to Mr. Hobbs trying his

professional skill upon it, using as many instruments, and of whatever kind he may please to select.

"That gentleman is quite aware of having been invited on more than one occasion to try his skill upon the 'English Protector Lock.' He is conscious that it is exceedingly simple in its arrangement, having no detectors, no catch under the bolt, or loose stump as in his own, or any obstruction of the usual kind as a preventive to the bolt's passage. Standing alone, it possesses an original simple principle, distinct from all other locks. Unlike all other cheap locks, I guarantee, this to be as secure as the most expensive. I cannot agree with your correspondent, P.L.O., that a lock, which in a few minutes may be picked, can be by any arrangement proved to possess great security; for the object of any lock, however, moderate its price, and of any improvement in one, must, when practically and commercially considered, be to produce this result, namely, equal security, although at a diminished cost.

"The originality of the principle upon which the English protector lock is contrived consists in it being impossible to fix up the tumblers in succession as in other locks; for, after raising one tumbler, the attempt to do so with a second necessitates the fall of the first. A portion of the bolt is always jutting against a steel cylinder working in the top and bottom of the lock. This cylinder is so placed that it is impossible to move the key, or any instrument inside the lock, without at the same time giving motion to it; and in any attempt to pick the lock, this cylinder will always prevent the bolt being pressed against the tumblers, thereby destroying the power of fix them in any particular position.

It is only when the tumblers are all raised by the key to their exact position that the portion of the bolt described above can advance, and upon doing so, it passes under the key and enters the cylinder, filling an opening in it. It will therefore be readily understood that, supposing a false instrument be introduced, the tumblers will not be raised to their required situation; and although one may be fixed, a second cannot be; for, immediately the attempt is made to remove the instrument in use, for the purpose of introducing others; motion is given to the cylinder, and necessarily the bolt, immediately causing the fixed tumbler to return to its original position. It is only an instrument exactly like the key which will produce any effect, and of course one like the key would be the key, therefore not picking the lock.

"The above lock is made in unlimited quantities, without having any two locks the keys of which would suit each other.

"Excuse my remarking, in conclusion, it is not single unpickable locks which manufacturers of locks care about, although they may be very interesting mechanical curiosities. It is to have an exceedingly simple and yet never-failing preventive to any one who endeavours to pick a lock, being able to ascertain the required position of the tumblers to effect this object. This preventive should be of one uniform shape or configuration, so as to dispense with mental labour on the part of the workmen, and thus enable quantities to be made at a price. The variation of each lock should consist solely in the tumblers, or in the depth of the notches in the key.

"I am prepared to show, whatever it may be required, that no lock has yet been brought into manufacture by Mr. Hobbs, or anyone else, which will equal the English protector lock in bearing an enormous amount of pressure upon the bolt.

"After stating these advantages, I trust I may be acquitted of egotism in believing this lock fulfills every condition required by the Society; viz., uncommon strength and freedom from disarrangement by dirt, and at no risk of its security. It is sold at a price which challenges comparison with any unpickable lock of the day.

"I am, Sir, yours respectfully,

"THOMAS RESTELL."

To the previous letters Mr. Saxby replied as follows:--

"Sheerness, July 9th, 1983.

"Sir, –The question of the propriety of awarding the prize to me for the lock is one which belongs, of course, to the Society, and not to the inventor. I should, however, feel greatly obliged if you will make the following explanation public:--

"The committee were satisfied that the idea was original to me, and I care not to disabuse the minds of other persons who may believe the poor mechanic to be guilty of piracy. As a general

rule, it is not such as we who live on the wits of our fellows.

"The only part of Mr. Hobbs' first letter on which I think an explanation is due is that which refers to the insecurity of my lock against fraudulent attempts. Now, Sir, I must plead as my defense that I did not conceive the idea until about a fortnight before the specimen was due, and could not apply myself for more than half-an-hour at a time to is manufacture; and not being a locksmith, I had the rudest tools imaginable. The consequence was that the specimen illustrated the principle, but did not defy the ingenuity of Mr. Hobbs, who had previously examined it, and discovered that neither the notches nor the rim were accurately made, either in form or corresponding dimensions. Had they been so, he would have had much more difficulty in succeeding.

"Allow me to suggest that the comparison Mr. Hobbs is so desirous to make for the information of the committee might be of some advantage to himself. If Mr. Hobbs has ever seen Cotterill's lock (and I believe he has), he must be aware that the statement made in the Journal of June 24th is altogether untrue, viz., 'that my lock is precisely the same, both in principle and arrangement, as Mr. Cotterill's, without the slightest modification, in fact only differing from it in the inferiority of its workmanship.' All this is untrue; and if no member of the committee requires to be enlightened by the comparison, Mr. Hobbs probably may.

"It would have sounded somewhat strange if Mr. Hobbs had stated this one fact in connection with the above, that when Mr. Cotterill made him a very liberal offer if he would pick one of his locks he declined, thinking it wiser to wait a little.

"It is scarcely necessary to remind the public that Mr. Hobbs is not the only individual capable of estimating the quality of lock; nor O.P.Q., who has at least made one discovery, viz., 'that of course a small key is always a light one;' nor Mr. Tucker, who has got £100 more than I have to spend in convincing the public that his lock and not mine should have got the prize.

"Other men equally competent to form an estimate of it have assured me that of 100 persons who could easily pick a common lock, 99 would fail in picking mine were the parts accurately fitted, which might readily be done with the necessary machinery at a low price. Hence there is an advantage over common locks of 99 per cent, in point of security.

"I am, Sir, your obedient Servant,

"H.G. SAXBY."

The following is from the Circular of Bankers, of July 9th:---

"The Society of Arts and their Prize Lock."

"We have received a copy of the Journal of the Society of Arts, containing a reply to Mr. Hobbs's letter respecting Mr. Saxby's lock, by an anonymous correspondent, which has not at all altered the views we expressed on this subject last week. In fact the vindication set forth by the writer is almost too ridiculous to notice, were it not that the subject is connected with the management of one of our oldest scientific institutions.

"The writer defines the term 'great security' by saying that it means 'great security against the attempts of the idle and the mischievous.' But if the funds of the Society are to be appropriated to be the advancement of science, surely they ought to have a higher aim than to award a prize for a lock that is only secure 'against the idle and mischievous.' We require as 'great security' in a lock for the cash box that we carry in our hand, as for the strong room where we deposit money and securities, as far as ingenuity in construction is concerned. And there can be very little skill required in picking locks for which the Society of Arts has awarded the prize, if by a simple piece of steel Mr. Hobbs could effect it in a few minutes.

"Mr. Hobbs has proved very clearly that most of the locks made in this country can be easily picked; and there can be no 'great security' in a lock until we are certain that it cannot be picked, even by the ingenuity of a Hobbs."

The contents of previous letters brought Mr. Cotterill into the field. The Times of July 13th contained the following letter:--

"COTTERILL v. HOBBS."

"To the Editor of the Times.

"Sir, –I perceive in your column of Thursday last a

paragraph from the Banker's Circular, which, if allowed to pass unnoticed, might, in the minds of those unacquainted with the merits of my lock, disparage the eminent position it has reached, and now legitimately confirmed by the united testimony of the highest scientific authorities in the realm, who, after severely testing the security of my invention, have generously allowed me to publish their unanimous opinion as to its perfect inviolability; among the goodly number I have the honor to name Mr. Robert Stephenson, M.P., Mr. Richard Roberts, of Manchester, and many of the leading members of the Institution of Mechanical Engineers. I am also proud to state that the leading mechanical journals have deemed it of such importance to the public as to give many illustrated articles on the principle of my lock, in order to prove its security. With such an array of strength on my side, it is not to be supposed that I shall shrink from meeting manfully any and every insinuation made which has for its object the lowering of my invention. Now for the paragraph in question:--

"'It appears that the Society of Arts issued a circular last year for premiums on various articles of manufacture, among which was one for a good and cheap lock. The prize was £10, and the successful competitor was a Mr. Saxby, of Sheerness, by trade a blacksmith.

"This lock (a six-inch rim) I am informed by the constructor himself could be sold at 2s. each. This cheap lock excited the curiosity of the trade, and foremost was Mr. Hobbs, who, after examining the lock at his leisure, and as often as he thought to his interest, found something in the construction resembling my patent lock, probably about as much as a wooden Dutch clock resembles a best-made chronometer; for observe, even by the aid of machinery in manufacturing, I cannot afford to sell my patent six-inch rim locks for less than 30s. each, net. From this fact alone I might leave the public to judge how far this 2s. lock resembles my patent one in those essentials which constitutes its preeminence, and which renders it the only commercial lock extant.

"I must also leave the friends of honest truthfulness to form their own estimate of a man who, in the face of such authority as the names I have quoted, could give to the public the following observations, viz.:--

"'But, so far from this lock (Mr. Saxby's) possessing that great security required, he (Mr. Hobbs) discovered that it was

merely constructed on the principle of the Yale lock (a name I never applied to any of my locks), such as are manufactured by Mr. Cotterill, of Birmingham, and to prove that the principle possessed no security he would pick this said lock.

"This 2s. lock, the picking of which he accomplished, according to the report, in three minutes, having had previously many opportunities of examining the key and the interior of the lock, and taking impressions and also measurements if he felt so disposed, picking this cheap lock under such circumstances I consider about as miraculous as his tinkering about sixteen days with a basketful of instruments, in attempting to pick Bramah's lock. I say attempting, because I believe, judging from newspaper reports, which have not yet been disproved, that Bramah's lock was not honestly picked.

Any common observer would suppose, from the eager manner in which the press gives publicity to every little movement of Mr. Hobbs, that no man in England could pick a lock; but in this I differ, being able to produce at any moment several poor working locksmiths, capable of picking any lock in half the time Mr. Hobbs occupies, and withal, consider they have done nothing worth fussing about. In reference to the remarks applied to Mr. Chubb in this matter, I have no doubt but this gentleman's long experience and well-earned reputation as a lockmaker will enable him to meet the aspersion cast upon his judgment, and give a different complexion to the whole affair.

"I shall, now for the second time, put Mr. Hobbs' ability to pick a lock upon my patented principle and my manufacture to the test, by the following challenge:--

"I will fix one of my commercial locks to a door and allow him one entire day to operate upon it, and should he succeed in picking it, I will reward him with 50 guineas. After this is disposed of, I will take him upon higher ground-viz., I will fix one of my best locks (not a Manchester machine like his) upon an iron door, and at the same time deposit 200 guineas in the hands of any respectable person, and should he be successful in violating this lock, taking a reasonable time to perform his take, he shall at once claim and receive the said 200 guineas; and in order to show that I mean business, I will pay his expenses to Birmingham; or, if he prefers it, I will bring the locks to London.

"My attention has only just been called to the paragraph in

question, otherwise this reply would have appeared earlier.

"I am, Sir, respectfully yours,

"EDWIN COTTERILL.

"105, New Street, Birmingham

Mr. Hobbs replied to Mr. Cotterill in the following letter, which appeared in the Times of the 15th of July:--

"To the Editor of the Times.

"Sir, –As you have given the publicity of your large circulation to a letter form Mr. Cotterill, in which my name is somewhat freely mentioned by that gentlemen, I trust to your sense of justice for permission to say a few words in reply. The question, however, is not one that primarily concerns myself, or indeed Mr. Cotterill (though he has given it a more personal aspect by a change in the words quoted from the Banker's Circular), but the Society of Arts, whose committee awarded a premium for a lock which has proved to be worthless. At the same time, I am not less sensitive of insinuations which really tend to lower my character for candour and honesty, though I will not resume to say that such is their object, than Mr. Cotterill can be of such as 'have for their object the lowering of his invention.'

"By 'insinuating' that I might, 'if so disposed,' have taken impressions and measurements of the interior of the lock invented by Mr. Saxby, and rewarded by the Society of Arts, and by speaking in different parts of his letter of the leisure and opportunities afforded me for examining it, Mr. Cotterill really leaves the impression on the mind of his reader that such was the case. It is a common trick in argument to begin by putting a suppositious case, and after rambling up and own the statement, and thereby mystifying the reader, to speak of it in the end as if the case were actually as the writer had supposed. These cobwebs to catch the unwary are easily brushed away by the simple statement that such opportunities were not afforded, and, in short, that they were quite unnecessary. The absence of any difficulty in the lock would have rendered any resort to such a means a mere waste of ingenuity.

"So much for the fact; and now with regard to the principle of the lock and the price at which it can be produced. I should

be most happy to submit the lock of Mr. Cotterill, for comparison with that of Mr. Saxby, to the gentlemen named by Mr. Cotterill, as having expressed their opinion of his lock, and leave to them the verification of my statement in the Journal of the Society of Arts–vix., that the lock of Mr. Saxby, which the committee of the Society judged worthy of a premium as a new invention, is constructed on precisely the same principles as the Yale lock, described in a paper read before the Society in January, 1852, and that it is precisely the same both in principle and arrangement as the Cotterill lock. The inferiority of its workmanship was a point particularly named by me; and, with regard to price, it is absurd to suppose, even such as it is, that it can be manufactured and sold for 2s.

"One word in regard to lock-picking. It seems to be taken for granted that I am open to challenges like that of Mr. Cotterill if only a sufficient inducement is held out in the shape of a pecuniary reward. I beg to assure that gentleman, and others who have mad the same mistake, that they will hardly catch me 'tinkering,' as it is elegantly expressed, 'with my basket full of instruments,' either upon their demand or that of any other man. When I came to this country it was as a competitor at the Great Exhibition; and in order to satisfy the public that the principle on which locks were constructed was not secure, I picked the locks then considered the most secure in the country, and in turn offered to submit my own to the same test. This is a privilege I still claim, without laying myself open to such demands as those I have felt it necessary to comment upon. Mr. Cotterill speaks contemptuously of my success on the Bramah lock. I have only to say that it did not rest with me to decide whether I had succeeded or not, but with a committee, whose impartiality it is both too late and too absurd to call in question. Your readers will remember that the gentlemen of the committee, whose decision was also unanimous, were the late Professor Cowper, of King's College, Mr. George Rennie, and Dr. Black.

"'Any common observer would suppose,' Mr. Cotterill remarks, 'from the eager manner in which the press gives publicity to every little movement of Mr. Hobbs, that no man in England could pick a lock; but in this I differ, being able to produce at any moment several poor working locksmiths capable of picking any lock in half the time Mr Hobbs occupies.' Mr. Cotterill does not perceive that the ease with which locks can be picked is my own argument, and I agree with him that there are many who can accomplish the feat in less time than myself. In conclusions, it is not in Mr. Hobbs that either the public or the press feel any

particular interest, but in the security of the enormous wealth confided to locks and keys so recently proved to be utterly valueless.

"I am, yours, &c.,
"A.C.HOBBS.

The editor of the Times appended a note to his letter to the effect that any future correspondence on the subject could only be inserted as an advertisement. The following remarks, which concluded the controversy on the "Saxby lock" affair, appeared in the Circular to Bankers, on the 23rd of July:--

"The remarks which we made in the Circular of the 2nd of July respecting the Society of Arts and their prize lock have created quite a commotion amongst the English lockmakers. But several of them who have addressed us appear to have mistaken the real object we had in view; and some of them have gone so far as to pervert the language we made use of altogether to suit their own purposes. Our attention was directed to the subject not to decide whether Mr. Hobbs or Mr. Cotterill, of Birmingham, could make a lock that cannot be picked; but to show that the committee of the Society of Arts, in awarding a prize for Mr. Saxby's lock, with Mr. Chubb as chairman, which Mr. Hobbs easily picked in three minutes with a small slip of steel, placed themselves in an unfavourable light before the public.

We did not take upon us to decide whether Mr. Hobbs' locks, or those manufactured by Mr. Cotterill or by Mr. Chubb, were the safest and best. The defense put forward on behalf of the committee by a correspondence in the Journal of the Society of Arts, to which we briefly referred last week, was that the 'great security,' as set forth in the prize list, meant great security against the attempts of the idle and mischievous; but it certainly never aspired to defy the systematic ingenuity of a professional lock-picker like Mr. Hobbs.

We hope the committee of the Society of Arts, for is own honor, will not acknowledge this weak defense; for Mr. Cotterill says –'He is able to produce at any moment several poor working locksmiths capable of picking any lock in half the time Mr. Hobbs occupies.' His condemnation of the Society's committee is, therefore, virtually stronger than our own; for he evidently does not rank Mr. Hobbs as a professional 'lockpicker,' but puts him on a footing with the 'poor working locksmith.' If, then, the Society of Arts be desirous of awarding prizes for the promotion of mechanical skill in its application to domestic purposes, it

ought to confer them upon those whose productions are most worthy; for in the present instance it is has been clearly shown that the lock for which the prize has been awarded can be easily picked.

"We have nothing to do with the controversy between the lockmakers and Mr. Hobbs. This is a matter they must settle amongst themselves. But we regard the question solely in a public light. Several extraordinary robberies have occurred that have rendered the security of locks an important desideratum in banking and other establishments; and whether the honor of accomplishing it be won by Mr. Hobbs or any one of our own countrymen, he is equally entitled to public support."

We have now arrived at the year 1854, which gave birth to such great events in connection with the Lock Controversy, the particulars of which will not soon be forgotten. In order that the following letters may be better understood, we shall here insert the official report of the discussion on Mr. Hobbs' paper "On the Principles and Construction of Locks," read before the Institution of Civil Engineers, February 21st, 1854.

"A succinct description was given of the various recent modifications generally introduced by makers of locks, and it was argued, that most of them were simply alterations of form, without materially adding to the security. As exception might, perhaps, be made in favor of Mr. Denison's lock; which was so constructed, that the bolt was shot by turning a handle, without the intervention of a key, which in fact was only used for placing the tumblers in a proper position, to allow the bolt to be withdrawn, or unlocked, by the handle, the keyhole being kept closed during the passage of the bolt; the key might, therefore, be always retained in the possession of one person, whilst the lock could be closed by any subordinate; this was important in banks and other similar establishments.

"The principle of the bolts being shot by a handle was not new, but the other arrangements were admitted to possess novelty.

"Mr. Whishaw's electro-magnetic lock, now exhibiting at the Polytechnic Institution, was explained, but was admitted not to be applicable to all the ordinary uses for locks.

"The principle of Mr. Cotterill's patent climax detector lock was then examined, and it was shown to be entirely based upon the Bramah lock, but was less secure in its arrangement,

inasmuch as the form of the key admitted of so little variation in the depth of the grooves, for moving the slides, that a lock, having six slides, might be opened by the end pressure of a piece of soft wood, and that any lock on that principle, with any number of slides could be easily picked by the pressure system.

"It was explained that the American permutating lock, which had been so fully described in the paper, was not intended for ordinary domestic purposes, but for banks and establishments requiring extreme precautions for security, and that the chief object in the introduction of Hobbs' moveable stump, or protector lock, was to supply a secure lock at a moderate price.

"In the course of manufacturing, as might be naturally supposed, the weak points of this lock had not escaped detection, and it was soon discovered, that although the principle was correct as long as the stump remained moveable, if by any means the stump could be held fast, the lock became one of the ordinary tumbler locks, and was as easily picked as the others. For instance, in a till or drawer lock, where the keyhole was parallel to the bolt, it was easy, by the insertion of a piece of watch-spring beneath the bolt, to catch and hold the stump, and to open the lock. This, however, was readily prevented by the insertion of a tongue in the backplate, fitting into a corresponding groove in the back of the bolt, thus cutting off all access to the moveable piece under the bolt; and further, to preclude access to the stump itself, a piece of steel was riveted into the front plate, reaching through the tumblers into a groove in the bolt, thus placing an effectual barrier between the keyhole and the stump. With these slight additions, which were not introduced, it was contended that locks constructed on the principle of the moveable stump might be considered secure.

"It was shown that Mr. Gaoter, who was connected with the establishment of Mr. Chubb, had succeeded very ingeniously in picking three of Hobbs' till locks, by the means which had been described; those locks, however, not having the additions for security which had been alluded to.

"This opening of these locks was admitted to be perfectly legitimate, showing slight defects in the details of construction, but demonstrating the correctness of the principle; and it was argued that it was only by such means that the manufacture of locks could be tested and improved, indeed, that the lockmakers were greatly indebted to Mr. Hobbs for showing them the weak points of the locks constructed prior to 1851.

“The manufacture of locks in this mechanical country had hitherto been conducted in the rudest manner, and with the most primitive tools; and whilst the price of common and insecure locks was incredibly low, that of locks of good construction was much too high to introduce them into general use. It was, therefore, the object of Mr. Hobbs, by the employment of good machinery, to produce locks of uniformly correct construction, on sound principles, and at such a modified scale of pries as would insure their general adoption; being assured that whoever might be the maker, the most secure locks, at the lowest price, would eventually take the lead with the public.”

It would appear from the following letters that Hobbs’ protector lock had been picked by Mr. Goater, some time before the meeting of the Institution of Civil Engineers on the 21st of February, and that statements to that effect were in circulation; and at the meeting referred to the modus operandi was explained by Mr. Hobbs himself. Without further preface, we now give the whole of the correspondence at length:--

The first letter from Mr. Goater appeared in the Morning Advertiser, February 24th.

“To the Editor of the Morning Advertiser."

“Sir, –About a year and a half ago I obtained one of Hobbs’ patent protector locks, and after carefully examining its construction, I felt convinced that I could pick it. I then prepared suitable instruments, and picked the lock in five minutes; this I did again and again, the third time it occupied only one minute and a half. I also picked another lock about two months since. Hearing the week before last that a paper on locks was to be read at the Institution of Civil Engineers by Mr. Hobbs, I requested my employer, Mr. Chubb, to allow me to operate on Mr. Hobbs’ locks in such a manner as to prove to the world, beyond any doubt, how easily they may be picked. Mr. Chubb then on Friday, the 10th of this month, put into my hands one of Hobbs’ locks, sealed up, the only access to the interior of it being through the keyhole. I had to make fresh instruments for this lock; I commenced operating upon it on the Monday morning, and in two hours I succeeded in picking it. I neither saw the keys nor the interior of this lock. I then picked two other of Hobbs’ locks under the circumstances detailed in the following certificate:--

"'London, Feb. 20, 1854.

"'On the 13th of February, Dr. Lobb and Mr. S. Maw called at the shop of Messrs. Hobbs and Co., Cheapside, and asked for, and purchased, two of Hobbs' best patent protector locks, with different keys. Each lock was accompanied by a label, stating that "the peculiarity of these locks consists in the arrangement of the tumbler-stump, it being attached to a moveable piece that works under the bolt, thereby preventing the possibility of ascertaining the proper position of the tumblers, which renders the lock secure against picking."

The locks were then taken to Messrs. Liddiard and Co., Friday street, where the bolt of one was locked out with its own key; the lock was then enveloped in paper, and sealed with the seals of Messrs. Liddiard, Sheriff, and Lobb, the keyhole only being left open. This lock was placed in the hands of John Goater the same evening, who returned it picked (still sealed up as when given to him) on Wednesday, the 15th of February. The second lock was then sealed in the same manner by Dr. Lobb, Mr. Copeland, and Mr. Arthur Lobb. This was delivered into John Goater's hands at nine o'clock on Thursday morning, who picked and returned it sealed as when given to him) at three o'clock the same afternoon. The keys of the first lock still remain sealed up in the custody of Mr. Sheriff, and those of the second in that of Mr. Arthur Lobb. Both these locks were fairly picked by the use of certain instruments, solely through the keyholes, and neither previously nor since has the undersigned John Goater seen either the keys or the interior of the locks.

"'We, the undersigned, append our signatures to vouch for the truth of the above statement, so far as each of us is concerned therein.

"'S. Maw, 11, Aldersgate-street.
"'J.M. Copeland, 2, Vernon-place, Bloomsbury-square.
"'William Lobb, 12,Aldersgate-street.
"'G.W. Sheriff, 61, Friday-street.
"'W. Liddiard, 61, Friday-street.
"'Arthur Lobb, Stock Exchange.
"'John Goater, 14, St. James's-walk.'

"In order to show there was no unfairness in the way I picked these locks, I explained the manner in which it was done to Mr. Carpmale, of Lincoln's inn, and on Friday last Mr. Carpmael purchased a lock at Mr. Hobbs' shop, which he sealed up

and gave to me; this I picked the same afternoon.

"It was not my intention to have explained the manner which I adopted in picking these 'unpickable American locks,' but upon second consideration, the plan being so simple, easy, and certain in its results, and knowing that the fact of their having been picked would set so many to try their hands at it, that it was sure to be discovered, induced me to alter my mind; therefore I described one of the methods at the Institute of Civil Engineers on Tuesday last; it simply consists in the application of a piece of watch-spring and two common picks.

"I am, Sir, your obedient servant,

"JOHN GOATER.

"14, St. James's-walk, Feb. 3, 1854,"

The following is the reply of Mr. Hobbs, in the same paper of the 25th of February:--

"To the Editor of the Morning Advertiser."

"Sir, –Amongst the advertisements in the Morning Advertiser of the 24th instant is a statement by Mr. Goater, foreman of Messrs. Chubb's establishment, which is calculated to convey to the public so erroneous an impression as to the security of the 'Patent American Lock,' that I deem it incumbent on me, in self-defense, to state explicitly the true facts of the case, and the only legitimate conclusions to be drawn from them.

"At a recent meeting of the Institution of Civil Engineers, after describing the peculiar advantages of my patent moveable stump lock, I took the opportunity of pointing out certain defects which I had discovered in its construction, which rendered it possible in the common till or drawer lock to introduce a piece of watch-spring, so as to fix the moveable stump or protector, and thus convert the lock into a mere ordinary tumbler or Chubb lock. Of course I made no secret of the fact, that so soon as this was accomplished there was no longer any difficulty picking it. I stated further, that upon discovering these defects in my own locks, which I had thus pointed out, I had lost no time in adopting such improvements in its construction as would effectually obviate them. These improvements I described to the meeting, and drew attention to some locks so constructed, which were then lying on the table.

"After I had thus openly explained the defect of a certain small class of my own locks, and the means by which these defects were now effectually removed, it was triumphantly announced to the meeting by Mr. Chubb that Mr. Goater had actually succeeded in picking that identical class of locks, and in the identical manner that I had already described. But more, or rather much less than this, it must be understood that the locks thus picked by Mr. Chubb's foreman, instead of being properly fastened to a drawer or box, were simply enveloped in paper, thus having the end of the bolt exposed so that a pressure could be applied by the hand, instead of requiring any instrument in the keyhole, as would be the case whenever the locks were really in use.

"And because Mr. Goater has thus achieved the very humble feat of bearing practical witness to the truth of what I stated only in words, the public are led to infer that he has proved the whole of my locks, including the 'Unpickable American Lock,' as insecure as their own. I say as their own, for it must be borne in mind that this wonderful triumph of Mr. Goater amounts simply to this: that through an oversight in the construction of a small class of my locks, he succeeded in so fixing the moveable stump that the lock became precisely the same as the ordinary Chubb or tumbler locks.

"I am, Sir, your obedient Servant,

"A. C. HOBBS
Cheapside, February 24, 1854."

The second letter from Mr. Gaoter is from the Morning Advertiser, February 27th.

"To the Editor of the Morning Advertiser."

"Sir –In replying to my letter to you in which I announced my picking the "Unpickable American Locks," Mr. Hobbs has thought fit, in his advertisement in reply, to drag the firm of Chubb and Son into the discussion. Allow me, Sir, to say that they are not parties in the matter. The question is: Have I picked the Hobbs' locks or not? He owns that I have done so, but he insinuates that it was 'after he took the opportunity of pointing out certain defects which he had discovered in their construction.' This, Sir, is simply untrue. I picked Hobbs' locks eighteen months ago. Again, he says, 'I made no secret of the fact, and lost no time in adopting such improvements in its construction as would effectually obviate them.'

Then, why did he not mention the insecurity of his locks in his lectures at the first meeting, and why did he then say that they were secure? And whey did he delay hinting at the insecurity of his locks until he knew that some of them had been picked by me? Nobody better knew the worthless character of the locks than Hobbs 'himself.' Such a notoriously clever lock-picker as Mr. Hobbs must have well known how easily they can be picked. Mr. Hobbs now questions the mode in which I picked his 'Unpickable American Locks.' At the meeting of the Civil Engineers he admitted, over and over again, the fairness of the whole proceeding. This is other of his after-thoughts.

"As a practical lockmaker, I assert that the principle of Hobbs' locks is bad and worthless; and I do not care what alteration he may make in it, I will pick them as easily as before. As to the locks which I picked, I simply chose locks sold by him as unpickable; but I can pick all forms and sizes, and the larger the better; and if fixed, still it makes not a bit of difference. I beg also to say that the pressure on the bolt was applied through the keyhole only. Now I would ask, Sir, what reliance the public can place on the promised improvement in locks, by a man coming from American to condemn the English locks, and who sells a very inferior article to those he condemns, some of them only taking one minute and a half to pick? In short, his ten shilling American locks are but a little better than a one shilling Birmingham lock. Again, on Tuesday week, he said his locks were perfect; but, as I have before said, the next Tuesday, having ascertained by movements, he acknowledged defects.

"In conclusion, Hobbs' locks have been picked; the bubble is burst, and let him blow as many more as he likes, they will all share the same fate. I have not yet done with Mr. Hobbs. It was under great and un-English provocation I drew the sword, but having done so, I have thrown away the scabbard.

"Yours, &c., JOHN GOATER.
"14, St. James's Walk,
February 25, 1854."

In reply to the above, the following letter and challenge appeared on the 28th:---

"To the Editor of the Morning Advertiser."

"Sir, –In reply to Mr. Goater's letter in the Morning

Advertiser of today, I shall simply refer, for the truth of the statement made by me on the 24th instant, to the printed official minutes of the Institution of Civil Engineers. Perhaps it may be as well to state that the lock claimed to have been picked was not, as Mr. Goater would have the public believe, "The American Lock,' nor was it in any respect similar in its construction. It was simply a lock constructed to be secure for all ordinary purposes, without materially increasing its costs. That Mr. Goater picked this lock eighteen months ago, and kept it a profound secret until the present moment will hardly be credited after the feeling he has displayed in his letters on the subject.

"But in order to give him an opportunity of proving his boast that he will pick all and any of my "Unpickable American Locks,' notwithstanding any alterations that I can make, I beg to inform him that one of my "Unpickable American Locks,' without additions, alterations, or improvements, shall be submitted to him, upon any terms, and for any length of time that shall be agreed to by a committee appointed for that purpose; and the sum of 200 guineas shall be deposited in their hands by me, to be paid to him in the event of his picking the lock.

"I am, Sir, yours, &c.,
"A. C. HOBBS.
"97, Cheapside, February 27, 1854."

"To Mr. Goater, in the employ of Mssrs. Chubb and Son."

\+ "Sir, –There are, in the employment of Messrs. Hobbs and Co., fifty skillful English mechanics, part locksmiths and part machinists, who, having read your bombastic advertisement in this journal of yesterday, come forward to rescue the article of our production (the protector lock) from the very sweeping condemnations you have thought fit to pass upon it. We wish to fix your attention to one point only at present, and that is, you affirm that you can pick Mr. Hobbs' protector lock with any alteration he may make: very well, then, you shall try; for we, the fifty workmen of Mesrs. Hobbs and Co., give you the following challenge –to pick this simple lock for £50, subject to regulations that may be agreed upon by a committee of five gentlemen; and in order that you shall not give us trouble for nothing, one condition is that you shall deposit £50 likewise, so that if you attempt to pick the lock and fail, we, the fifty men of Messrs. Hobbs and Co., shall have the £50 deposited by you. Should you not think fit to accept this challenge, which, be it remembered, is given in connection with the true meaning of your advertisement in this paper on Monday, the 27th of February, we

hereby give you notice that the omission shall be duly noticed, with additional points, from your advertisement before referred to. Anxious for a reply, we beg to remain,

"Your very humble servants,
"THE WORKMEN OF MESSRS. HOBBS & CO.
"97, Cheapside, 27th Feb., 19854."

The following extracts will show how considerable was the public interest excited by this incident in the Lock Controversy.

"LOCKS AND LOCK PICKING. –The workmen of Mr. Hobbs, the well-known lock manufacturer, have set a novel example of combination, which is somewhat remarkable at the present moment. A rumor having become current that the locks of their employer were as subject to the tampering touch of the 'pick' as that of most others, they, considering themselves and their skill compromised in the charge, have offered to deposit £50 against the like amount, to be forfeited on either side, in the event of any person fairly picking the American lock. This is in addition to the 200 guineas offered by Mr. Hobbs for a similar result."
—The Sun of Tuesday Evening, Feb. 28. 1854.

"THE LOCK CONTROVERSY. –Mr. Hobbs, the patentee of the American lock, in reply to some charges recently made against the security of that piece of mechanism, has offered 200 guineas to any one who can accomplish this task. It would further seem that the amor propre of the artisans in Mr. Hobbs' employ –some fifty in number, all British workmen –has been touched by the assertion of Mr. Goater, and they have entered an independent challenge for £50 against his picking the locks of their workmanship under this patent."
—The Globe of February 28, 1854.

"THE LOCK OF ENGLAND AND AMERICA. –It would appear, from a paper war now going on, that the lock question of 1851 is again open, a champion for the defeated manufacturers of that period having entered the lists. Mr. Hobbs, against whom the lance is poised, has accepted the gage, and with it has offered to reward the valiant knight with 200 guineas if he fairly sustains his menace. Nor are the large body of artisans who work for Mr. Hobbs silent spectators of the melee, but have undertaken, through the columns of the Advertiser, to wager £50 on the issue being in favor of their chief."
–The Standard of March 2, 1854.

The Morning Advertiser of March 1st contained the following from

Mr. John Goater:--

"Hobbs' Locks Picked.

"To Mr. A. C. Hobbs, and my 'very humble servants, the Workmen of Messrs. Hobbs and Co.'

"Gentlemen,–'Catch a Weasel asleep.'

"I am, Gentlemen, yours very truly,
"JOHN GOATER,
"The picker of four of Hobbs' Locks, all warranted by
"Mr. Hobbs as 'secure against picking.'
'14, St. James's Walk, February 28, 1854."

The following concluding letter from the workmen in the employ of Messrs. Hobbs and Co. appeared in the Advertiser of March 4th, 1854:--

"HOBBS LOCKS.

"To the Editor of the Advertiser."

"Sir, –Mr. Goater, in the employ of Messrs. Chubb and Son, has publicly boasted that he could with the greatest ease pick any of Hobbs' patent protector locks, notwithstanding the improvements which Mr. Hobbs has added for their more perfect security. Feeling satisfied, as practical workmen employed in the manufacture of these locks, that he was unable to make his boast good, we offered at our own risk to take him at his work, and stake £50 on the issue.

"Mr. Goater, with an assumption of dignity rather inconsistent with his position, declines this fair and open challenge from workmen employed like himself, and like him, of course, personally interested in the value and reputation of the locks they are engaged in manufacturing; and as he thus refuses the opportunity we have offered him of establishing beyond dispute what he has so freely and so easily asserted, we feel perfectly satisfied in now leaving the result with the public, assuring him, however, that should it be necessary to select a champion 'to maintain the character of English locksmiths against American (or even native) misrepresentations,' we, as members of that body, will hope to find one not only ready to correct the errors of others, but with sufficient candour to acknowledge merit, and honorably confess to a fair defeat.

"We remain, Sir,
"Your obedient Servants,
"The Workmen of Messrs. Hobbs and Co.
"97, Cheapside, March 3, 1854."

The next lock-picking experiment which we have now to notice is one of considerable importance, and is the only unsuccessful public one which has resulted from Mr. Hobbs' manipulations. The circumstances which led to it, and the incidents connected therewith, are so fully described in the reports from the Manchester Guardian, (which we shall insert at length) that have but little to state in addition thereto.

(From the Manchester Guardian of Saturday, April 29, 1854.)

"Circumstances, which may be gathered from the following statement, led Mr. Edwin Cotterill, of Birmingham, the patentee of a safety lock called "The Patent Climax Detector Lock.' to challenge Mr. A. C. Hobbs (who picked the Bramah locks and those of Messrs. Chubb and Son) to pick his lock, offering to pay him fifty guineas if he succeeded within the time specified. After much correspondence, it was finally agreed that the lock to be subjected to this clever picker should be one upon an iron chest, sold some months since to Mr. B. Fothergill, consulting engineer, of this city.

As the lock and key had been for some time out of Mr. Cotterill's possession, it was agreed that the patentee should be allowed to take the lock off in the presence of Mr. Fothergill, and minutely examine it, and then reaffix the lock to the door of the safe. This having been done, a meeting of a few gentlemen was held at Mr. Fothergill's offices, Queen's Chambers, on Thursday morning week, for the purpose of making the requisite arrangements for carrying out the test. Besides Mr. Cotterill and Mr. Hobbs, there were present Mr. Richard Roberts, C.E., Mr. Fothergill, C.E., Mr. Charles Beyer, M.E., Mr. J.F. Roberts, Mr. Harland (of the Manchester Guardian), and Mr. Morris.

The agreement, written and signed in duplicate, was then read over, and it was fully assented to on both sides. It stated that Mr. Cotterill had done to the lock, in the presence of Mr. Fothergill, just what the agreement authorized and no more. Mr. Cotterill then named Mr. Roberts as the gentlemen to remain with Mr. Hobbs during the visit he was to be allowed to make to the lock, for the purpose of taking measurements from the outside of

the keyhole for adjusting his instrument by which to pick the lock.

This operation commenced at 11:6 a.m. on Thursday; at 11:15 Mr. Hobbs removed the nozzle-drop; and he concluded taking measurements at 12:24 p.m., thereby occupying one hour and eighteen minutes in this visit to the lock having the remainder of the day to make any alteration in the instruments he thought necessary, and this was granted in addition to the twenty-four hours allowed for actual operation. The outer brass shield of the lock was then carefully sealed up by Mr. Roberts, so that the lock could not be subjected to any further experiment till that should be authorized.

"Yesterday (Friday) morning, at half-past ten, the gentlemen already named reassembled at Mr. Fothergill's offices, together with Mr. Salt, secretary of Liverpool Polytechnic Society, Mr. Weild, engineer, and Mr. Morris, a reporter. Again the agreement was read over, and it was intimated that the words 'one entire day' must be construed as twenty-four hour consecutive hours. Mr. Hobbs said he had made his instrument and was ready to begin. Mr. Cotterill drew a cheque on the Birmingham Banking company for £52 10s., payable to Mr. Hobbs or bearer, and handed it to Mr. Richard Roberts. Mr. Hobbs then said that he wished to observe that this challenge was not of his own seeking. At the Great Exhibition of 1851 he was challenged by a Mr. Cotterill to pick his lock, and if he had thought that it was at all different in principle from those of Bramah or Chubb, he would have tested it; but thinking it to be much the same as Bramah's, he declined the challenge. Then his name was put forth in Mr. Cotterill's circulars and advertisements to the effect that he had been fairly challenged to pick the lock, and had declined.

This went on for some time; until he (Mr. Hobbs) reading a paper on locks at the Society of Arts, he had referred amongst others to Mr. Cotterill's lock, not with any view of calling him out. On this Mr. Cotterill again challenged him, and he again declined; and his name was again put in Mr. Cotterill's window as not daring to test his lock. [Mr. Cotterill said that what was stated was –"Mr. Hobbs has declined my challenge."] –He did not wish to test the lock; but he had certainly felt annoyed by his name being thus used, and at length, when Mr. Fothergill wrote to him, he took up the challenge; believing that otherwise his name would be again held up as shrinking from the test.

He wanted everything during this trial to be perfectly

smooth and pleasant; he would throw aside all feeling of annoyance, and ask the gentlemen present to look upon the matter simply as the solving of a mechanical problem. Whether he succeeded or not, everything he did should be made public; the instrument he would use should be shown, and its application to the lock; nothing should be concealed; and he hoped everything would be conducted with the best feeling and understanding.

–Mr. Cotterill said that Mr. Hobbs had represented him as acting upon the offensive. This he must deny; he was merely upon the defensive. Mr. Hobbs had spoken in disparagement of his lock; had called it a Bramah lock, as if there was no difference, and said it could be easily picked. His only object was to prevent these statements being injurious to his reputation as the patentee of this lock, and to prove its security. As Mr. Hobbs had publicly spoken of the ease with which he could violate the lock, he thought it the best method to give him the opportunity of doing so. Rumor was sometimes stronger than truth; and what Mr. Hobbs had positively stated would be believed extensively, and he was aware that what he had stated was working to his (Mr. Cotterill's) injury; therefore he felt it imperative upon him to bring his lock and Mr. Hobbs to the test. He offered him a handsome inducement; and if Mr. Hobbs was convinced that the lock was in substance a Bramah's, why it would be so much easier for him to operate upon it.

Mr. Hobbs, as a maker of locks himself, must influence the business of others and his own by showing the insecurity of other locks; for he was thus in a great measure and by implication proving the security of his own. For these reasons he felt bound to challenge him; and when Mr. Hobbs declined that challenge, he thought it legitimate to let the public know he had declined. He had never spoken one word disrespectfully of Mr. Hobbs; he had merely stated facts; he had published his own letter and Mr Hobbs' reply; he had offered no comment of his own, and he did not see that Mr. Hobbs had any real ground for feeling annoyed.

—Mr. Fothergill explained that, happening to attend one evening a meeting of the Institution of Civil Engineers, he heard Mr. Hobbs read a paper on locks, in the course of which he named Mr. Cotterill's lock. He (Mr. Fothergill) meeting Mr. Cotterill at Birmingham shortly after, to pay him for the safe with his patent lock now to be experimented upon, told him what Mr. Hobbs had said. This led to the challenge: he had been a medium of communciation between them, and it was at length agreed that the lock on this safe should be the one subjected to the test. Mr.

Cotterill said that that safe had been sold and delivered some months, and before he had ever dreamed of Mr. Hobbs making experiments upon it; therefore it would be seen at once that it was not a lock which was made for the purpose of resisting any such extraordinary operations. When Mr. Hobbs had referred to his lock at the Institute of Civil Engineers would be between two and three months ago.

"All preliminaries having been amicably settled, Mr. Roberts broke the wax round the lock, which having been repeatedly locked and unlocked with the key, was finally locked, and the hands of Mr. Cotterill, to prevent any access to them. Mr. Hobbs produced a small rod, which he had used in taking measurements the preceding day. The lock has twelve radiating slides, and as these marked the sides of the rod, he filed away the marks till he got a sort of model for his instrument. This pick-lock (which must have occupied some days in constructing) was the most ingenious tool of the kind he ever saw; consisting of a series of twelve radiating iron needles or wires, with screw ends, which could be gently inserted, and each in turn carefully propelled forward till it reached the requisite point. Where it did not at once act, as was most usually the case, a little filing was applied where its smoked surface showed that it impinged on the slide within. Before beginning, Mr. Hobbs, by means of an instrument, raised the nozzle-drop, which is to guard the interior of the lock against burglarious efforts.

"Mr. Hobbs commenced to use his instrument at five minutes after eleven a.m. yesterday, and for many hours applied himself diligently to his task, advancing but slowly in the adjusting of needle after needle to the requisite length and form. At five o'clock, after he had been engaged about six hours, he was still quietly seated before the chest, occasionally poking in this instrument; and we understand that with the exception of ten minutes or a quarter of an hour for some light refreshment, he had remained steadily at his work throughout the day. At 8 o'clock Mr. Hobbs left the room for a time, to get some tea; he returned at a quarter before nine, and soon afterwards resumed his efforts. About a quarter before ten o'clock this instrument broke, or became unsoldered; and accompanied by Mr. Weild, with some difficulty, he succeeded in inducing a watch-maker in Salford to solder it. He returned a few minutes before eleven o'clock and resumed his labors. There remained in the room with him, but not near him, Messrs. Richard Roberts and J.F. Roberts, Mr. Weild and Mr. Cotterill. He appeared determined to continue his efforts throughout the night, and said he should not work

after eleven on Saturday morning; when the twenty-four hours allowed for the trial will have elapsed."

(From the Manchester Guardian of Wednesday, May 3, 1854.)

"In the Guardian of Saturday, we gave an account of the challenge by Mr. Edwin Cotterill, of Birmingham, patentee of 'The Patent Climax Detector Lock,' to Mr. A. C. Hobbs, the celebrated American locksmith, whose picking of Bramah's and Chubb's locks created so great a sensation during the Great Exhibition, to pick that lock within 'one entire day of twenty-four consecutive hours,' and, if successful, Mr. Cotterill bound himself to pay him fifty guineas; if unsuccessful, all Mr. Cotterill required was to receive from a committee of gentlemen, appointed to witness the experimental test, a certificate to that effect.

In our last, we published an agreement signed in duplicate by Mr. Cotterill and Mr. Hobbs, and described the commencement of the experiment and the progress supposed to have been made by Mr. Hobbs from Friday forenoon at 11:5 up to the same hour on Friday night, being just twelve hours, or half the time allotted for the experiment. In a later edition of our Saturday's paper, we briefly stated the fact of Mr. Hobbs having failed to pen the lock within the twenty-four hours. We now briefly sketch the proceedings during the latter half of that time, and those attending the subsequent examination of the lock.

In the third edition of Saturday's paper we stated that Mr. Hobbs said he had succeeded in lifting or raising ten of the twelve slides which the lock contains; but this was subsequently proved to be an involuntary error of Mr. Hobbs'. He might have raised ten slides a certain portion of the distance necessary; but it was clear that he had not raised one of them sufficiently, and that if he had even forced eleven of them into the proper position, the lock could not have been opened.. Indeed, if all had been raised by his ingenious instrument, in turn, he could not have opened the lock, which will yield to nothing but a simultaneous action on all the twelve slides at once, and this could only be effected by the legitimate key.

"We stated that up to eleven o'clock on Friday night Mr. Hobbs continued his efforts to open the lock; four gentlemen remaining at the other end of the room, so as not to disturb him by over close and inquisitive inspection of his labors. These gentlemen were, Mr. Richard Roberts, C.E., and his son, Mr. J.F. Roberts; Mr Weild, mechanical engineer; and Mr. Edwin Cotterill,

the patentee of the lock under trial; the other gentlemen having retired for the night. After having got his lock-instrument soldered, Mr. Hobbs resumed his labours a few minutes before eleven o'clock on Friday night. After continuing before the lock till 12:30 (midnight), he said he would go and recruit himself by a few hours' sleep, and would resume his work at five in the morning. He accordingly proceeded to the Royal Hotel, and went to bed. The four gentlemen remained in Mr. Fothergill's offices, Queen's Chambers, awaiting his return.

He was back at his post a little earlier than the time named, and recommenced his labors at 4:26 a.m., Saturday. At 7:45 a.m. he again suspended his operations for further rest and breakfast; and he once more sat down before the hitherto impregnable lock at 9:20 am. A few minutes before the expiration of the twenty-four hours, he quietly arose, and said, 'The lock's yours; I give it up.' The committee having reassembled, Mr. Hobbs repeatedly said he had not succeeded, and that all that remained was to have the lock taken off and examined. Mr. Cotterill produced the sealed packed containing two keys for the lock; both these were tried, and the lock was opened, and found both to lock and unlock freely; thus proving first that Mr. Hobbs, in his operations, had not injured the interior; and, second, that no accidental obstruction had resulted during his experiment, so as to raise up an unexpected obstacle to his success.

Mr. Cotterill's workman was then called in, and in the presence of the committee and the two parties to the trial, and several witnesses, took off the lock, and, removing the inner plate, revealed the whole of its construction; so as to show that it was no little addition introduced for the occasion, but the construction of the lock itself, which had baffled the ingenuity of Mr. Hobbs. A few moments examination sufficed to reveal to him that this latter was the fact.

There were two obstacles, either of which would singly have defeated his attempt, but combined, they rendered the actual difficulty insuperable. One of these was a detector. Mr. Hobbs next examined another and still more formidable obstacle to his success, consisting of an outer ring of steel around the circular brass lock; and every slide on being pushed, by key or instrument, from the centre to the periphery, at first impinges on this external steel ring; but on increasing the pressure applied simultaneously by the regular key to all the twelve slides, they force themselves, by means of a sloping or bevelled

edge, into a groove in this outer ring, and till all the slides do this at once, the lock cannot be opened.

–Mr. Hobbs examined this portion of the construction carefully, and then said: 'Really it is very ingenious. I believe it to be a regular, fair, commercial lock, and I really think it is a very pretty arrangement, and I think great credit is due to Mr. Cotterill. A man might work a lifetime, and never overcome it.' Mr. Hobbs was then asked (after he had minutely examined the internal part of the lock) whether he would again encounter with the lock upon the same terms? He answered, no; adding, that if allowed a month, he could not accomplish the task. After some further examination and conversation, Mr. Hobbs, turning to Mr. Cotterill, said: 'Well, you will make the most of this in trade, and you have a perfect right to do so; but, at the same time; I hope we shall not have any personalities.'

–Mr. Cotterill: 'Mr. Hobbs, I confess I think there has been a little aggression on your part; but I dislike personalities as much as any one, and I hope we shall part friends.'

–Mr. Hobbs: 'I have never made any attack on you. I have described your lock in public and private, as I have seen it, and as I saw it at the Great Exhibition. This lock [one of Mr. Cotterill's earlier make, which Mr. Hobbs had bought and experimented upon, and made his instrument by,] was bought within six months; and as such I have described that lock.'

—Mr. Cotterill: 'I could pick a Bramah lock in a minute; I have tried to pick my own, and failed; and, as its inventor, if it had weak points, I may be supposed to have known them. The lock I make now I consider inviolable, and I shall take my stand upon it; for I may now say that it is a practical impossibility to pick my commercial lock.'

–Mr. Hobbs: 'I was just as near picking it when I first put the instrument in it yesterday, as I was at the last moment.'

–Mr. Cotterill then expressed his acknowledgments to the gentlemen of high mechanical knowledge and skill, who had given their valuable time and attention to this experiment, and one which none would attempt to gainsay. Much had been said than that it had passed the severe ordeal of Mr. Hobbs' manipulation during so many hours. He felt that Mr. Hobbs had in this instance acted very handsomely, in making the admission that the

lock was a good one, and that if he had tried for a month he should not have succeeded. He hoped that in these contests every man would try to rise higher, and not to drag others down to a low level. He thought his lock had now that security about it as to demonstrate that it was much easier to take care of money that to get it; and he hoped the commercial community of Manchester would, therefore, give him a share of their patronage.

–[Laughter] Mr. Hobbs: 'It is said, "Let him laugh who wins;" but here, I think we are all winners. Mr. Cotterill wins reputation for his lock; and I have won something, for I have learned something by it.'

–Mr. Cotterill then said that Mr. Hobbs had been kind enough to offer him the same privilege to test his (Mr. Hobbs') lock upon [we think] a three-inch scale. He had declined accepting that challenge for himself; but, if Mr. Hobbs had no objection, he would accept it for his young man, reserving to himself the privilege of constructing the instruments only. –Mr. Hobbs said he had no objection whatsoever.

"Mr. Cotterill having requested the committee to furnish him with the certificate stipulated for in the written agreement, the following was hastily drawn up, read over to both parties and to the committee, and when Mr. Cotterill, Mr. Hobbs, and the committee had expressed their full approval of it, it was signed by the committee and by other gentlemen who had been more or less witnesses of the experiment:--

"'Queen's Chambers, Manchester, April 29, 1854.

"'We, the undersigned, being the committee appointed to see that the "Patent Climax Detector Lock" of Mr. Edwin Cotterill, of Brimingham, should be fairly subjected to the manipulation of Mr. A. C. Hobbs, of London, during twenty-four consecutive hours, to be picked or opened by him, with an instrument or instruments constructed by him or for him for the purpose, do hereby declare that the experiment has been fairly tried, during the time, and under the conditions of the written agreement in duplicate, signed by the respective parties; and that Mr. Hobbs has failed to pick the lock, and has declared that it is a very ingenious one, and that if he had tired to pick it for a month, he should have failed.

"'RICHD. ROBERTS, C.F. J. HARLAND.
"'C. BEYER, M.E. THOS. MORRIS.

"'Signed in the presence of us, who have also witnessed the experiment,

"'BENJN. FOTHERGILL, C.E.
"'W. WEILD, M.E.
"'PETER J. LIVSEY, C.E.
"'J. F. ROBERTS.'

"The experiment having thus terminated, and the greatest good feeling prevailing, Mr. Cotterill invited Mr. Hobbs, the committee, and other gentlemen, especially the four who had remained in the room (with the exception of a short absence for refreshment) during the twenty-four hours, to partake of luncheon, at the Clarence Hotel. This invitation was accepted, and a very pleasant afternoon ensued. Amongst the toasts were —'The Queen;' 'The President of the United States;' 'The committee;' 'Mr. Cotterill;' 'Mr. Hobbs;' 'Mr. Richard Roberts,' C.E.' 'Mr. Benjamin Fothergill,' consulting engineer; 'Mr. Bennet Woodcroft,' of the Great Seal Patent Office; "The Press, &c."

In this experiment Mr. Hobbs had evidently miscalculated the chances of opening the lock. It is only fair to state that it was not a test lock, as it had been sold in the regular way of trade, affixed to the door of an iron safe, some months prior to the experiment being made. That it was a better and a more secure lock than the earlier locks made by Mr. Cotterill must also be admitted. By referring to the description of Cotterill's lock [at page 489], the action of "the ring" will be understood; and a drawing of a similar instrument to the one used by Mr. Hobbs in the experiment will be found on page 314, the only difference being that the former is suitable only for a lock with six slides, whilst Mr. Hobbs' pick was constructed for the lock in question, which had twelve slides.

In operating upon a Cotterill's lock with this instrument, the sliding wires (**e**, **figure 136**) are first all set free. It is then inserted in the lock, and pressure is applied to feel which of the slides bind, when such slide is forced into its true position by the wire in connection with it, and so on with the remainder. The manipulation requires a firm as well as a great delicacy of touch. We are not surprised that Mr. Hobbs did not succeed in picking the lock.

Many of the remarks made in reference to the Bramah lock equally apply to this one. We admit that a badly-made Cotterill

lock is not difficult to pick by a clever lock-picker with an instrument similar to **figure 136**; but a lock with twelve slides and well made, containing both the "ring" and the "double click," we consider sufficiently inviolable for any purpose for which a lock may be required.

We have shown in the course of the work how Bramah's, Chubb's, and Cotterill's locks had been subjected to the severe trial of being operated upon by Mr. Hobbs, who is acknowledged to be one of the most ingenious and clever engineers of the day, and the result of his manipulations in respect to each of them; and also how Hobbs' protector lock had been picked by Mr. Goater. We now come to the affair of Goater's tampering and the defiance lock of Parnell and Puckridge at the Crystal Palace, Sydenham, which will form a contrast to the honorable and open course pursued by Mr. Hobbs in respect to his experiments with the locks before described.

It would appear that at the opening of the Crystal Palace, Sydenham, in 1854, Messrs. Parnell and Puckridge, like many other manufacturers, rented space in the building for the purpose of exhibiting their locks and other goods. Amongst the former was a "Defiance" lock, with a label attached thereto in the usual way, offering a reward of two hundred guineas to any one who should fairly pick it, and a pamphlet was circulated containing the terms and conditions of such trial. The lock was a twelve-inch one-sided rim deadlock, very strongly made, and with the cap-plate perforated so as to show the working parts of the interior, and sufficiently open to allow the hand to pass through. It would further appear from the evidence given at trial which resulted form Goater's conduct, and from Lord Campbell's charge to the jury, that Mr. Goater, who was then a foreman in the employ of Messrs. Chubb and Son, of St. Paul's Churchyard, did in the absence of Messrs. Parnell and Puckridge, and without notice to them, and before and after the hours when the Crystal Palace was open to the public, clandestinely get access to the lock possessed himself of it, and made a key to it. When the trick was sufficiently ripe for execution, he (Goater) addressed to Messrs. Parnell and Puckridge the following letter:--

"Saturday, August 5th, 1854.

"Gentlemen, –I beg to acquaint you that I am prepared to put the bolt of your lock back this 5th day of August; and hope to

meet you at the Crystal Palace this morning between the hours of eleven and twelve of the clock.

"I am, Gentlemen,
"Your obedient servant,
"J. GOATER.

"To Messrs. Parnell and Puckridge."

Messrs. Parnell and Puckridge having discovered that the lock had been tampered with, refused to submit that particular lock to Goater to experiment upon, but proposed to send to their depot in the Strand for another similar in all respects, which was to be screwed on to a door suited to the purpose; and after adjusting the usual preliminaries, Goater was to be allowed to commence operations. This proposal was declined by Mr. Goater; when, to prevent any misunderstanding, the following notice was delivered to him by Messrs. Parnell and Puckridge:--

"August 5th, 1854.
"Mr. GOATER,

"Sir, –We beg to inform you, that we entirely ignore your proceedings in respect of the attempt to open our lock in our absence, without due notice, and in defiance of the printed terms and conditions, laid down by us, of such trial; and we hereby give you notice, that we are quite willing to submit a lock precisely similar to that with which you have experimented for the purpose of attempting a similar experiment upon, provided that it be conducted in our presence, with due notice, and upon terms and conditions to be agreed; and we shall be prepared to submit such a lock to you on Tuesday next, at one o'clock, p.m., in the Crystal Palace, in such a situation or position as may be determined.

"We remain, Sir, ours, &c.
"PARNELL & PUCKRIDGE."

In accordance with the latter notice, Messrs. Parnell and Puckridge attended at the Crystal Palace with the second lock and their friends; and "Mr. Goater and the Messrs. Chubb were at their stand in the building, but did not come forward." In two days afterwards Mr. Goater send to Messrs. Parnell and Puckridge the following answer, which was inserted in the public papers:--

"Parnell's Patent Lock Picked.
"6, White Lion Buildings, White Lion Street, Petonville,

"August 10, 1854.

"Gentlemen, -On Saturday last I fairly picked your 'Patent Defiance and National Lock,; at the Crystal Palace, in the presence of several witnesses; for picking which particular lock you affixed a label offering 200 guineas reward. I then and there again offered to pick the same lock in your presence, and before some hundreds of persons then present.

"This offer you cowardly declined, and dishonorably refused to pay me, a working man, the reward I had earned; and then you took away the lock and label amidst the groans and hootings of spectators.

"Mind, I do not decline your present challenge; but until the 200 guineas you owe me are paid, either from your own sense of justice, or the compulsion of a verdict of a jury, I decline having anything to do with Messrs. Parnell and Puckridge. I confidently appeal to a host of gentlemen connected with the Crystal Palace Company, who were present on the occasion, for the truth of what I state.

"I am, Gentlemen,
"Your obedient Servant,
"JOHN GOATER.
"Messrs. Parnell and Puckridge, 52, Strand."

Messrs. Parnell and Puckridge replied to the above in the following letter, which was inserted in the Daily News and Morning Advertiser of August 12th:--

"Parnells' Patent Defiance Lock has not been picked and is unpickable.
"52, Strand, August 11, 1854.

"To Mr. John Goater, Messrs. Chubb and Son, Lockmakers.

"Sir, -Your very specious but lame reply to our challenge will not serve the purpose you desire.

"What you assert and wish the public to believe you have already done fairly, surely you can do again. You must admit that you did not even 'put back the bolt' of our lock in our presence, much less 'pick the lock fairly' before us.

"Why decline to pick any other lock than the one referred to by you? Which, be it remembered, had been without its cover

plate, and unprotected in any manner, exposed openly upon our stand in the Crystal Palace for a considerable time, you and others having ready access thereto, if you chose to violate propriety and our exclusive rights by trespassing upon our property. Moreover, it was from off that particular lock that you admitted having broken the label referred to, not while operating on Saturday morning (the time you stated you proposed to 'put back the bolt of our lock,' not pick it), but previously to Friday morning,' for it was only upon Friday morning that we found that that lock had been removed from off our stand, opened, chipped, and scratched all over, bearing strong and unmistakable evidence of having been opened and worked upon, and the label forcibly broken off from it, evidently with a view to render it more portable and the easier to be removed from our stand, or probably out of the building, without exciting observation.

"That you broke the label off that lock was admitted by you.

"That on Saturday, when we received your note at 10 o'clock appointing 11 to 12 o'clock the same day, for the purpose, as you state (of putting back the bolt of 'your lock'), we believe we saw at once the explanation of the extraordinary state in which we found our lock on the previous day, and but for going to the Crystal Palace on Friday morning last, we might, in our confidence in the sacredness of our stand and the goods thereon after the ours at which the attendants leave, and before the usual hour of their admittance in the morning, have been in ignorance of; and but for which we should have been ready to fall into your proposition and plan.

But upon entertaining the suspicion that something most unfair had been practiced upon us, and which suspicion we considered was confirmed afterwards, determined us to act only under advice, feeling that you were not, by your own admission, entirely free from the suspicion which we saw good reasons for entertaining, and we would ask any honorable and disinterested man if he does not agree with us that under those circumstances you were not in a position to persist in your attempt, and that we were justified in objecting thereto.

We cannot but remember that the temptation of 200 guineas is great to any working man; moreover that the opportunity of asserting even for a short time, and without regard to truth, that the Defiance lock had been picked, is probably a greater temptation to a rival patentee and lock manufacturer whose locks have been picked. If you have no other object to serve than that

which you stated, why did you not rather accept the proposition that we should send to our shop in the Strand for the fellow lock, which you could not be charged with having tampered with, or making instruments representing the key, from having had access to the working parts of the lock? And if you had succeeded in picking that lock, the matter would have been set at rest on Saturday last. This, we felt assured, would have been done by any competent person who had confidence in his ability to pick our patent Defiance lock.

"In conclusion, we beg to remind you that our object is not an idle display or desire to figure unnecessarily in print. The extent of our business demands our whole time; our object is to defend our property from unfair and improper attacks; and our confidence, as well as that prat of the pubic generally in the high character of our locks, has been increased rather than diminished by your conduct towards us and our lock.

"We are, Sir, your obedient Servants,

"PARNELL AND PUCKRIDGE."

We extract the following from a pamphlet on this subject, published by Messrs. Parnell and Puckridge:--

"The effrontery and indecency of this letter require no comment; every man expresses himself in the language congenial to his temper and habits.

"We are amazed at any person of character or respectability countenancing Mr. Goater in this attempt to cheat us of two hundred guineas. There were some who appeared to us to approve of his conduct, and who assisted, we understand, in aspersing us, and circulating injurious reports.

"A very unfair and damaging notice of the proceedings having been furnished to the public papers by interested parties, our friends, seeing the inevitable tendency of any further discussion to degenerate into personal altercation, and fearing lest from the general persuasion of mankind, that where much is positively asserted something must be rue, we might be injured in our business, advised us to require Mr. Goater to retract and apologize, and in default of his doing so to bring an action against him. Mr. Goater having declined, on the contrary persisting in his injurious statements, we commenced proceedings at once.

The case was tried at Guildhall, before Lord Chief Justice

Campbell and a special jury, on the 21st of December, 1854. The defense was rather remarkable. Mr. Goater, who was examined, told by the jury he had not seen our notice requesting of the public not to touch the goods, nor our pamphlet (though we were distributing it generally at our stand) wherein we distinctly stated preliminaries should be settled with us, nor our printed preliminaries (which some days before his exploit one of his employers, Mr. Charles Chubb, procured for us at our depot, 52, Strand). Of these Goater never heard. However unaccountable and suspicious it may seem, he saw nothing on our stand but the lock and label. None so blind as those who do not choose to see. The charge of his lordship on this part of the defense renders any comment form us superfluous.

"He also attempted to persuade the jury he could pick any lock as well as ours, but after four months' preparation he altogether failed to satisfy the jury either that he had fairly picked or could fairly pick our lock. Exposed as our lock was, any ordinary workman, provided with an uncut blank key, by removing the cover-plate and cylinder for a few minutes(and we are sure our lock was taken to pieces by some one) could complete a key in a few hours. A key could, without very much mechanical ingenuity or skill, be made to any lock under similar circumstances.

"Even the clap-trap operation of making a key in open court to one of our small inferior locks was but a sham and a deception. This lock was in his possession for several months, and he had his supposed blank ready prepared, but which, with becoming gravity of course, he passed through the ceremony of smoking at the candle. He might as well have dipped it in the Thames.

"If Mr. Goater could pick our lock by this simple process, how can anyone give credit to certain stories about convicts, trained and skilled in all the mysteries of smoked blanks and skeleton keys, being offered a free pardon and a reward of £100 if successful in picking inferior lever locks, and after months spent at it, giving up the attempt. (See Chubb's Pamphlet on Locks.) Mr. Goater is a very clever and ingenious mechanic; he prides himself on his powers of lock-picking. He showed very great ingenuity in picking some of Mr. Hobbs' Protector locks, before the late improvements in them. We are well aware of his capabilities; and, in his assault on us, he had more than one motive to stimulate him to put forth his whole strength. In case of success, the honor and glory of crushing us –the advantage to

his employers from an unwelcome competitor being pushed out of the way –and the premium of two hundred guineas; and, in case of failure, damages, costs, and loss of character. He failed. If success were possible he would not have failed.

The trial above refereed to took place as stated, the following account of which we here copy from the Daily News of December 22, 1854:--

“COURT OF QUEEN’S BENCH, DECEMBER 21."

“Sittings at Nisi Prius at Guildhall, before Lord Campbell and Special Juries.–Parnell and another v. Goater –The Battle of Locksmiths –Alleged Libel.

“Sir F. Thesiger, Mr. Montagu Chambers, and Mr. Needham, appeared for the plaintiffs; the Attorney-General and Mr. D.D. Keane represented the defendant.

“This was an action for an alleged libel published in the Morning Advertiser, reflecting on the characters of the plaintiffs, the proprietors of a patent lock called “The Defiance Lock,” brought by them against the defendant, as the writer of the article complained of, a workman in the employ of the Messrs. Chubbs, the patent lockmakers, and who, it will be remembered, had succeeded in picking the lock constructed by Mr. Hobbs, the American.

“The plaintiff, Mr. Parnell, stated that his firm had exhibited their lock in the Crystal Palace, and appended to it a label offering a reward of 200 guineas to any one who should succeed in opening it. Goater, the defendant, superintended the stall kept in the Crystal Palace by the Messrs. Chubbs, and had therefore many opportunities of seeing the plaintiffs’ lock. On the 14th of July the defendant came to the plaintiff, and after some conversation remarked it was foolish to offer the reward, for they would surely have the Yankee, meaning Mr. Hobbs, down upon them, as he would do anything for money; to which he had replied that anyone was welcome to endeavor to pick the lock, subject to the preliminaries. Goater then went away.

On the 4th of August, having gone to the Crystal Palace, he found that someone had been tampering with the lock. It had been misplaced; the iron stay by which the label offering the reward was attached to the lock was broken, the skeleton cover-plate had been removed, and had been but partly screwed on again, and there

were marks of fingers and thumbs on the interior works. On the following day a note was sent by the defendant to plaintiff's shop, in which he stated he was prepared to pick the lock, and hoped they would meet him at half-past eleven that day. On receiving the note he went down to the Crystal Palace, where he arrived about half-past eleven, before the doors were open, as it was a Saturday. The defendant asked him if he had received a note from him. He replied he had, and asked him if he meant what he had written. The defendant said he did, and that he had prepared all his instruments for the purpose, on which the plaintiff observed that the lock had been previously tampered with. The defendant said he had broken off the label in getting out his instruments. He also said he wanted nothing for doing it, nor did he want to make it public, and that if the plaintiff would take the lock into Mr. Deane's room he would show him how he could pick it. Mr. Charles Chubb subsequently said that Goater could do it, and that he had himself found a way by which the lock could be made undeniably safe. The plaintiff then said he did not believe that either Mr. Chubb or his man could pick the lock fairly; on which Mr. Chubb replied –'By G— he had seen his man do it four times.' The plaintiff then said –'They ought to be ashamed of themselves; for they had no right to touch the lock without observing the preliminaries.'

Mr Puckridge, the other plaintiff, and Mr. W. Smith, C.E., then arrived, and Mr. Charles Chubb and Goater kept calling on them to allow Goater to try to pick the lock. The plaintiffs offered to have a lock brought from the Strand and put on a door, when Goater might attempt to pick it; but that offer was declined. The lock was then wrapped up in paper, and sealed up. Goater than said –'He had fairly picked the lock, and that they would not pay him the reward, and that he was prepared to do it again, but they would not let him.'

The plaintiffs had subsequently examined the lock more closely, and found that some instruments had been used on the lock. There was also a spot of tallow grease on the inside. The plaintiffs sent the defendant a notice that they repudiated his attempt; but they were prepared to submit another lock for trial, and would attend at the Crystal Palace for that purpose on Tuesday, the 8th of August. They went to the Crystal Palace in pursuance of that notice, but neither the defendant nor Mr. Charles Chubb attended.

"Cross-examined. –He had published two editions of a pamphlet descriptive of the lock; the first edition was withdrawn

on the 14th of July. He had placed 500 copies of the second edition on the stand and in the safes which they exhibited in the Crystal Palace. He had told Mr. Deane that the conditions had not been complied with, and he said he did not know of any conditions. He had never examined the lock with a candle, and would swear positively that when it was put up in the Crystal palace the spot of grease was not on it.

"Mr. Puckridge, the other plaintiff, was then called, and corroborated his partner's account of the interview with the defendant and Mr. Charles Chubb in the Crystal Palace.

"–Tebbutt, who had charge of the plaintiff's stand in the Crystal Palace, proved that about ten o'clock one morning, about a fortnight before the 5th of August, he saw Goater and one of the firemen, named Perry, at the plaintiff's stand. After some conversation about the reward, Goater got a chair, and touched the cylinder of the lock with something like a key. He was not up a second when he got down, and said he could pick that lock in six hours, but as he was a friend of Mr. Parnell's, he would not wish the witness to mention what he had said.

"Cross-examined –The defendant had advised the plaintiffs in a friendly way to take the lock down, for the offer would surely be taken up. He should say he had not seen any of the pamphlets containing the conditions on the title page prior to the 5th of August.

"Mr. William Smith, C.E., was then called, and proved the state of the lock when it was examined in his presence, after it had been tampered with as alleged, and as to which he had given a certificate.

"Mr. William Cooper, the superintendent of the Crystal Palace, deposed that, soon after ten o'clock on the morning of the 5th of August, the defendant expressed a wish that he should go to the stand of Mr. Parnell to see him open the lock, on which the witness asked if the parties belonging to the stand would be present. He said he had sent a boy with a letter, asking them to be present, but he wished him to see him do it before they came, as he had already opened it that morning. He then showed witness the key or instrument with which he had opened it, and which he said he had made in five hours.

"The plaintiffs' foreman proved the state of the lock when it was first placed in the Crystal Palace, and the condition in

which it was on its being examined by the plaintiffs and others.

"The printer's foreman deposed that 500 copies of the second edition of the pamphlet were delivered to the plaintiffs on the first of July.

"A copy of the Morning Advertiser, containing the alleged libel which the defendant admitted he had written, was then put in evidence. It ran as follows:--[See Goater's letter, dated August 10th, at page 736]

"The Attorney-General, on behalf of the defendant, said that though he was only a workman, he might, like love, laugh at locksmiths; he would call him to prove that he had never removed the lock, or had acted in any way that was unfair; and he would also show to the jury the very simple process which he had adopted, and by which he had succeeded in opening them much vaunted lock of the plaintiffs.

"John Goater, the defendant, was then called. He said he had been for 27 hears foreman to the Messrs. Chubb. Mr. Charles Chubb was not a partner. On the 27th of July, his attention was first called to the lock in the Crystal Palace. There had previously been a smaller one there. Mr. Parnell never at any time gave him a pamphlet. He had told the plaintiff that either he or Hobbs would pick the little lock; and he replied he had nothing to fear, as Hobbs had had it in his possession for eighteen months, and failed. He never removed the lock from the plaintiff's stall. He had never removed the cover-plate, nor had he unscrewed it. The defendant then exhibited to the jury the very simple but most ingenious process which he had adopted.

He first took a small till lock manufactured by the plaintiffs, and measured the keyhole. He then obtained from a wooden model a blank key made of brass, which he blacked by means of a candle. He then inserted it, and the smut was removed in those places where each impediment met it, which portion was filed away, and the process having been repeated, a perfect key was obtained. The entire operation, including the filing of the key, occupied six minutes, and the defendant stated he cold pick four locks in the same time, but he felt nervous on the present occasion.

"Mr. Chambers suggested that this lock had not the recent improvements.

"The Attorney-General said that the defendant would pick the

same lock that he had picked at the Crystal Palace, if they got an assurance that it was in the same condition as it then was.

"The plaintiff said it was, with the exception of an alteration of one of the levers.

"Lord Campbell–That may alter the whole.

"Mr. Chambers–Whey did you alter it?

"The Plaintiff –To present it to him to pick in Tuesday, if he could. (Laughter.)

"Lord Campbell –Did you give him notice of the alteration?

"Plaintiff –We told him we would be prepared to meet him. (Laughter.)

"Lord Campbell (to defendant) – Do you undertake to pick any lock?

"Defendant –I undertake to pick any lock, it is a matter of time.

"Mr. Chambers –Can you pick your master's, Mr. Chubb's lock?

"Defendant –That is also a matter of time, but not so easily as I can Parnell's. (Laughter.)

"The defendant further stated that, on Thursday, he took the model, and on Friday he could have picked the lock but the instrument required some trifling alteration, and on the following day he opened the lock in the presence of several persons employed in the Crystal Palace. He had broken the stay to the label accidentally, and had at once given information of it to Mr. Cooper, that the officials might not be blamed.

"Cross-examined. –He had told Mr. Chubb that he intended to pick the plaintiff's lock, but he had advised him not to do so. He then said to Mr. Chubb that if he prevented his trying he would leave him. He had picked Hobbs' lock, which was wrapped all up in paper, the keyhole only being exposed. He spent five or six hours in manufacturing the instruments, at a cost not exceeding 20s. altogether. He cold not pick Chubb's lock by the same process.

“Several of the employees in the Crystal Palace were then called, and proved that they had seen the defendant open the lock. One of the witnesses stated there were only four firemen in the Crystal Palace, and they who had the entire charge of the building were on duty for twenty-four hours at a time in rotation. Some of the witnesses said they saw no pamphlets on the plaintiffs’ stand.

“Scientific evidence on the subject of the similarity of the principle in the large and smaller lock having been given,

“The Attorney-General summed up the defendant’s evidence; and

“Mr. Chambers then replied on the entire case.

“Lord Campbell, in summing up, said the question was not whether Mr. Parnell’s lock was capable of being picked or not. If they thought it could be picked, that would entitle the defendant to their verdict. He must say he thought the defendant had not acted rightly in operating on the lock clandestinely and behind the backs of the plaintiffs. Having accepted the challenge, he should have given fair notice of his intention. The fist count charged the defendant with breaking into the plaintiff’s stand in the Crystal Palace, and damaging their property; to which he pleaded leave and license. On this point the jury would say whether the defendant was at that time aware of the pamphlet containing the conditions; for, if so, he was bound to go to the plaintiff’s depot, and have the preliminaries settled, before he commenced operations on the lock. The second count charged the defendant with slandering the plaintiffs; and the third charged a written libel. They had the evidence of the plaintiff that the lock was safe until the 4th of August, when he discovered it had been tampered with by someone. The defendant pleaded that he had fairly picked the lock; and, taking all the facts into consideration, they would say whether the lock had or had not been fairly picked.

“The Jury found for the plaintiff on the first issue, as they considered the defendant had not the leave or license of the plaintiffs to enter their stand in the Crystal Palace; secondly, that the defendant had obtained wrongful possession of the lock; and thirdly, that he did not fairly pick the lock.

“Lord Campbell.–That is a verdict for the plaintiffs. Now, gentlemen, you must assess the damages.

"Mr. Chambers said he would be satisfied with such damages as would carry costs.

"The Jury then awarded damages of £10 on each count."

The following extract is from Messrs. Parnell and Puckridge's pamphlet before referred to:--

"We do confess we are elated at this result. Mr. Goater's audacious assertion, that he had fairly picked our lock, is disposed of; and we commit ourselves and our adversaries to the judgment of the PUBLIC. As to the question whether the Defiance lock is capable of being picked, our answer is, 'Let it be done.'

"In conclusion, we return our thanks to our competitors in business, who would not countenance shabby, unbecoming tricks, and were willing to give us their valuable assistance in exposing them. Fair, open rivalry in business, we rejoice to think, does not, except in some individual instances, extinguish the amenities of society, or dispense with the proprieties of trade.

"Some, perhaps, may be curious to learn what part Messrs. Chubb took with their foreman. We can only tell what we know. Mr. John Chubb attended the court the whole of the day during the trial, and assisted in conducting the defense, and Mr. Charles Chubb was present on the 5th of August, at the scene at the Crystal Palace; he was Mr. Goater's bottle-holder on the occasion; he urged him to enter our premises and take possession of our lock, and operate on it (that is, open it with a key made in the manner so properly condemned by Lord Campbell); he remonstrated violently with us before everyone present, and upbraided us for not giving Mr. Goater the premium; and he announced openly that Mr. Goater would not want money, for he could get £500 in ten minutes to carry on the war with us. Moreover, the Wolverhampton Chronicle has given up the Messrs. Chubb to us as the parties requiring the insertion of the article headed, 'Scene at the Crystal Palace,' that gave a very incorrect and highly colored account of what took palace, and which went the rounds of the provincial papers.

"Now, notwithstanding Mr. Charles Chubb's assertion as to the defendant Goater being able to pay £500 to 'carry on the war against us,' the defendant, upon being defeated, retreated, and up to the date [February 5th, 1855] of this pamphlet has not paid the costs and damages in thie action."

The last lock-picking experiment we have to notice is one that took place during the present year (1856) in America. The lock operated upon was one of Day and Newell's Parautoptic Bank Locks, described at page 470. The simple circumstance was announced in the papers, when the following particulars appeared in the Banker's Circular for June 22nd, 1856:--

"PICKING EXPERIMENTS ON HOBBS' LOCKS.– The following paragraph, copied from the Ilion Independent, having gone the round of the papers, shows that great interest is still manifested in the American lock question. An explanation of what is termed 'Mapping the Lock' may therefore not be unacceptable. But first, as to the report itself:--

"'THE HOBBS' LOCK PICKED. –The Ilion Independent asserts that the Day and Newell Lock, manufactured at New York, commonly known as the "Hobbs' Lock," has at last been picked by Lynus Yale, jun., of the adjoining village of Newport. It says –"The exact modus operandi of picking the lock of course is not expected to be made known to the public just at present; but it is sufficient to say that by a singular and ingenious method, the action of the key upon the curves and tumblers of the lock is mapped out, from which a wooden key is made, which unlocks and locks the lock, and in all respects operates on it as perfectly as the true key."'

The method of mapping the tumblers is here treated as a mystery, but any person acquainted with the mechanism of locks may understand how it is accomplished. With an instrument made for the purpose, a little printer's ink, or other suitable material, is deposited on the tumblers in such a manner that the next time the proper key is used, the ink is distributed along the edge of the tumblers at distances corresponding to the several lengths of the bits or steps of the key. The lock being thus prepared, the proper key must be used, which, of course, can be done only by the proprietor, or others possessed of it.

After this, access must again be had to the lock, and a key-bit made of wood, cut to suit the curve of the tumblers, and covered with paper, must be inserted into the keyhole. This instrument being pressed against the tumblers, takes an impression from the ink previously distributed by the proper key, and thus shows the form of key that had been just previously used in the lock. It is about a year since this method of experimenting on the American Bank Lock was first made known in

England by Mr. Hobbs. It is evidently another application of a method long since practiced to obtain a mapping of the tumblers by means of smoke, to prevent which a ring or curtain placed round the keyhole. Farther, on this new experiment being made, an additional precaution was taken by adding what are termed 'wipers' to the ring; and as this piece of mechanism both precedes and follows the key along the edge of the tumblers, it of course renders it impossible to get an impression. Such a precaution, indeed, was almost unnecessary; for though the process of mapping may be successful as an experiment, performed by leave of the proprietor, it could not, under any circumstances, be accomplished without the proper key being used in the course of the operation, as described above."

We have in the course of this work fulfilled our promise to fully explain the several modes of picking the various locks, and we have done so in the spirit of the great naturalist Reaumur, so that those who use locks should be made aware of their weak points, as well as the thieves who make such defects their constant study. We cannot teach these clever rogues more than they already know, but manufacturers may often learn a great deal which they never knew before from these professors of the locksmiths' vocation.

This leads us to notice a way of opening Chubb's combination latch, which we omitted to state when describing it (at page 417). When it was first told to us we felt amazed at the simple mode, and now state it in order that a remedy may be applied, or the use of it discontinued where real security is desired. The combined latches, or the levers which when combined form the latch, are secured when the latch is not required to act by a pin or cotter which goes right through the cap, the latches or levers, and the case. To open the latch when locked, from the outside, a hole is drilled with a centre-bit, or even a gimlet, through the front of the door over this pin-hole, and then the pin being out, a knitting-needle or any other similar instrument is then inserted into the hole of each lever in succession till it has gone through all, when by its aid the latch is lifted out of the catch and the door opened.

That the Lock Controversy has produced good effects must be admitted by all parties, even by those whose reputation as "lights" in the trade has been somewhat diminished; and if it is continued in an open, honorable, and generous spirit, further improvements will be the inevitable result.

Ignoring motos, "No friendship in trade," and "Two in trade can never agree," we would suggest that all connected with "the art and mysteries" of the locksmith's profession should act as friends and by that 'generous rivalry' consistent with such a feeling, endeavour to produce such well-constructed articles as should entitle England to be considered as the first country in the world for meritorious inventions in locks and keys. We are sorry to say that the custom is sadly too general, when one inventor or manufacturer has produced anything better than his brethren in the craft, for most of the members of the same body to unjustly criticize it and knowingly misrepresent it.

We hope, however, to see a higher principle manifested for the future, by giving to every man his due, and that others will disclaim all title to be considered as the only inventors of merit, and that they will also discontinue assuming that position in the trade which undoubtedly belongs to other, though humbler members. We do not object to one maker trying to pick another's lock, so long as it is done in a proper spirit and openly, in accordance with the term we have before used, and which fully expresses our meaning, namely, "generous rivalry." Though it may not be possible universally for "each [to] esteem other better than himself," still all who desire to be considered as honorable and respectable members of the commercial community could not lose caste by adopting such an exalted principle of action.

In closing this chapter we wish it to be particularly understood that the liability of a good lock to be picked by the professional and scientific operator and the practical thief cannot be placed on the same footing. The former understands the principle of the lock he is about to experiment upon, the peculiarity of its construction, and its weak points, and he has generally a duplicate lock (though of a different combination) of the same make and size by him, to assist him in his manipulations.

He has the opportunity of carefully preparing his instruments beforehand, and if he breaks them he can repair them and again resume the task. He operates with the assistance of the light of Heaven, and he has no qualm of conscience to make him nervous, nor the fear of detection and consequent punishment to hurry him in the performance of the feat; whilst with the thief nearly all the circumstances are the reverse, and before he has the remotest chance of picking a good lock he has first to discover who's lock it is; and there are now so many locks of the various patentees which have the keyholes of the same size, that in the absence of

the key the interior of the lock must be minutely examined before the particular make of the lock can be known.

In most cases the principal essential in effecting a robbery is TIME; and we have before had occasion to remark, that whatever contrivance necessitates more time being requisite to effect an opening into any repository, in the same degree does it add to its security, and this is especially the case with respect to the picking of a lock. Only add the slightest limb to a lock, or alter its construction in the smallest degree, and place it in the hands of the most scientific and expert operator, and tell him it is such and such a lock, and he will in vain try to pick it, though he might have picked dozens of the same lock before. Mr. Hobbs states the reason why he did not succeed in picking Cotterill's lock at Manchester to be this very circumstance, viz., that the lock was somewhat differently constructed from those locks he had before seen on the same make.[8(538)]

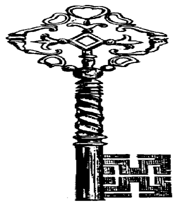
CHAPTER EIGHTEEN: On Keys

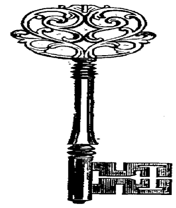
In most of the locks in general use, the key is the only part that is *seen,* or that has to be *handled.* In the earliest examples of metal keys great variety of form has been given to the bow or handle. The first bows were of the ring kind, as shown in Nos. 1, 2, and 3, figures **69**, **70**, and **71** respectively. Next came those of the shape of figures 72 and 73, and other similar forms.

In the sixteenth century, when lock-making had risen to such a state of perfection, the key-bows were generally elegantly decorated in patterns more or less intricate, and of artistic design in proportion to the destination of the lock to which they belonged (see figures **74** and **75**).

Whether it was for common security, or was affixed to the magnificent cabinets of the middle ages, the locks and keys of which are so elaborately worked, and as beautiful in detail as the furniture to which they were affixed, all were more or less unique in shape, forming a strong contrast to the plain and

unique in shape, forming a strong contrast to the plain and unseemly rings subsequently adopted.





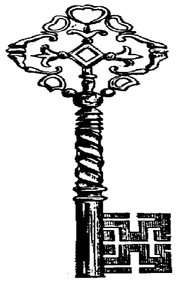


Figure 286.

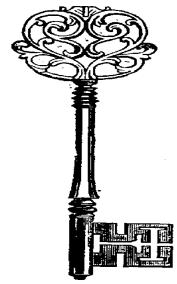


Figure 287

"One of the great reasons of the excellence of much of medieval design was that, in almost all, the manufacturer was led to take a personal pride and interest in the productions of his establishment, and frequently in the emulation excited by the admiration and approbation of his guild."

Those old trade associations did an infinite deal of good; they maintained feelings of benevolence one towards another; they led to sociality and the exercise of much charity; they assisted in rewarding the industrious apprentice and in punishing the idle; they prevented the admission of quackery and uneducated professors by regulating the qualifications to the practice of their trade; and in all these several ways tended to elevate the social position and self-respect of the tradesman as tradesman.

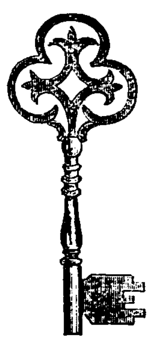


Figure 288.

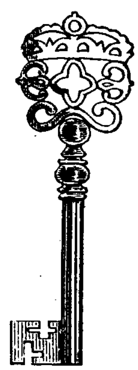


Figure 289.

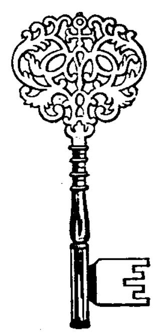


Figure 290.

Now, when too many of our manufacturers go with the hounds, shoot in Scotland, send their sons to Oxford, and teach their daughters that inanity is refinement, 'sinking the shop,' as it is called, and leaving the conduct of every part of their business (except, perhaps, the financial) to understrappers whom they despise, what chance is there that the branch of commerce they practice can receive any dignity or improvement from their connection with it?

So long as the immediate object of supplying the public demands in the most wholesale way with the cheapest things is carried out, their mission is fulfilled, and every grace beyond that point may, they consider, "'a gang tapsalteery, oh.'"

Most of the following figures have been drawn from old keys, while others have been engraved from the Art *Journal,* five from the *Illustrated Dublin Exhibition Catalogue,* and two (figures 288 and 290) are from the *Journal of Design.* We have attempted to classify them in groups, as it is thought by some that from the generic character of the designs they were produced by various members of different and distinct families.

One style of work belonged exclusively to the members of one family, whilst another style was the invariable production of the members of another family. We believe this was so, and that the "filing and finishing" of these exquisite bows were confined to a very small number of artists.

We think it more than probable that the whole of *the finest* antique bows were elaborated by *steel toy and watch chain makers,* as the only individual now in Wolverhampton, who professes to file and *finish first-class* fancy bows, is by trade a steel-toy maker; and his father and grandfather were also in the same business.

The expression "filing and finishing," must be understood to include the entire elaboration of the bow, which consists of first drilling the perforations, and then finishing as desired with very fine small files and a graver. The key is then "casehardened" by the usual process, and is hence called a steel key.

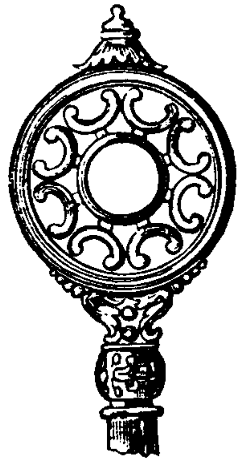


Figure 290A.

Some of the modern fancy bows are produced from *dies by* the stamping press. Figure 290 represents a bow of this description.



Fig. 291



Fig. 292



Fig. 293



Fig. 294



Fig. 295



Fig. 296



Fig. 297



Fig. 298



Fig. 299



Fig. 300



Fig. 301

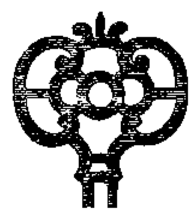
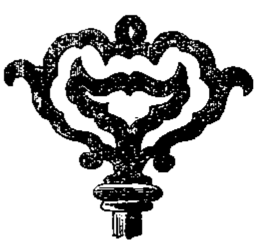
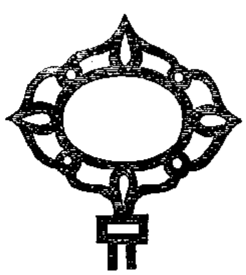
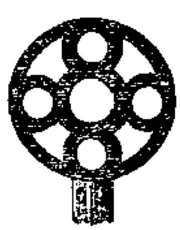


Fig. 302









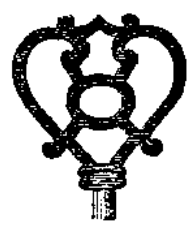


Fig. 303 Fig. 304 Fig. 305 Fig. 306 Fig. 307

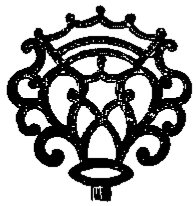
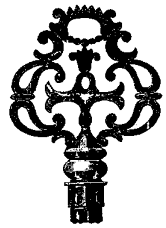
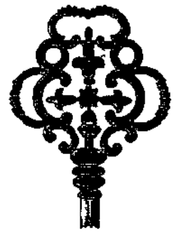
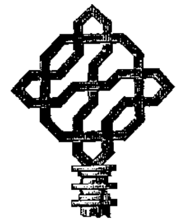
    

Fig. 308 Fig. 309 Fig. 310 Fig. 311 Fig. 312

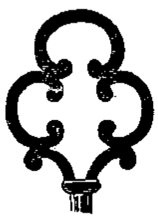
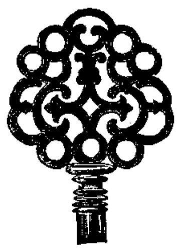
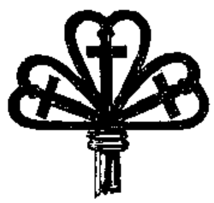
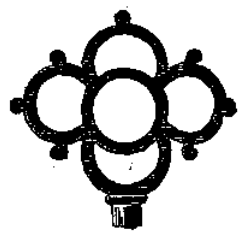
    

Fig. 313 Fig. 314 Fig. 315 Fig. 316 Fig. 317

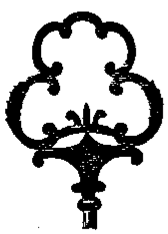
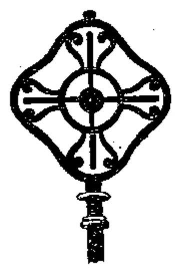
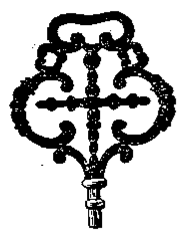
    

Fig. 318 Fig. 319 Fig. 320 Fig. 321 Fig. 322

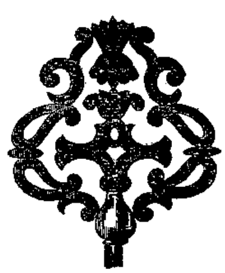
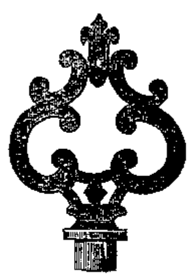
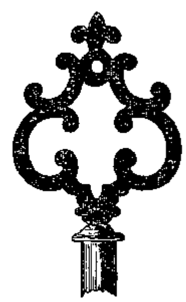
    

Fig. 323 Fig. 324 Fig. 325 Fig. 326 Fig. 327

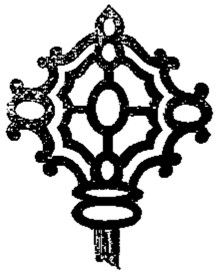
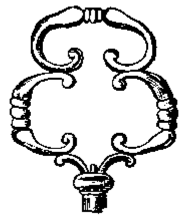
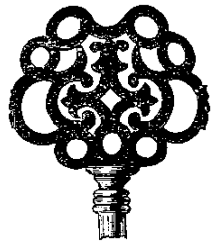
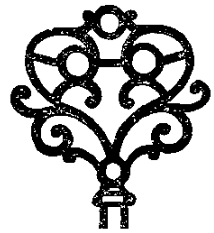
    

Fig. 328 Fig. 329 Fig. 330 Fig. 331 Fig. 332

Fig. 333 Fig. 334 Fig. 335 Fig. 336 Fig. 337

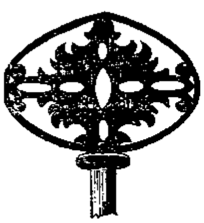
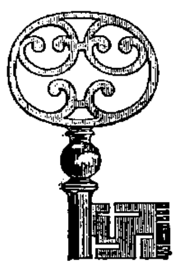
    

Fig. 338 Fig. 339 Fig. 340 Fig. 341 Fig. 342

Figures 286, 287, 289, 340, 343, and 344 are from the originals at Marlborough House. We are of opinion that these, together with the whole of the preceding specimens (with two or three exceptions) are of English workmanship of the sixteenth and seventeenth centuries. Figure 343 was originally brought from Penshurst.

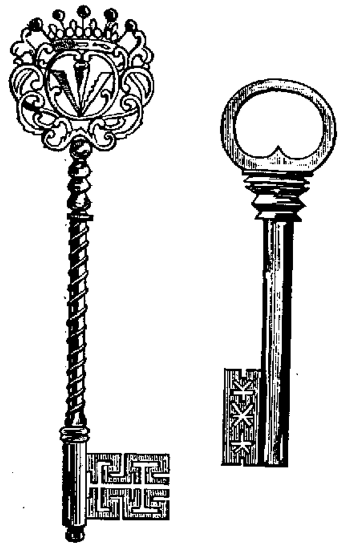


Figure 343. **Figure 344.**

Figures 345, which is drawn half the size of the original, represents a noble outer-door key, that belonged to the old Town Hall of Wolverhampton.

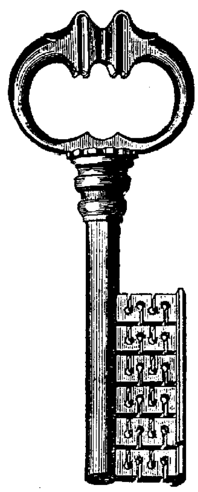


Figure 345

The bow, although of a bold character, corresponding with the office of the key, is not inelegant in form. The particular construction of the lock it belonged to is unknown; but we are of opinion that all the locks containing such intricate and numerous wards were constructed similar to the spring locks of the present day, in which the key *does not* perform *a* revolution.

On no other hypothesis could such wards be placed in the lock;

and that all the wards represented in the keys of these antique locks were really contained in the locks is evident from the specimens in the collection at Marlborough House.

Figures 291 to 299 inclusive and figures 301 represent fancy bows of a very early date, and serve to mark the period when the ordinary ring was changing to a shape of an ornamental character. The same idea appears to have suggested the whole of the examples in this group.

Figures 302, 304, 305, 306, 307, 308, 309, 316, 317, 318, 321, 323, 329, 332, and 339, are all of a similar character, being composed of scrolls, curves, circles, and lines, and show what pleasing designs may be obtained by a tasteful combination of such simple figures.

Figures 312, 318, and 323 represent modern bows, which have a very pleasing appearance, and are the design and workmanship of Mr. Henry Yates, lock manufacturer, Wolverhampton.

Figures 333 to 338 and 342 are unquestionably the production of one individual. The figures are ingeniously introduced into them, and stamp them with a character peculiar to themselves. The freedom of these designs prove it was no ordinary artist that "filed them out." The whole of them, with most of the previous and following specimens, may be studied with advantage.

Figure 344 represents a key with a bow very plain and simple, yet exhibiting artistic feeling in the design.

Figures 354 is a good specimen of a foliated bow; the scrolls are tastefully introduced and agreeably disposed.

Figures 356 is another bow with foliage introduced, and is very pretty. Figures 341 is unique.

As plain examples notice seven figures, 300, 313, 319, 324, 326, 327, and 330, which are formed of three elliptical curves, than which nothing could be more simple.

Figures 328 is the only example of its style, as besides its beautiful form, the scrolls are chased.

Figures 315 and 331, composed of scrolls and ornament, have the appearance of net work, a style peculiar to the bows of the seventeenth century. The center of each of these examples, as

will be observed, partakes of the form of the cross; and this was a very common ornament at the time in question. The same characteristic is observable in the bows represented by figures 310, 311, 314, 320, 322, and 325.

Figures 351 is a beautiful design from Feuchere, but it is too elongated and is more suited for a *whip* handle than the bow of a key, which should always have a considerable breadth *across* the bow.

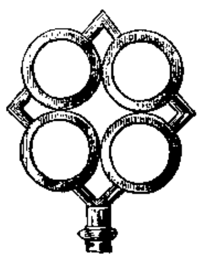
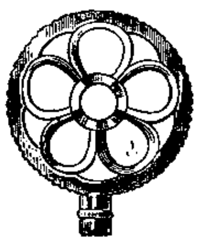
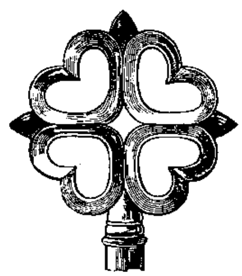
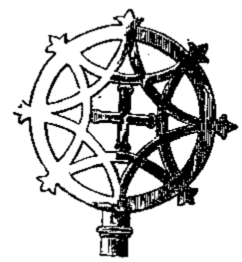
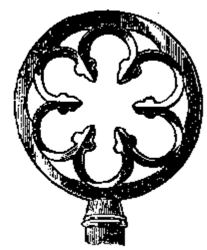






Fig. 346 Fig. 347 Fig. 348 Fig. 349 Fig. 350

Figures 346 to 350, which are of Gothic design, formed part of Messrs. Chubb's collection exhibited at the Great Exhibition of 1851. Messrs. Chubb and Son have devoted much attention to the improving of key-bows which may be described as restorations, for by taking the best antique models, they have in some instances improved upon them, and have thus substituted forms of much elegance for the ungainly shapes of later times.

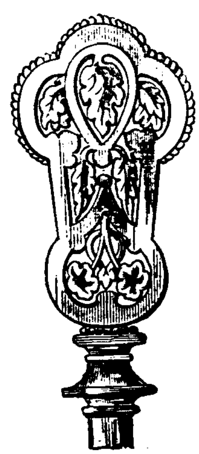


Figure 351.

Figures 353, 356, 357, 358 and 359, without explanation, would be supposed to represent the handles of *keys,* but we think it only

right to mention that they represent *skewer* handles, as manufactured by Mr. Penny, London, in electroplated metal. We were so struck with the beauty of the designs and their applicability to the more refined and honorable office of key-handles, that we could not refrain from copying them from that truly admirable and art-instructive work, *The Art Journal.*

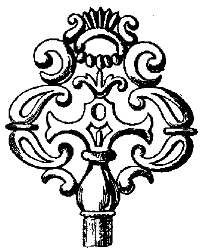
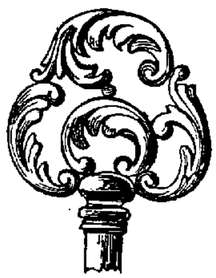

Fig. 352


Fig. 353


Fig. 354

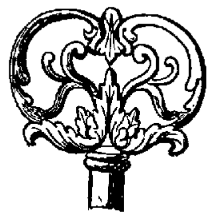

Fig. 355


Fig. 356


Fig. 457

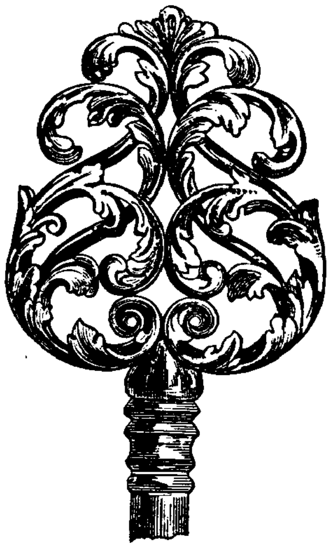

Fig. 358

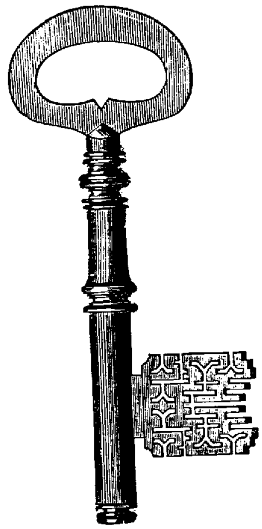

Fig. 359

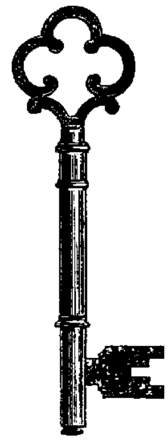
Figures 352 represents a bow more massive than most of the preceding examples in the same class. It appears to have been a favorite design two centuries ago.

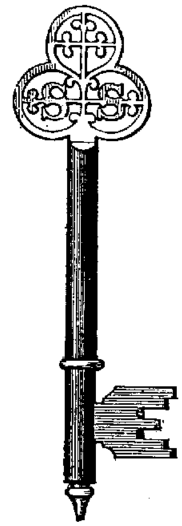
Figures 360 represents the bow of a chamberlain's key of office, and is an elegant example of *gilded German work.* The foliated ornament forming the bow is most skillfully disposed. The original key is at Marlborough House.

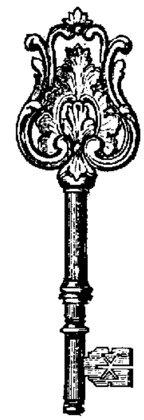
From these beautiful specimens of the sixteenth century, the bow gradually degenerated in design until it again assumed its primitive form, the common ring, when within the last few years, and more especially since the Great Exhibition of 1851, considerable advances have been made towards attaining the same perfection in the design and workmanship of fancy key-bows as prevailed several centuries ago.


Fig. 360


Fig. 361


Fig. 362


Fig. 363


Fig. 364

Figures 361 represents a noble key drawn half the size, belonging to a lock with most intricate wards, manufactured by Mr. James Gibbons, jr. of Wolverhampton, but we think the bow might have been much improved.

Figures 362, 363, and 364 are by the same maker. Figures 364 represents a key with a beautifully embossed bow in or-molu. All these belong to *two-sided* locks.

We had wished to have given more examples of these art specimens of the lock trade, but our space forbids. We had intended to have given also a few examples of ornamental locks besides the one which is by Mr. James Gibbons, jr. of Wolverhampton, but the same cause prevents us. The specimen referred to is a very creditable and beautifully executed piece of work in *blued-steel.*

Mr. F. W. Fairholt, in a communication to the *Art Union* of March, 1846, on "The Industrial Arts in Paris," makes the following remarks on the subject of "key-handles:"

"In the present day, our characteristic utilitarianism has bestowed the greatest possible attention on the wards of the lock, and that part of the key which opens it, to the nearly total neglect of the handle. It would be folly to quarrel with such an arrangement, because the principal object is considered; but it is not, therefore, to be denied that an extra trifle in outlay should not be bestowed on the key-handles, more

particularly as they are often left in the locks; and, as in most instances they are too small to admit the hand in turning them therein, the more reason is there that the oval space be filled with some ornament which should please the eye, and would really at the same time afford a firmer and better hold in turning than the open band of steel now so universal.”

"If the cost of the work be objected to, or any elaboration of design scouted as unnecessary, this, after all, will not defend the thoughtless monotony of our ordinary key-handles, because designs as simple might be found, still exhibiting artistic feeling and some taste in construction.”

"I should, however, imagine that a little extra outlay would be well laid out by the manufacturer in this one branch of our trade, for people will generally buy what is good; and certainly nothing in the way of elegant improvement is made in vain in England. The public generally appreciate and purchase such things in preference to others of less excellence. And surely we are not less likely than our ancestors were to secure for our best cabinets and choicest cases articles combining utility and tastefulness at the same time."

After giving numerous examples of antique key-bows, several of which we have copied in the preceding pages, he says,

"I close a subject that would admit of many more examples being given; my object has been merely to show that as the handle of an ordinary key does not admit the hand, it would really be a more serviceable thing if filled with ornament, which would give a firmer hold in turning it, and render an article of utility also one of ornament, and this at an outlay that would well repay itself.”

“It is surely worth while in these days of improvement to look well to all these things, as the public eye is open to their appreciation; and now a reaction is taking place, and the enriched style of internal decoration in use by our ancestors is being so much adopted by ourselves, it would be worth the attention of the manufacturer to supply the market with characteristic accessories."

We quite agree with the above remarks, and it will doubtless as much surprise Mr. Fairholt as our readers generally to be told that even were the public willing to pay for ornamental bows to their keys, there are no artists now in the trade who could

elaborate such specimens as shown in figures 74 and 75, and other inimitable specimens which may be seen at Marlborough House.

It is supposed that the ornamental parts in these bows were cut out with a *graver,* and afterwards finished with very fine files. We are of opinion that the keys represented were originals, and that few if any duplicates were made of these or others in the same class. The value of such specimens at the period of their production must have been from ten to twenty guineas each.

It must be understood, as before stated, that the filing of fancy bows is a trade quite distinct from either lock making or key-making; it is of a more artistic character. We must remark that most of the elegant bows exhibited by some makers and so full of work are genuine *antique* specimens soldered on to *modern* stems.

As it may interest some of our readers to know the cost of these ornamental keys, we here give the following table, showing the value of some of the bows before referred to. To these charges respectively must be added the cost of making the key:—

			s.	**d.**				**s.**	**d.**
Figure	300	...	1	6	Figure	335	...	8	0
"	302	...	4	0	"	336	...	8	0
"	304	...	7	6	"	337	...	12	0
"	309	...	12	0	"	338	...	7	0
"	310	...	25	0	"	342	...	7	0
"	311	...	14	0	"	343	...	30	0
"	313	...	5	0	"	344	...	2	0
"	315	...	25	0	"	345	...	S	0
"	317	...	1	6	"	346	...	8	0
"	319	...	5	0	"	347	...	8	0
"	320	...	25	0	"	348	...	12	0
"	321	...	7	6	"	349	...	17	0
"	324	...	8	0	"	350	...	10	0
"	325	...	25	0	"	352	...	25	0
"	327	...	6	0	"	362	...	2	6
"	328	...	15	0	"	363	...	12	0
"	329	...	15	0	"	386	...	14	0
"	331	...	15	0	"	387	...	14	0
"	332	...	12	0	"	388	...	7	6
"	333	...	8	0	"	389	...	12	0
"	334	...	8	0	"	390	...	40	0

We lately discovered Richard Manning,a working key-maker, who

informed us that his father used to make fluted stems to keys more than sixty years ago, by the following process: A hole was first drilled up the stem of the blank key; a *mandrel* of the grooved triangular shape as represented in the cut (figures 76) was next driven up the hole and made to fit quite tight; the key containing the mandrel was then heated, and the stem hammered until the required shape was formed when, after cooling, it was finished by filing in the usual way.

Until lately, if a large door had to be secured by a lock, it was thought that it needs be a *large* one with a corresponding *large key.* This was universally the custom until the plan was adopted of throwing numerous bolts by a knob or handle, as described earlier, and securing these large bolts by a small lock and key. In the former instance, the keys were too large to be carried about the person, except by attaching them to the girdle, or to a chain worn around the neck.

As the convenience of small keys is becoming appreciated more and more every day, we may remark that the key, figures 361, which is drawn full size, is sufficiently large and strong enough to secure any door, however massive; and being so small, it may be kept on the key-ring in the pocket. Besides the convenience of a key so small, the lock is more secure, as it is always more difficult to pick or tamper with a small lock than with a large one.

The smallness of the keys of the locks exhibited by Messrs. Bramah and by Messrs. Chubb at the Great Exhibition of 1851, in comparison with the "ponderous and bulky" key belonging to Day and Newell's American bank lock, appears to have made a deep impression on the minds of the Jury, as it is almost the only point upon which they venture to give an opinion.

The use and advantages of *master* keys are very imperfectly understood and appreciated, otherwise the principle would be more generally adopted. How convenient and pleasant if you have fifty doors of various kinds, whether to rooms or articles of furniture, etc., to carry on your key-ring but three or four small keys, and yet every one of the locks to be different and incapable of being locked or unlocked by each others' keys.

We have in previous chapters treated on the subject of *suite* locks and master keys, and it is upon this principle that the locks are fitted to the various prisons. According to Mr. John Chubb, "two hundred and twenty locks *might* be made with one

keyhole, and a separate key to each, yet having one master key for the whole; but if a greater number was required, it would be necessary to have *two* keyholes."

Mr. Duce, jr. can make a suite of locks, each lock to differ, with master keys to pass the whole, and with but *one* keyhole to each lock, amounting to 1,100.

From the following passage in Dr. Plot's History of Staffordshire, it appears that the locksmiths of Wolverhampton were in the seventeenth century then celebrated for constructing locks in suites:

"But the greatest excellency of the *blacksmiths* profession, that I could hear of in this *county,* lies in their making *locks* for doors, wherein the *artisans* of *Wolverhampton* seem to be preferred to all others, where they make them in *sutes, six,* eight, or more in a *sute,* according as the *Chapman* bespeaks them; whereof the *keys* shall neither of them open each others lock, yet one *master key* shall open them all; so that these *lochs* being set upon the doors of a house, and the *inferior keys* kept by distinct *servants,* though neither of them can come at each others *charge,* yet the *master* can come at them all."

"Beside the *master* turning his key in any of the *servants* locks but once extraordinary, the *servants* themselves cannot come at their *charge,* neither shall the *servant* spoil his key or the lock in endeavoring it; for his, after the *master key* has given the lock a second turn, will only run round in it backward and forward, without either stopping at, or prejudicing it anything."

"Nay so curious are they in *lockwork* (indeed beyond all preference) that they can contrive a *lock, so* that the *master* or *mistress* of a family sending a *servant* into their *closets,* either with the *master key,* or (if they permit an *inferior key)* with their own, can certainly tell by the *lock* how many times that *servant* has been in, at any distance of time; or how many times the *lock* has been shot for a whole year together; some of them being made to show it 300, 500, or 1,000 times."

"Nay one of the chief *workmen* of the *town* told me (might he have *workman's wages)* he could make one should it to 10,000 times. Farther yet I was told of a very very fine *lock* made in this *town,* sold for 20 pounds, that had a set of *chimes* in it that would go at any hour the *owner* should think fit. And these

locks they make either with *brass* or *iron* boxes so curiously polished and the keys so finely wrought, that 'tis not reasonable to think they were ever exceeded, unless by *Tubal Cain,* the inspired *artificer in* brass and iron."

We have frequently in the course of this work spoken of the combinations that could be produced in some locks. The number of possible changes or *combinations is* found by multiplying the terms 1, 2, 3, 4, 5, continually into each other. Thus 1 x 2=2; 2 x 3=6; 6 x 4=24 24 x 5=120.

The changes that can be rung on twelve bells amount to 479,001,600, which is identical with the number of combinations which can be produced in a lock with twelve tumblers or levers. The twenty-four letters of the alphabet admit of 62,044, 840,173, 323,943, 936,000. So does a lock that comprises twenty-four pieces, which admit of the requisite variations in size or shape. Therefore to open a lock by "ringing the changes" would require either a number of keys equal to the number of combinations the lock is capable of, or a key which can be altered to an equal number of permutations.

It is true the very first might be the right one, and it is as equally likely that the lock would not answer to any but the last.

To illustrate the above principle of *combinations,* we will relate an anecdote. A person wishing to dine every day with a small family, happened to drop in when the family comprised six persons besides himself. He asked mine host the amount he should pay him to take up his abode in the house as long as he could place the six members of the family and himself in a different position at the dinner table every day. Mine host thinking it would not be long, named a trifling sum. "Oh, I am quite satisfied," replied the stranger," for I shall now have to sojourn with you for 5,040 days!"

Figures 365, which represents a key with four steps besides the terminal step, is the key of a four-lever lock. The following table shows how the twenty-four changes are produced by the four steps of the key. We will start with the arrangement of the steps as shown, in the cut and numbered 1, 2, 3, and 4 respectively.

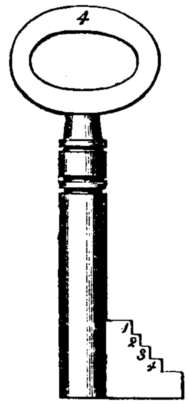


Figure 365.

Now the second combination is produced by simply placing the step No. 3 in the place of the step No. 4, and *vice versa;* and the whole number of the twenty combinations are effected by the simple transposition of which answer to the four steps the four figures, of the key:

SERIES OF 24 CHANGES, FOUR LEVERS IN EACH LOCK					
1st	combination	1234	13th	combination	3124
2	"	1243	14	"	3142
3	"	1324	15	"	3214
4	"	1342	16	"	3241
5	"	1423	17	"	3412
6	"	1432	18	"	3421
7	"	2134	19	"	4123
8	"	2143	20	"	4132
9	"	2341	21	"	4213
10	"	2314	22	"	4231
11	"	2313	23	"	4312
12	"	2431	24	"	4321

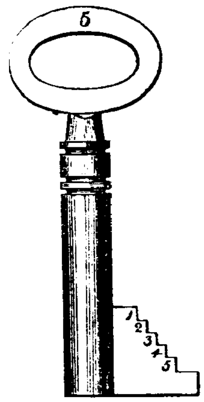


Figure 366.

Figure 366 represents a key similar to figures 365, but with five steps; and the following table shows how the 120 combinations are effected in a lock with five levers:

SERIES OF 120 CHANGES; FIVE LEVERS IN EACH LOCK.

1st combination		**12345**	**61st combination**		**34125**
2	"	12354	62	"	34152
3	"	12435	63	"	34215
4	"	12453	64	"	34251
5	"	12534	65	"	34512
6	"	12543	66	"	34521
7	"	13245	67	"	35124
8	"	13254	68	"	35142
9	"	13425	69	"	35214
10	"	13452	70	"	35241
11	"	13324	71	"	35412
12	"	13542	72	"	35421
13	"	14235	73	"	41235
14	"	14253	74	"	41253
15	"	14325	75	"	41325
16	"	14352	76	"	41352
17	"	14523	77	"	41523
18	"	14532	78	"	41532
19	"	15234	79	"	42135
20	"	15243	80	"	42153
21	"	15324	81	"	42315
22	"	15342	82	"	42351
23	"	15423	83	"	42513
24	"	15432	84	"	42531
25	"	21345	85	"	43125
26	"	21354	86	"	43152

27	"	21435	87	"	43215
28	"	21453	88	"	43251
29	"	21534	89	"	43215
30	"	21543	90	"	43521
31	"	23145	91	"	45123
32	"	23154	92	"	45132
33	"	23415	93	"	45213
34	"	23451	94	"	45231
35	"	23514	95	"	45312
36	"	23541	96	"	45321
37	"	24135	97	"	51234
38	"	24153	98	"	51243
38	"	24315	99	"	51324
40	"	24351	100	"	51342
41	"	24513	101	"	51423
42	"	24531	102	"	51432
43	"	25134	103	"	52134
44	"	25143	104	"	52143
45	"	25314	105	"	52314
46	"	25341	106	"	52341
47	"	25413	107	"	52413
48	"	25431	108	"	52431
49	"	31245	109	"	53124
50	"	31254	110	"	53142
51	"	31425	111	"	53214
52	"	31452	112	"	53241
53	"	31524	113	"	53412
54	"	31542	114	"	53421
55	"	32145	115	"	54123
56	"	32154	116	"	54132
57	"	32415	117	"	54213
58	"	32451	118	"	54231
59	"	32514	119	"	54312
60	"	32541	120	"	54321

On reference to Mr. Parsons' table, the number of the various combinations which may be produced by the different numbers of levers in a lock will be seen at one view. An idea of the immense number which can be made may be formed from the fact that to work out the changes in a lock with 12 levers, and make 10 changes a minute, would require 91 years, 3 weeks, 6 days, and 6 hours to exhaust the variations.

To explain the theory of "working the changes," we will take only seven figures: l, 2, 3, 4, 5, 6, 7.

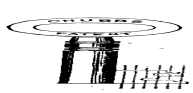
1	2	3	4	5	6	7
3	4	5	6	7	1	2
5	6	7	1	2	3	4
7	1	2	3	4	5	6
2	3	4	5	6	7	1
4	5	6	7	1	2	3
6	7	1	2	3	4	5

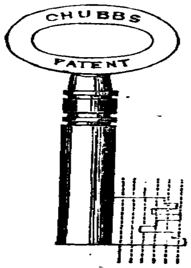
The seven figures are placed in the first horizontal rank in their numerical order. The second rank (the next below the top or first rank) may either commence with 2, 4, 5, or 6, but in our example it begins with 3; the third rank, therefore, must begin with 5, the fourth with 7, the fifth with 2, the sixth with 4, and the seventh with 6.

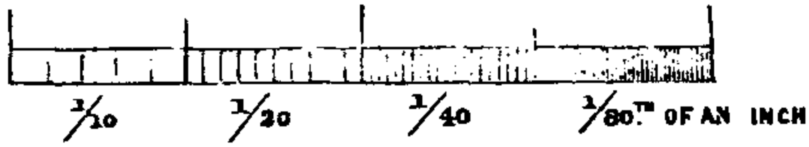
The commencement of the seven ranks being thus determined, the other numbers, as observed, must be written down in the order in which they stand in the first rank, going on to 5, 6, and 7, and returning to 1, 2, etc., until every number in the first rank be found in *every rank* underneath, according to the order chosen at the commencement.

From this arrangement it will be evident that no number can be repeated twice in the same rank, and consequently the seven numbers 1, 2, 3, 4, 5, 6, and 7 being in each rank must of necessity make the same sum.

Mr. Chubb, in his paper before referred to, states that 2,592,000 changes may be effected on the key (figure 367) of a three-inch drawer lock; and we have also heard of locks being made with a variation between their separate combination parts of only one-millionth part of an inch; but all such statements must be considered as figures of speech, and not as facts, as from an examination of the following scale it will be apparent that such niceties in practice are utterly impossible.




CHUBBS
PATENT


1/10
1/20
1/40
1/80TH OF AN INCH

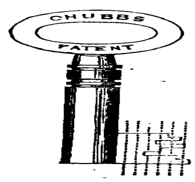


Figure 367. Chubb's Key to a 3-inch drawer lock.



Figure 368-Scale of parts of an inch

Figure 368 represents a scale of 10, 20, 40, and 80 parts to an inch, showing how moderate even the tenth part of an inch is, and that the 80th part can only just be indicated by the graver on the wood block. We do not deny that the above number of changes can be effected on a key sufficiently large to admit of the requisite variations, but we distinctly say that it is impracticable with the key of a three-inch drawer lock, or even with that of a ten-inch rim lock.

The bit of the key represented by figures 367 measures 13/40" from its junction with the stem to the extreme point of the longest step; and the shortest step measures 5/40".

Now it must be borne in mind that whenever a series of combinations is required different from those effected by the transposition of the various keysteps forming the bit, it must be done by *shortening the length of the steps,* but (and this must be particularly noticed) all the steps must be reduced in the same ratio, consequently the key of a three-inch drawer lock to be capable of being reduced, as Mr. Chubb says, twenty times, thereby giving 14,400 combinations, would require the bit to be at least one inch longer than that of the key shown in figures 367.

The shortest step must always be cut at least a sixteenth of an inch from the stem, and the lever which that step is intended to work would remain "dead," or in a quiescent state, i.*e*., both it and the key would cease to be levers in action, as the bit in revolving would merely pass that particular lever without lifting it at all.

On reference to the scale (figure 368), it will be apparent that instead of the step in question being capable of twenty reductions, allowing each reduction to consist of not more than the 40th part of an inch, two reductions would be the most that could possibly be effected, the *extreme* length of the shortest step being but 5/40".

But we go further, and say that these additional combinations cannot be made for practical purposes by reducing the steps as

above described with a variation *less* than the *twentieth* of an inch, and therefore that such a key could only be reduced throughout the six steps it contains once, which with the 720 combinations effected by the transposition of the steps, as shown in the cut, would give 1,440 as the total number of changes such a key is practically capable of with safety.

A few more changes, however, can be made by cutting the deep step right to the shank, and of course all the others in the same proportion; but this is very objectionable, as it separates the bit into two parts, and thus makes it very liable to be broken.

If a lock is *gated so* closely at first that there is no play allowed for the levers, in a very short time the wear of the key, as well as the wear of the combination parts of the lock which come in contact with the *nose* of the key-bit, is quite sufficient to prevent the lock answering to its key. On this account it is the custom with some in the trade, who have given this point due consideration, to leave the gatings of the levers a little wider in the back part to compensate for such wear, otherwise the levers would drop, and so prevent the stump of the bolt from passing through the gating from one rack to the other in locking or unlocking, or the stump would be *dragged* through the main-gating.

For the same reason, it is customary to bevel a little to the side of the stump which enters the main-gating in the act of locking, or to make the end of the main-gating next to the to center of motion a little wider than the other end.

Although the keys are *hardened* after being cut and finished, which makes them of course much harder than the brass of which the levers are made, yet it is the fact that the hard iron key-bit wears considerably more than the soft brass levers; therefore to talk of such close fitting is simply absurd. Like many other theories, it may *appear* feasible, but it is never carried out in practice.

It is found when two keys are stepped to the same lock, with a variation of the 40th part of an inch between the steps on the one key and the steps on the other, that both keys will work the lock. So much for the *theory* of combinations, and now for the manner of properly effecting them in locks.

To carry out the principle of having every lock different requires more care than is usually given to the subject, for

unless a proper system is adopted and a register kept, the same combination is sure to be frequently cut over and over again in the key-bit.

There are two ways of cutting the steps of the key-bit: one by a machine, the other by hand. Those who cut by a machine with reasonable care cannot go wrong, that is, they will not cut a duplicate key unless so required, while with those who cut by hand the same combinations are weekly cut over again.

In some shops different workmen, who have been stepping keys as they thought quite different from each other, have found that the keys passed each others' locks. The men from use, get a certain combination in their minds, which is frequently repeated in the key.

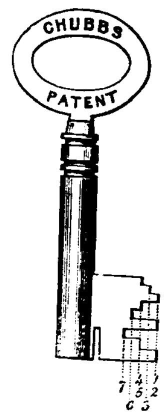


Figure 369 Key to a Chubb's 7-lever Detector Lock

Another serious objection to cutting keys by hand is that two steps in the same key are often cut of the same length, as shown in figures 369, thereby lessening the security of the lock; for, as before shown, if the key-bit has seven steps and corresponding levers in the lock, there are 5,040 combinations; whereas, if two of the steps are alike: that is, of the same length, it would only be equal to a lock with six levers, having 720 combinations; and if two others in the same key were also alike, it would then be only equal to a key with five steps, having only 120 combinations.

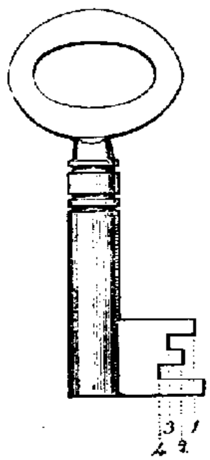
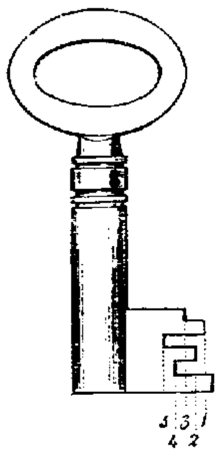
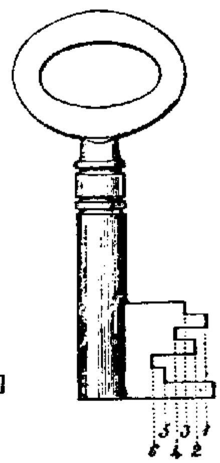
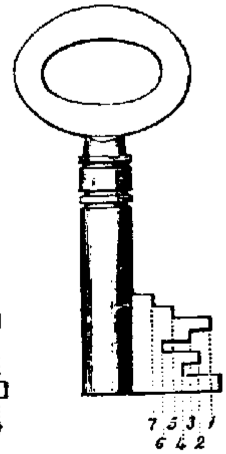
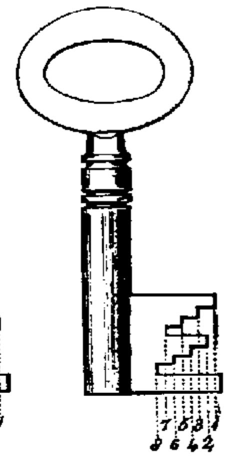
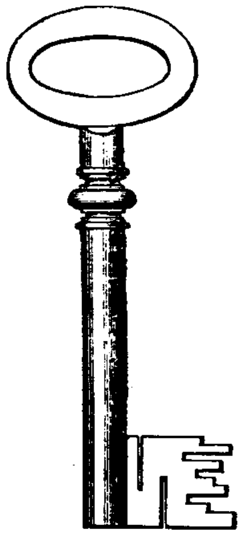






Fig. 370 Fig. 371 Fig. 372 Fig. 373 Fig. 374

The above cut represents a series of five keys stepped respectively for locks with 4, 5, 6, 7, and 8 levers. It will be noticed that in each key, no two of the steps are of the same length, thereby insuring the number of combinations each lock admits of, viz.,

4 levers = 24;
5 levers = 120;
6 levers = 720;
7 levers = 5,040;
8 levers = 40,320 respectively.

Keys with wards and guards cut in the bit, as shown in figures 375 and 376, although they may have the requisite number of steps, can never have produced in the locks to which they respectively belong, the number of combinations they are otherwise capable of, as the *deep* steps cannot be cut in the bit. To effect the true number would require the deep step to go right through the ward.



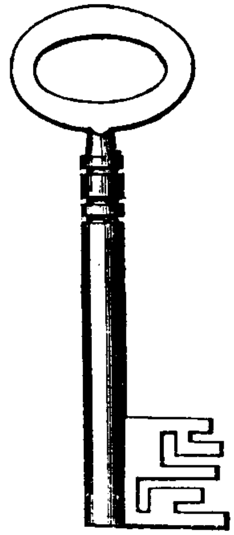


Figure 375 Figure 376

Before closing this chapter, we must notice a great defect in the construction of some makers' keys. A key to a lock with seven levers has eight steps on its bit: seven for the seven levers, and the eighth or bottom step to throw the bolt; and for locks which contain a curtain there is another step at the top, making altogether nine, as shown in figures **369**.

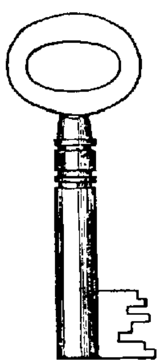


Figure 377 Weak terminal step

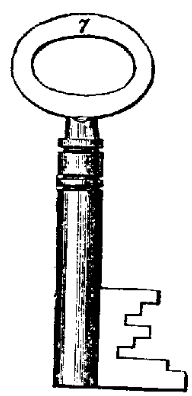


Figure 378 Strong terminal step

Now upon a moment's reflection it will be apparent that the work required from the bottom or terminal step and the others is very different, the seven steps having merely to lift the levers to their positions, while the bottom step by coming in contact with the talon of the bolt has to move it backwards and forwards in locking and unlocking, the bolt being much heavier than the levers, and its thickness about double that of one of the levers.

For these reasons, the step which moves the bolt should always be double the thickness of one of the other steps, or even more. Figures 377 and 378 will show more clearly what we mean. There is another important reason why the bottom step of a key-bit should be particularly strong, and that is that when a key is dropped upon a hard substance, as a stone or brick floor, and it happens to fall on the bottomor terminal step, it is almost certain to break the end off.

With one maker's locks, some of which we have used, from this cause we have often had keys returned to us with just the point broken off the bottom step, and have had to supply new ones. In some cases the piece had broken in the lock.

Another defect in some makers' keys is that the *nose* of the bit is *too pointed,* as shown in figures 379, which causes the key to wear itself and the levers to a more considerable extent than is the case when the bit is shaped as shown in figures 380, in which the *angles* are only *just* taken off.





Fig. 379   Fig. 380

CHAPTER NINETEEN: The Various kind of Locks and their Comparative Prices

The various kinds of locks may be divided into the following classes, viz.:

1.—Brass cabinet and other best locks.

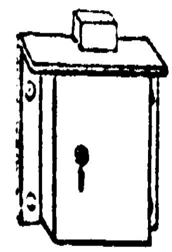
2.—Bright and japanned iron cabinet and other common locks.
3.—Stock or wooden-case locks.

Each class contains many varieties, and there are numerous sizes of most of the kinds, and also several qualities of many of them.

We will first describe the different kinds, and then show in a tabular form their various sizes and prices.

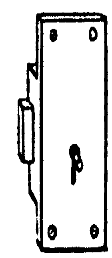
CLASS I. BRASS CABINET AND OTHER BEST LOCKS. This class comprises the following kinds, which are principally manufactured in Wolverhampton:

***Till or drawer* locks**, as represented by figure 381, are used in very large quantities, and are made of various qualities. This figure represents a *cut* till, which is the kind more generally used, but some are also made as the *straight* cupboard (figure 382), and are often used for the drawers of common iron safes. They are also made as *spring* locks, i.e., the lock locks itself by closing the drawer.



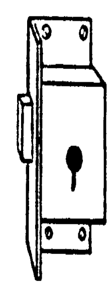
Figure

***Straight cupboard* locks** (figure 382) are constructed for screwing on to the door in the readiest manner, with the flat side against the woodwork, thus causing the whole of the lock to project from the surface of the door. They are made both for right or left-hand doors, as required.



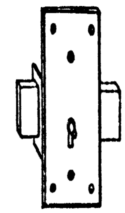
Figure

Cut cupboard locks (figure 383) are the same as the latter, except that a cavity has to be sunk in the door for the case and plate of the lock to occupy, so that the back-plate of the lock is flush with the surface of the door. Both these kinds can be made as spring locks if desired.



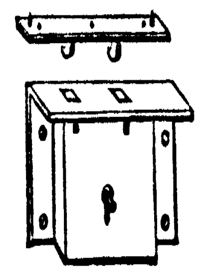
Figure

Double-handed straight cupboard **locks** (figure 384) are so constructed as to do for either a right or a left-hand door.



Figure

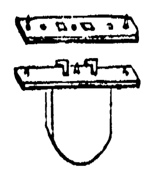
Box and sloping desk **locks** (figure 385) are both made with a link-plate, which is secured to the lid with two or three screws. For a desk which slopes the selvage of the lock-plate is made to slope accordingly. These and all other *link plate* locks, when affixed to wooden articles of furniture, afford no security against violence, as a very small lever or a turnscrew is sufficiently powerful to prize the lid open by drawing the screws out of the woodwork.



Figure

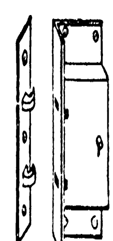
Iron chest locks are of this description, but are made much stronger. *Cash box* locks also are similar, but have generally a nozzle, and the linkplate instead of being made to be fixed with screws, is made so as to be soldered only.

Mortise camp desk **locks.** (Figure 386) These locks have a plate which is screwed to the lid of the desk, as in the last named, but the plate is *without* links. Holes are sunk in the lid where the plate is affixed to allow the bolt to enter and fasten.



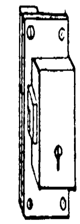
Figure

Pedestal or sideboard **locks.** (Figure 387) These locks are used for the pedestals of sideboards. They are similar to a box lock, but with the keyhole at right angles to the position of the keyhole in a box lock.



Figur

Link-plate cupboard locks *(figure* 388) are made so that the link-plate is fixed to the side of the cupboard at right angles to the bolt and face of the lock. They are used for the wings of wardrobes. They require very careful fitting to make the door and lock work pleasantly. Chamfering the link would be an improvement. The lock is of course let into the door, and made for right or left-hand as required.



Figur

***Traveling desk* locks.** (Figure 389) These are used (as their name implies) for portable or traveling desks and cases.

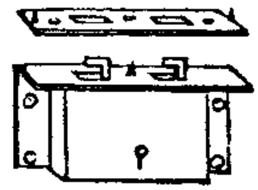


Figure 389

***Mortise box* locks** (figure 390) are of the same construction as figure 385 except that these are of the mortise shape.

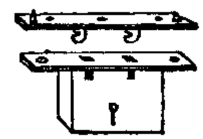


Figure 390

***Flush-bolt mortise traveling desk and pianoforte* locks.** (Figure 391.) These are similar to the locks (figure 386) described before, except that the bolt in these locks remains flush with the selvage of the lock-plate when the lock is unlocked.

Padlocks. (Figure 392) These, as is so well known, are used for carpet and leather bags, and for all other purposes where hasps and staples or chains are affixed to the articles or depositories to be secured.

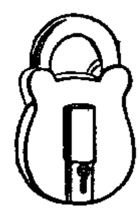


Figure 392

Puzzle or letter locks. *(List* No. 4) These are generally used for carpet and leather bags, and other similar purposes for which the

carpet and leather bags, and other similar purposes for which the ordinary padlock is applicable.

***Portfolio and writing case* locks.** (Figures 393 and 394) These are made either of the form of figure 393, or with a nozzle which projects from the face of the lock, as in figure 394. They are secured to the above-named articles with rivets.

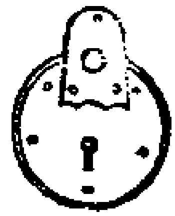


Figure 393

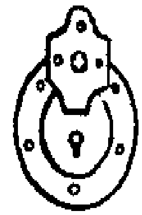


Figure 3

***Trunk and portmanteau* locks** (figure 395) afford no security against violence, the whole of the lock being fixed outside the article it is intended to secure with screws or rivets.

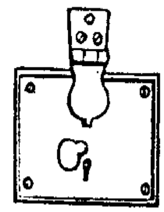


Figure 39

Book-edge or ledger locks. (Figure 396) These are made with a spring-bolt to lock itself on the book being closed.

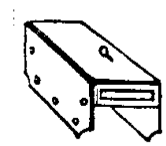


Figure 39

***Carpet bag* locks.** (Figure 397) These are constructed so as to be secured by rivets to the iron frame of carpet and leather bags.

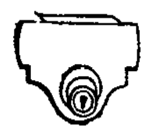


Figure 39

***Letter bag* locks** (figure 398) are precisely of the same construction as the trunk locks (figure 395), but of a smaller size.

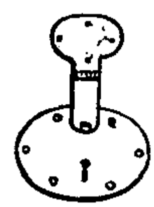


Figure 398

***Escutcheon* locks.** (Figure 399) These are used for securing the keyholes of iron safes, &c., from the prying curiosity of children and servants. (See pages 56 and 322)

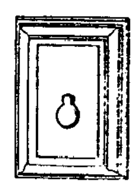


Figure 39

All the preceding locks are made of brass.

Combination **latches** (figure 400) are constructed with a number of separate latches, as described before, which when combined form the latch. They are principally used for street doors.

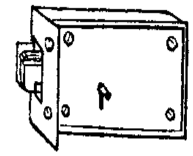


Figure 40

Flush night **latch.** (Figure 401) This is let into the door, and is therefore *flush* with the surface of the woodwork.

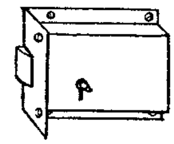


Figure 401

Rim night **latch.** (Figure 402) This is made to screw *on* to the door, and consequently it p*rojects* from the surface of the door as all rim locks and latches do.

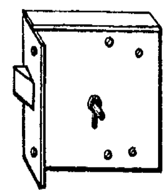


Figure 40

Mortise night **latch.** (Figure 403) This is the same as the two former latches, except that it is mortised into the thickness of the door.

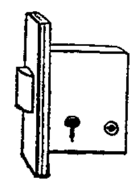


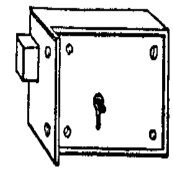
Figure 403

All these (figures 401, 402, and 403) are made to open on the *inside* by drawing back the knob, and on the outside with the key only. They are usually made to spring only, but can, if required, be made to lock as well. There is also a small vertical slide that fits into the bolt, which either fastens the bolt back altogether, or when the bolt is shot out secures it so that the latch cannot then be opened with the key from the outside. They are usually fitted with small keys, and are much used as night latches for street doors, having superseded the use of the insecure *French* latch.

Rim dead lock, to lock on one side only. (Figure 403) This is

Rim dead lock, to lock on one side only. (Figure 403) This is constructed with one bolt, which can only be shot out and in by the key—hence called a dead lock.

Rim dead lock, to lock on both sides. (Figure 404) This lock is constructed in the same manner as the latter, except that it locks and unlocks from *both* sides of the door to which it maybe affixed.



Figure

Spring rim or drawback locks for front doors. (Figure 405) These are constructed with but one bolt, to lock and spring by the key, and to draw back by the knob on the inside. They are principally used for the front doors of dwelling-house, and may be described as extra large and extra strong night latches.

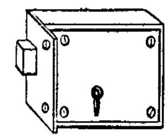
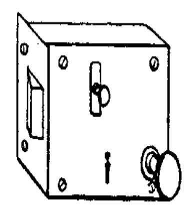


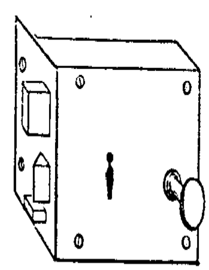
Figure 4(

***Three-bolt rim* locks** (figure 406) are constructed with a spring latch-bolt, which is worked by the knob, a main-bolt, which is worked by the key, and a private bolt, which is worked by a slide fixed to the under-side of the rim when the lock is fixed. This and figures 400, 401, 402, 404, 405, 406 and 407 have the cases made of iron japanned black, but with brass bolt-plates or striking-plates, whichever the locks require, and with other best furniture.



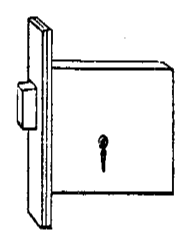
Figure

Formerly *rim* locks were used for the doors of parlours and even drawing rooms, but their unsightly appearance soon caused the substitution of the *brass-cased* locks, which in their turn were superseded by the *mortise* lock, the inventor of which useful and elegant improvement we have failed to discover.



Figure

***Mortise one-bolt dead* locks.** (Figure 408) These are used for the same purposes as the lock figure 405, but in addition are sometimes used as extra locks for the doors of dwelling-houses, &c. This and the two following varieties are *two-sided* locks. It must be particularly noticed that all two-sided locks are not so secure as one-sided ones the number of the levers in each case being equal.



Figure

A *one-sided* lock with five levers is about ten times more secure against being picked than a two-*sided* lock with the same number of levers, as by referring to figures 288, 290, 302, and 304 (pages 758 and 780), it will be seen that the steps in the upper half of the key-bit are precisely the same as those on the lower half; the deep step being in the middle, and dividing the bit into two equal parts.

***Mortise two-bolt* locks.** (Figure 409) These are constructed with a spring latch-bolt, which is withdrawn by the knob; and also one bolt, which is shot out and in by the key. These locks are used for chamber and other room doors.

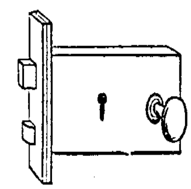


Figure 40

***Mortise three-bolt* locks.** (Figure 410) These are the same as the last described, but with the addition of a private bolt, which can be worked from the *inside* of the room only by turning a small knob; and this bolt secures the door against its being opened from the outside, thereby dispensing with the use of the *main-bolt,* which is moved by the key.

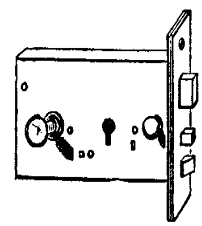


Figure 41

***Mortise drawback or spring* locks.** (Figure 411) These are constructed with but one spring-bolt, but which can be withdrawn by the knob, and locked *out further* by the key; in the latter case, the bolt can only be withdrawn or unlocked by the key.

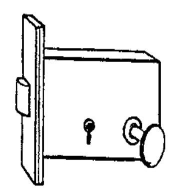


Figure 41

Besides the locks before described, there are many other kinds, as gate locks, alcove locks, "box of wards," which used to be employed for securing the doors of iron safes (see figures **4, 23** and **236**), and "iron door locks, with projecting bit," some of which are also now *used* for the same purpose as the "box of wards." (See b, figure 36). Also spring book-case or wardrobe locks, which are constructed with a knob, and are similar in all respects to the two-bolt mortise lock, figure **409**, but considerably less in size.

There is also another lock used for front doors, called a two-bolt knob or drawback; it contains two *spring bolts,* both of which must be released before the door can be opened. One of these bolts is acted upon by turning the knob, as in an ordinary

rim lock; the other by pulling the knob back, as in a drawback lock. The key releases the drawback bolt from the outside, and also locks it, as in the *ordinary drawback* lock. It is, in fact, a rim lock and drawback lock combined.

From the preceding description of the various kinds of locks it will be seen that rim locks are those which project from the surface of the doors to which they are attached. *Dead* locks are those the bolts of which require to be shot out and in by the aid of a key, etc. *Spring* locks are those in which the bolt locks itself out by coming in contact with the striking-plate. In most door locks there is a *latch-bolt,* which acts in the latter manner. The term rim applies to the *case* of the lock and its appearance when fixed; *dead* to the *action* of the *bolt; mortise* to the manner of fixing it in the woodwork flush denotes that the lock is *let into the woodwork and made flush with the surface.* Figure 173 shows the construction of a rim lock; and figures **270** and **277**, the construction of a three-bolt mortise lock.

A grave defect in most spring locks is that the bolt can be shot back (the lock unlocked) by means of a piece of sheet steel, and sufficient force applied to overcome the power of the spring.

The following summary prices have been taken from the patentees' lists themselves, or have been adapted from the lists of the various makers by reducing the gross to the net cost, and then adding thereto a scale of profit which we consider fair between the purchaser and the retailer, supposing the latter "buys well." But those who are obliged either to take or to give the very long credit customary in some districts, the prices throughout would be higher in proportion.

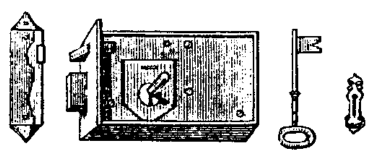
CLASS II. BRIGHT AND JAPANNED IRON CABINET AND OTHER COMMON LOCKS.

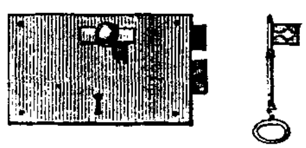
This class comprises a very immense variety, and contains locks suitable for almost every conceivable purpose. For several centuries past these locks have been made by the cottagers inhabiting the outskirts of Willenhall, as well as at Lane Head, Short Heath, and New Invention, within the township.

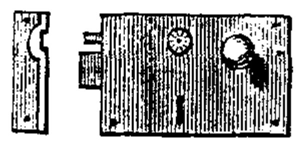
Nearly all the country makers still continue to make these with the same primitive tools that have been in use in the trade from time immemorial, but in the township several manufacturers have adopted the press and steam-power to their production, and the locks of these latter makers are, in consequence, far better

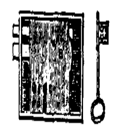
looking than those which are completely made by hand labour. They are made in very great quantities, principally for the foreign market.

An idea may be formed of the character of some of these locks from the fact that *"tumbler cupboard locks"* can be bought *wholesale* at 12s. 6d. per gross. "Chest locks" at the same price, and drawer locks as low as 6s. 6d. per gross, all net. An anecdote is told of a locksmith engaged in making *chest* locks having been visited by a friend in his shop, when the former dropped a lock from his bench, and went on making others without picking the dropped one up; and this being pointed out to him by his visitor, he replied— "Ah! bless thee, I can always make another before that has done ringing" —meaning that he could make another lock in less time than it would take him to pick the dropped one up, or, as he said, "before it had done ringing;" and this is the fact, for whatever number may be dropped in the course of making, they are always left to be picked up when the shop is swept. An apprentice boy will make one gross per day.


Figure 412


Figure 413


Figure 414


Fig

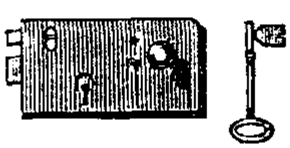
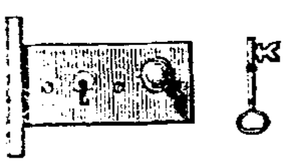
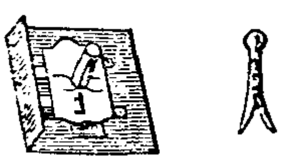

Figure 416


Figure 417


Figure 418


Figure 419


Figure 420


Figure 421

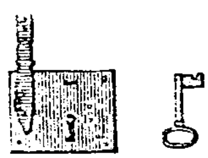

Figure 422


Figure 423




Figure 424

Figure 425

Figure 426

Figure 427
Figure 428

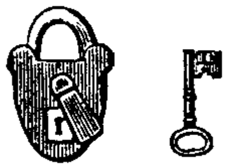
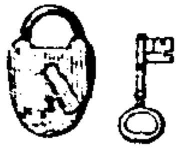
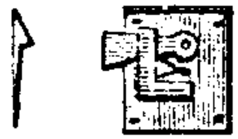

Figure 429

Figure 430

Figure 431

Figure 432

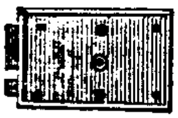

Figure 433

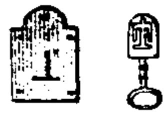
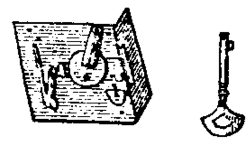
Figure 434

Figure 435

Figure 436

Figure **416.** These are the same as rim locks, but with the angles rounded off:

Figure **417.** A lock is made of this description which is known in the trade as n "four-inch common closet lock," and is sold at 7d. each, or with fine wards at lid. each.

Figure **423.** Best quality lock contains three wheels and hook-ward, strongly made, with double links, well finished, with stepped key. Medium quality lock contains two copper wheels and bridge-ward, fancy key-bit and screwed cap. Common quality lock contains two copper wheels screwed cap, and double hoks.

The same japanned black. Best quality lock contains two copper wheels,, thick drill-pin, S-bitted flat-bow key, double-link, tumbler, and bright brass cap. Medium quality the same, but with a bright iron cap. Common quality lock contains one copper wheel, double-link, tumbler, and japanned cap.

Figure **425.** Best quality lock contains three copper wheels, L-ward, tumbler, broad bolt, screwed cap, and flat-bow key. Medium quality lock contains one copper wheel, broad bolt strongly made, and S-bitted flat-bow key. Common quality contains one wheel and short-bitted key. These locks are frequently sold in sets of five for chests of drawers, with one, two, three, or more keys to the set as required. Per sot of five locks, with two keys, 1s. 1d. per set. If with five loose nozzles for the fronts of the drawers, 4d. per set extra. They are also sold in dozens, with three or four keys to the dozen, and are known in the trade

as "three-keyed till locks." The same kind of lock is also made for the German market with two keyholes, which are suitable either for drawers or cupboards.

Figure **110.** Best quality has two wheels, with T nose, and bridge-wards. Medium quality contains one wheel and nose-ward. Common quality contains one wheel and taper key.

Figure **431.** Common quality is complete with brass furniture and patent spindle plain spring. Medium quality is the same, but with a Scotch spring. Best quality is the same, with bolts.

Figures **432** and **433** are complete with best furniture and patent spindles.

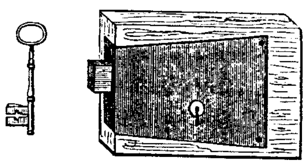
Figure **435.** Common quality is complete with the requisite ironwork. Medium quality contains full wards and an oval-bitted key. Either quality can be had with nuts and screws at 8d. extra.

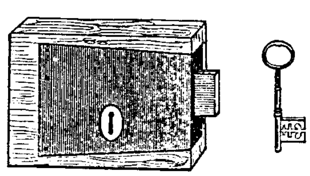
CLASS III—STOCK OR WOODEN-CASE LOCKS.

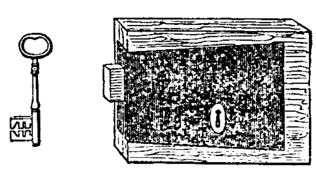
All wooden locks are called "stock locks," from the circumstance of the works of the lock being embedded in a *cavity cut out* of a block of wood to receive them. Besides the following there is another lock of this description called the "Banbury lock," in which the various limbs composing it are fixed *separately* in the piece of wood; whereas in the others the lock is first *made complete on its plate,* which is then inserted in the cavity of the stock prepared for its reception.

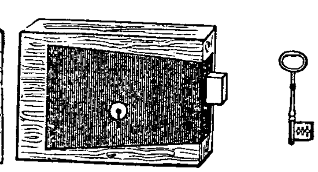
The *Banbury* locks are inferior, and are consequently lower in price than the following kinds:— "Steele's patent" (figures 444 and 451) is simply a *double-handed* stock lock. (See Figure **419.**)

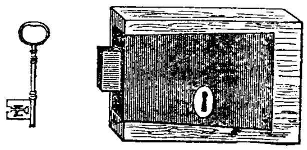
Young's patent lock (figures **450** and **454**) has the chamber for the works of the lock to occupy formed of a circular shape, which is cut out by a tool in a the, which gives the lock a neater appearance.

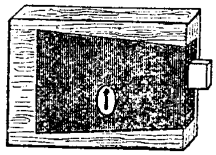

Figure 437

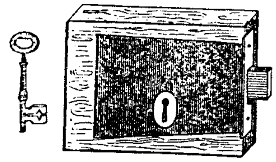

Figure 438

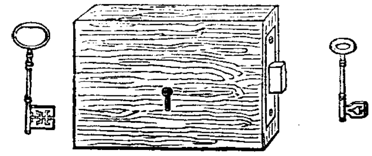

Figure 439

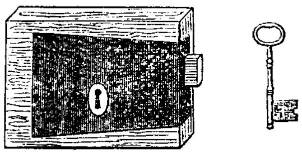

Figure 440

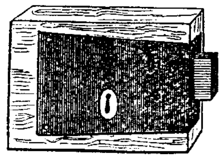

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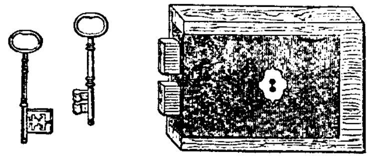

Figure 442

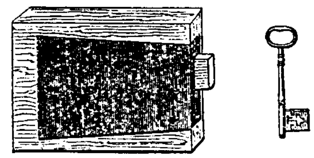

Figure 443

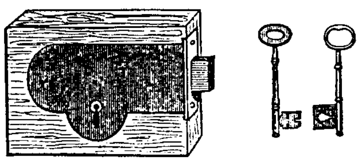

Figure 444

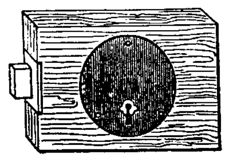

Figure 445

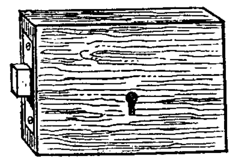

Figure 446

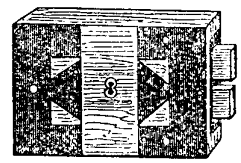

Figure 447

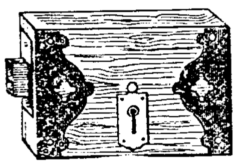

Figure 448

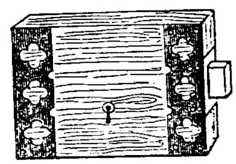

Figure 449


Figure 450


Figure 451


Figure 452


Figure 453


Figure 454

Besides the foregoing "Fancy Plate Locks," there are other qualities known as "Bastard Plate," "Fine Plate," "Best Fine Plate or B 1," "Best Best or B B," "Common Irish," "Best Irish," and "Barrack Irish," all of which are inferior end consequently lower-priced than those described in List No. 10. The three latter sorts are made especially for and are mostly sold in Ireland. Extra best locks are made to order. Larger sizes are also made, which are principally used for church doors. There are various patterns of fancy bars (see figures 452, 453, and 454), which are charged according to the design and workmanship.

Any of the foregoing locks cap have the bar, as shown in figure 453, at 3s per dozen locks extra. The various qualities are subject to the following extra charges, viz., if made with copper wards, 6s. per dozen; if with solid brass wards, 3s. 9d. each if twice dead (ie., the bolt by a second revolution of the key is shot further out), screwed and barred, up to 12 inch, 10s per dozen; above 12 inch, 12s. per cozen; S-bits and ring-keyed, 6s, per dozen, screwing, 2s. per dozen; filling bows with brass, Is.

6d. per dozen; filling bows with iron, 3s. per dozen; if pin-bushed, 8s. per dozen; full-bushed, 10s. per dozen. Extra keys, from ls. to 2s. each.

In figures **437** to **454** inclusive, *which* represents the parts which are of brass; the *dark* shades, bright iron, or iron japanned black, and the grained portion oak.

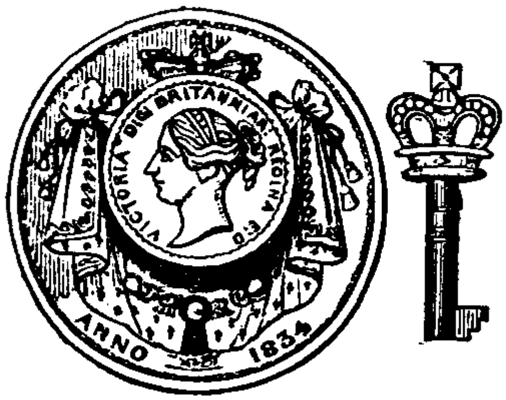


Figure 455

CHAPTER TWENTY: An Historical account of Wolverhampton; its Lock-trade and Locksmiths

It is somewhat remarkable that no historical account of the manufacture of locks, as carried on in England in general, or at Wolverhampton in particular, has ever been published. This is the more surprising, as the manufacture of locks was for several centuries the staple trade of the parish of Wolverhampton, including Bilston and Willenhall. In the few records that relate to Wolverhampton, the *lock trade is* the only manufacture particularly mentioned.

Wolverhampton, which is of great antiquity, was, previous to the introduction of lock-making altogether an agricultural town, and was celebrated for its wool. Its earliest importance resulted from the foundation of the Collegiate Church.

The followings account is taken from a loan of the town, surveyed by Isaac Taylor, and published by Thomas Jefferys, London, in 1751.

"Wolverhampton is a populous town, situated in the southeast part of the county of Stafford, in north latitude 52 deg. 40 min. (as is nearly the whole parish, except what belongs to the Church in the manor of Stowheath, whereof the Right Honble. John Earl Gower, Lord Privy Seal, and Thomas Giffard, of Chillington, Esq., a minor, are joynt lords), and is distant from London 100 computed and 130 measured miles; its present number of houses are 1,440 and inhabitants 7,454."

"This town was first called Hanton by the Saxons from its high situation, then Hamton and Wullfrunes Hamton, and so Wolverhampton, from the Princess Wulflune, its owner, a daughter or sister to King Ethelred, who came to the crown in 979; here she founded a Collegiate Church for a dean and seven prebendaries, an official, and other inferior officers, and to each of these eight she gave a power over his own lands equal to that of any lord of a manor, and to the dean the same power in spiritual matters as any bishop enjoyed, making the whole body and parish subject to him, and him subject to no man's visitation except that of the King, or Lord Keeper of the Great Seal under him. Edward the Confessor made it one of his royal free chapels, and Edward IV., in 1477, annexed the deanery to that of Windsor."

"The present magnificent church, except the chancel, was built by that great mall, Hubert Walter, A.B. of Canterbury, perhaps born here, about the year 1200. He also built proper houses round about it for the dean and prebendaries, etc., all which are long since gone to ruin; but the dean's was rebuilt by Mr. R. Guest, who farmed the excise of Oliver Cromwell, and the chancel by a voluntary subscription collected by the Reverend Mr. Allestree since that time. In 1258 Henry II. granted to the dean a market on Wednesdays, and a fair on the 26th of June; the church being dedicated to St. Peter; but tradition says they were granted by King John, his father."

"The free school was founded by Mr. Stephen Jennings, born here, who was lord mayor of London in 1509; the government and choice of the masters he gave to the Wolshipful Company of Merchant Taylors, of which he was a member. In 1714 they built the present handsome fabrick for a school and houses for the two masters. At present it has one church and three meeting houses for Roman Catholics, Quakers, and Presbyterians, all which will

not contain one-fifth part of the inhabitants, a charity school for fifty boys and forty girls. The iron manufacture and toy trade in gold, silver, brass, mother of pearl, etc., are here carried on, as also at Willenhall and Bilston, in this parish, after the same manlier as at Birmingham, Walsall, etc."

The Rev. Dr. Oliver, in his "Historical and Descriptive Account of the Collegiate Church of Wolverhampton," says— "I am inclined to think that in the time of Wulfere, the town of Hantune, now Wolverhampton, had attained to a good comparative population; which from the building of the church increased gradually to the Conquest; being improved by the weekly market held there which was probably established before that period. But it does not appear to have been a town of general trade in those early times, for in the reign of Edward III. the Nona Roll states that the town had no merchants."

"The alteration which the face of the country about Wolverhampton has sustained from the time when Wulfruna flourished is striking beyond conception. Formerly it was a retired district, abounding in groves and streamlets, and occupied by a pastoral population, who were employed in tending cattle and feeding swine, which latter were herded in innumerable quantities amongst the woods and forests, and collected at night in a place called Swinesta (i.e., porcorum stabulum forte', vel haram), between Wolverhampton and Bilston; while the iron and coal lay quietly beneath the surface, undisturbed by the restless cupidity of man."

The forests were well stocked with deer, and the country intersected with paved roads, and crossed by at least one military way. Numerous small streams irrigated the herbage, and afforded nourishment to the cattle with which the district was stored. At present the herbage and all other natural productions have vanished before the speculations of commercial enterprise, and it has become a region of darkness and steam-engines.

The fitful appearance of numerous detached fires, the hissing and booming of the furnace blasts, the loud and frequent reports like claps of thunder from the iron forges; the dense clouds of smoke which always envelope this sterile tract, intersected by sluggish canals; the abundant population that swarm throughout the district men and women alike habited in the dark livery of the mine-combined with the appearance of total desolation which is everywhere exhibited, overwhelm a stranger with sentiments and feelings which he is at a loss to define; but they are usually a

mixture of pity for the presumed misery and privations of the people, and congratulations on the comparative felicity of his own lot, which has not been cast in such a dreary and inhospitable climate. In reality, however, the situation is perfectly wholesome and healthy, and the people generally, working at good wages, are happy and contented."

The particular year when the manufacture of locks commenced in Wolverhampton or the circumstances which led thereto, will perhaps never be known, but the fact of the iron (which was previous to 1768 all smelted with wood) being of a very superior quality, might have drawn the artisans here, or might have initiated the trade itself.

By the extract from Dr. Plot's "Natural History of Staffordshire," published in 1686, it is manifest that the manufacture of locks was the principal trade of the town, if not the only one, at that period.

Another notice of Wolverhampton occurs in the Harleian Manuscripts, which give an account of "The Voyage of Don Manuel Gonzales (late merchant of the city of Lisbon, in Portugal), to Great Britain; containing an Historical, Geographical, Typographical, Political, and Ecclesiastical Account of England and Scotland, with a curious collection of things particularly rare, both in nature and antiquity." This MS. was written about the year 1732, and was translated from the Portuguese, and printed in Pinkerton's Collection of Voyages and Travels. He says, "Wolverhampton in Staffordshire, about 117 miles from London, was anciently called Hampton, and so large a parish that it was nearly thirty miles in compass, and contained seventeen great villages."

"A priory was formerly built here by King Edgar, as Sir William Dugdale says, at the request of his dying sister Wulfruna; and for this reason the place was called Wulfrune's Hampton, which is since corrupted to Wolverhampton. It stands upon high ground, and is a populous town, well built, and the streets well paved; but all the water the town is supplied with, except what falls from the skies, comes from four weak springs of different qualities, which go by the names of Pudding-well, Horse-well, Washing-well, anti Meat-well; all appropriated to their several uses. From the last they fetch all the water which they use for boiling or brewing in leather-budgets laid across a horse, with a funnel at the top, by which they fill them; and to the other three wells they carry their tripe, horses, and linen.

To this scarcity of water and the high situation of the place is ascribed its healthy state, in spite of the adjacent coal mines; and it is said the plague was hardly ever known here, but the smallpox often, which has been observed to be an indication of the wholesomeness of the air. The chief manufacturers of this town are *locksmiths,* who are reckoned the most expert of that trade in England."

The town (which contained 7,454 inhabitants) had now (1750) become of great commercial importance. It retained its agricultural celebrity, and was the chief town of a district exceedingly rich in those three most valuable minerals: coal, ironstone, and limestone.

Besides the lock manufacture, the fancy steel-toy trade, comprising fine steel watch chains, buckles buttons, ornamental sword hilts, etc., all of which were produced in a costly and superb style, was at its height, and the foundation of all the trades of the ironmongery or hardware line, and of which brass, iron and steel form the component materials, and which latter trades have since assumed such vast proportions, were firmly established.

The following interesting table, which we have compiled from various sources, shows the rapid increase of the houses and inhabitants (Wolverhampton only), at various periods from the year 1750 to 1851:

Year.	**Houses.**	**Inhabitants.**
1750 ...	**1440 ...**	**7454**
1801 ...	**2532 ...**	**12,566**
1811 ...	**2937 ...**	**14,836**
1821 ...	**3612 ...**	**18,380**
1831 ...	**---- ...**	**24,732**
1841 ...	**7481 ...**	**36,382**
1851 ...	**9807 ...**	**49,989**
1855 ...	**---- ...**	**57,000**

The following is the number of houses and inhabitants in each street, in 1750:—

	Houses	**Inhabitants**
Belcroft Street	**24**	**160**
Berry Street, Workhouse, etc.	**91**	**599**
Boblake and Barns Street	**180**	**888**

Cock Street	**43**	**175**
Courts, Alleys, and Back Buildings	**52**	**237**
Bilston Street and Manor Lane	**114**	**784**

From the commencement of the present century Wolverhampton has increased in population, wealth, and importance more rapidly perhaps than almost any other town in the kingdom. Its race of wealthy ironmasters, and factors or merchants, have since the middle of the last century established an extensive trade with almost every part of the habitable world,, and whose industry, energy, and integrity of character are proverbial with the commercial classes in every part of the kingdom, and we may say, almost throughout Europe.

Other trades were now beginning to take root in Wolverhampton. The tin-plate and japan busisnesses which at the present time employ a larger number of hands than any other branch of trade in the town, were about this period firmly established, having been originally introduced about the middle of the last century.

We can only *name* the principal buildings and institutions of this town, as other particulars relating thereto would only be interesting to the inhabitants of the district.

	Houses	**Inhabitants**
High Green and Dudley Street	**214**	**1032**
Horse Fair	**55**	**264**
John Street	**66**	**335**
Lichfield Street	**57**	**228**
London Row	**22**	**148**
New Street	**14**	**77**
Rottons Row	**112**	**527**
Stafford Street and Middle Row	**127**	**718**
Tup Street	**209**	**854**
Worcester Street and Brickhill Lane	**60**	**428**
Total	**1,440**	**7,454**

In addition to the public edifices which existed in 1750 and noticed before, there have been erected since that period numerous temples for the worship of the Most High, as well as schools for the education of the children of the working classes, including a Ragged School and an Orphanage, which latter we take especial pride in naming as the noble and elegant building owes its foundation to the literality of a worthy man, whose father, by trade a keymaker, from the superior excellence of his work,

was called by the trade the "king of the keysmiths." Many a widow and many an orphan will rejoice in the circumstance that the son of such a "king" appreciating the value of a good education which had been purchased by the industry of his revered parent, by the utter forgetfulness of self, should have conferred the blessing of a sound and religious education, together with board, clothing, and lodging, on the many orphans who have already been admitted into the institution.



Figure 456. View of Wolverhampton in 1805. (From Bisset's Grand National Directory of that year.)

The South Staffordshire Hospital, situate in the Cleveland Road, is a fine structure, built in the Italian and Roman Dorie style of architecture. It was built by public subscription, and is supported by voluntary contributions.

The town, which was incorporated in 1848, contains a Town Hall, Public Office, Market Hall, an extensive and well-planned Cattle Market, a Fat Pig Market, a Corn Exchange, a School of Design and Practical Art, a Library, a Mechanics' Institution, a Theatre, Baths, Gas Works, Water Works, and the largest provincial Suburban Cemetery in the kingdom.

The London and North Western, Shrewsbury Birmingham, and Stour Valley Joint Railway station, and that of the Great Western, and the Oxford, Worchester, and Wolverhampton Railway Companies are situate nearly in the centre of the town, and comprise extensive erections. The town has also water communication by means of the Birmingham and Liverpool, the Stafforclshire and Worcestcshire,

and the Wyrley and Essington Canals, with every part of the kingdom.

The town was made a Parliamentary Borough at the passing of the Reform Bill in 1832, which includes Bilston, Willenhall, Wednesfield, and Sedgley, and returns two members.

We could say much more about this growing borough, but our space forbids. As before stated, it was in the sixteenth century that the lock-trade was at its height, not only in England, but also in France and Germany; and though we have no published records which describe the peculiarities of the construction of the English locks of that period, or other particulars relating thereto, yet there are numerous specimens which have been handed down to us which prove the ingenuity and taste of the locksmiths of that time. The ornamental and artistic designs of these locks and keys have never to the present day been excelled. We have, in chapters 13 and 18, given numerous drawings of locks and of the above early date, which will serve to indicate the steps by which such perfection in the art was arrived at.

Although Wolverhampton has always been the great storehouse whence locks were obtained, and is known commercially as the chief *locale* of the English lock-trade, yet it is at Willenhall, a township in the same parish, about three miles distant on the Lichfield turnpike road, that the great bulk of the common locks are manufactured in all their details. The better quality of locks are almost exclusively manufactured at Wolverhampton.

In 1770 there were the following locksmiths in the parish:

Wolverhampton	**134**
Bilston	**8**
Willenhall	**148**

At this period no patent had been taken out for improvements in the construction of locks and latches; nor for anything in any way connected with the trade, although the patent law had been in existence from the reign of James I.

In the year 1855 the number of master locksmiths in business in the district was as follows:

Wolverhampton	**110**
Bilston	**2**
Willenhall	**340**

Willenhall, as before stated, is not only the principal neighborhood for the production of locks and latches, but also for the manufacture of bolts, gridirons, currycombs, etc. Almost the entire population are employed in the various branches of the above manufactures, as up to the year 1844 there were but two inhabitants who were not engaged in business, and these were the clergyman of the township and the Wesleyan minister. At this period (1844) there were neither a resident magistrate, lawyer, or policeman.

This busy hive of the "Sons of Vulcan" has since 1801 increased in population five-fold, numbering now (1856) at least 15,000 souls. These are not all employed in the above trades, as since the mines of coal and ironstone in the immediate neighbourhood have been proved to be so rich and extensive, many of the persons employed in connection with these mining operations reside in the town.

There are, however, at the present time about 340 of what are termed "master men," the greater part of whom are in a small way, employing only a few hands each, and these are mostly apprentices. These small masters having no capital, and being very poor, are compelled to sell the produce of one week's work before commencing the next. They must sell their wares at some price, the principal purchasers being the Wolverhampton factors. This circumstance tends to keep down the price of the various kinds of manufactured goods, and hence the apparent, nay actual poverty of this humble class of manufacturers.

Amongst such a large number of master men, it would be strange indeed if there were none in a better condition; and on a recent visit to the town we were informed that there were a goodly number who had small manufactories, and were in thriving and well-to-do circumstances. Within the last few years numbers of this latter class have erected premises of some pretensions on their own freeholds, several of which are of considerable extent and importance, and far excel all other similar manufactories at Wolverhampton.

One of the largest concerns is that of Messrs. John Harper and Matthew Tildesley, and is called the "Albion Works," where the various kinds of locks described and illustrated in the last chapter, together with bolts, wood screws, etc., are produced in vast quantities. We here inspected many different samples of locks, etc., including patterns of locks, handles, bolts, and

bars used in the plantations of South America, which are made in large quantities, and are supplied at regular periods.

Figures 457 to 462 inclusive represent a set of these latter fastenings, which are larger than any we have ever seen. These figures also form a good illustration of the Willenhall manufactures. Messrs. Harper: and Tildesley are also the sole manufacturers of a patent tumbler padlock (see figure **426**), which is very saleable in the Levant and East India markets, and for simplicity and cheapness is one of the wonders of the age.

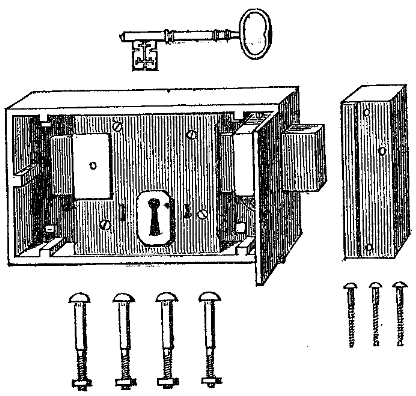


Figure 457

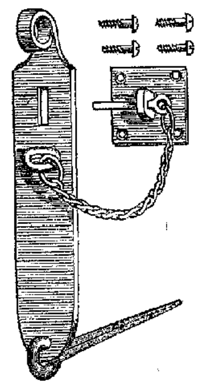


Figure 458

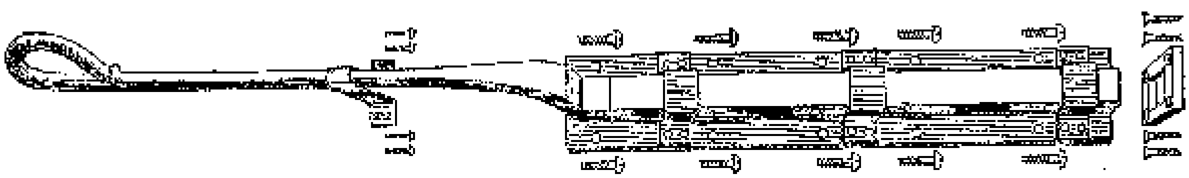


Figure 459

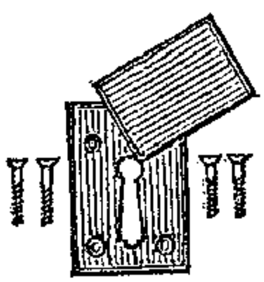


Figure 460

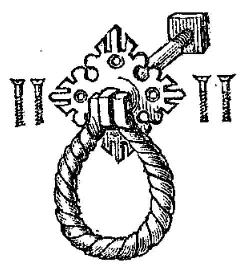


Figure 461

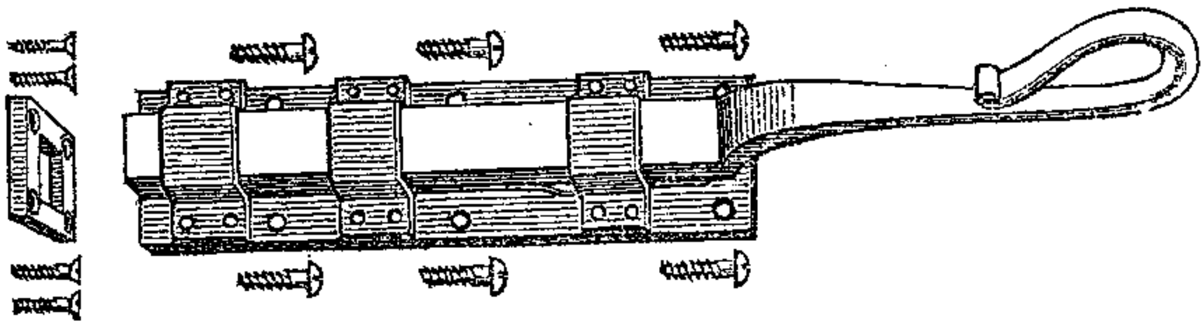


Figure 462

It is without exception the cheapest padlock in the world, as it can be sold retail from one penny each. They have been sold wholesale in quantities varying from five to ten thousand dozens at a time.

Although the principle of division of labour is not carried out to the extent it is capable of in the manufacture of locks and keys, yet many operations are carried on as distinct trades, as for instance key-stamping, pressing, casting, etc.; and it is interesting to note when some of these branches of the trade were first introduced, the circumstances which led thereto, and the results consequent upon their adoption.

We have before assigned as a reason for the establishment of the lock manufacture in this district to be the excellent quality of the iron before it was smelted with pit coal; and it is worthy of notice that many of the Willenhall little manufacturers still use no other than the very best *charcoal* iron, not, as may be supposed, for *best* work, but for many kinds of common locks, &c. A very superior quality of iron used to be made from the "swarf" or filings of iron, and hence called "swarf iron."

This iron was used formerly for all particular purposes in forged work, and even for links for best chest locks. A Mr. Daniel Daker, of Darlaston, used to go round the district collecting the swarf from the locksmiths, which he made into "swarf balls." Mr. Richard Tildesley, a cabinet or bright lock-maker, who died so late as the year 1816, not only used this iron for his "links," but he also bought old horseshoes, from which he made the internal parts of the locks.

The great grandfathers of some of the oldest inhabitants of Willenhall, in their day, had to work down thin iron for "lock-plates," &c., from *bars* which were considerably too large

for their use. Rolls for rolling sheets and plates were then unknown. It was the custom with the masters, towards nine or ten O'clock at night, to say to the apprentices, "Now, lads, leave work and come and strike," which was the process employed for drawing the bars of iron to a proper strength and size for use, as at that period iron was not made as it is now of every size and shape suitable for the various articles it may be required for, and hence called merchant iron. In connection with this subject an anecdote is told of a hard-working man, who had two apprentices and a spendthrift son named Tom. At night he had these two boys to strike the iron in the manner before described, when he (the master) would drop his hammer on the anvil between each blow, which his neighbours said chimed "Dad gets it—Tom spends it." "Dad gets it—Tom spends it."

In bolt-making, about 40 years ago, the plates were cut from sheet iron with a small pair of shears, and the screw and rivet-holes were punched out over the vice. Round bolts were then worked down from square rods; a process also done by a forger and strikers. Padlock shackles were also forged from square rods, and the plates cut into the required form with a pair of shears and a chisel upon the anvil.

Such was the crude method of forming parts of locks previous to the year 1790, when a Mr. Isaac Mason, of Bilston, introduced the present method of *pressing* various parts of locks by means of tools and the ordinary fly press. In the year 1796, Mr. Mason was induced by John Beebee, Esq., a factor, to take up his residence at Willenhall, where he carried on a lucrative business for many years. By the adoption of the press an immense amount of labour has since been saved. To this same Mr. Mason belongs the credit of adopting *cast* iron, both common and malleable, for lock purposes, about the year 1810, but who, after spending considerable sums in trying to produce the iron of a proper quality, finally abandoned the project in 1817.

The lock-makers were then dependent upon Birmingham ironfounders for their malleable iron castings, which were at that period used in very large quantities for Dutch and Spanish locks by Mr. William Badger, and afterwards by John Collett, whose family are still largely engaged in manufacturing common Dutch locks. The great demand for this class of work led Mr. Wells, of Walsall, to commence casting, and the various limbs were retailed by Mr. Joseph Hodson at so much per dozen—not by weight, as at the present time.

In 1830, Mr. Richard Tildesley (son of the Mr. Richard Tildesley before named), then a brassfounder, was the next to make another attempt at casting common and malleable iron for lock purposes, but which, like the preceding one of Mr. Mason, proved unsuccessful.

It was not till the year 1836 that the next attempt to perfect the manufacture of malleable iron castings was made in Willenhall, when the still increasing quantity weekly consumed in the fabrication of the different kinds of locks induced Mr. Richard Tildesley to make further experiments to accomplish this great desideratum; but who, like his predecessor, after spending a considerable amount of money, relinquished further trials. However the circumstance of being still compelled to obtain these castings either from Walsall or Birmingham induced Mr. Tildesley subsequently to try again, when at length his perseverance and labours were crowned with success. There are now (1856) three ironfounders in the township, Mr. Richard Tildesley, Mr. Knowles, and Messrs. John Harper, jun. and Co. We believe this latter firm were the first to produce locks entirely of *cast malleable iron,* and the perfection to which they have brought this branch of the lock manufacture may be estimated from the following figure, which represents a Bramah key as it came from the sand. It is without a mark or blemish of any kind, and the cuts in the barrel are quite perfect. The fineness and clearness of surface and its malleability far surpass anything of the kind we had ever before examined.



Fig

Prior to the year 1806, most, if not all of the keys used in Willenhall had to be forged, as before stated, from "swarf balls," when about this period several parties in Birmingham commenced *to stamp* keys and supply them (called key-blanks) to the Willenhall locksmiths.

In 1810, Mr. Hope, of Compton, near Wolverhampton, also commenced key-stamping, in which he soon excelled all other stampers, and has continued to the present day to turn out very superior work.

In the course of our researches we were shown a list of prices issued in 1810, jointly by the keymakers of Birmingham, John Grimley, William Taylor, and Charles Ash, in which the price of small keys was at that time 4s. 6d. per gross. Now the same sized keys are sold at 1s. 8d. per gross, and if made of malleable iron at 10d. per gross.

For some time, prejudice, that arch enemy of everything that is

new and of every attempt at getting out of the *beaten track,* prevented the general employment of *stamped* keys, but ultimately (1811) one of the above-named persons was induced to leave Bilmingham and commence key-stamping at Willenhall. In 1812, John Grimley also commenced there in the same business, and whose sons and grandsons continue to carry on the trade; so that the laborious and slow operation of *key-forging* soon became extinct, at least nearly so, there being now (1856) but "one" left, and his services are only occasionally required.

"Lock-making, as carried on in Willenhall, is divided into mortise locks, box and trunk locks, cabinet locks, rim locks, bright locks, brass-case locks, closet locks, dead locks, and padlocks, in iron and brass. Except some of the parts of the brass-work, which are cast, the processes by which all these locks are made are forging, pressing, and filing. The forging is a light process of smith's work, affording variety of action in the use of a light hammer, and blowing the bellows. Children and young persons are employed at it. *Pressing* is work done at a press, by which certain parts of the lock are pressed, i.*e.*, stamped or cut out."

"The presses are of various sizes. All require strength; the large ones considerable strength. This press has a horizontal lever, the centre of which (if it have two arms) crosses the top of a perpendicular screw, which is the fulcrum. There is generally an iron weight at each end of the lever, according to the power required. One of these arms of the lever is grasped by the right hand of the presser and whirled round with a jerk, while the fingers of the left hand place the metal to be worked upon, and remove it at each operation. Very often the press has only one arm, i.*e.*, a lever, one end of which is fixed in the top of the screw; perhaps, also, it has no weight at the other end. Children and young persons are employed at it."

"The age and strength of the child, and the power required, as well as the hours of labour, should be properly adjusted, which they very seldom are. Filing is the most general of all the processes, and is prolonged indefinitely, and with scarcely the least variety of action. Children are placed standing upon blocks so as to be able to reach the vice, and set to work with a file almost as soon as they can hold one. Key-making is divided into light forge-work, stamping, piercing, and filing. The forging, as previously described, is light smith's work."

"The process of stamping is effected by placing the end of

an iron wire, taken red-hot from the forge, into one-half of a key-mould, made in a kind of anvil or block. A heavy weight is then raised between an upright frame-work, in the grooves of which it runs (like the knife in a guillotine), by means of a cord, which is drawn by both hands, with the assistance of one foot in a stirrup attached to the end of the cord. At the bottom of this weight, thus raised, there is the other half of the key-mould. The foot in the stirrup being suddenly raised, and the cord loosed, the weight falls upon the red-hot wire, and the blow stamps it into the two moulds, which are brought accurately together by means of the slides or side-grooves in the framework in which the weight runs."

"The rough key is also trimmed and cleared by this stamping apparatus; that is, the surplus metal all round is cut off by a single blow from above, and the metal which fills up the rim or ring is punched, cut, or stamped out by a blow given in the same way. Children never use the cord and stirrup, as they have not strength to raise the weight. It is always done by adults, or by young persons of at least sixteen or seventeen years of age. Children and young persons very commonly do the forgework; the former blowing the bellows, and the latter placing the heated rod in the mould below, either for stamping the key, or trimming, and clearing it.

The *piercing is* making the hole or pipe of the key, which is drilled by a small machine worked with the foot, like a lathe. This is done both by young persons and children, but seldom under eleven years of age, as it requires skill. *Filing is* the process that finishes the key. The wards are cut, and the key made bright entirely with the file. Children and young persons work at this in all descriptions of common keys. Keys that have complicated wards are only entrusted to adults and to apprentices of some years' practice"

We have previously described various improvements which have been introduced from the earliest times to the present day into the manufacture of locks and keys, but it will doubtless surprise many of our readers to find that these improvements are so few in number; but though few, still they have been of vast importance to the trade, and the only wonder is that other improvements, the want of which has all along been so apparent, have never yet been introduced, as for instance the adoption of machinery to do half the work that is now done by hand.

In prosecuting our inquiries in connection with this subject, we

were astonished to find that, at Wolverhampton, the Messrs. Chubb and other large makers should still produce the whole of their work with the same primitive tools which have been in use from time immemorial; they do not employ a single machine, and we believe throughout the trade in this district the only makers who use machines at all are Mr. Duce and Mr. Aubin. That most of the limbs of which a lock is composed are capable of being produced at a much cheaper rate, and with a degree of uniformity impracticable by hand labour, has been lately proved by Messrs. Hobbs, Ashley, and Co., of London, whose machines, invented by Mr. Hobbs, are not only of the most interesting character, but perform their work in the most admirable manner. Mr. Hobbs, who has twice thrown open his establishment for our inspection, and who has in the most unreserved manner given us all the information we required on various matters connected with this subject, and also with respect to each machine, has commenced a course of action, which must ultimately lead to success.

The only doubt we have, is, whether London is the right place for establishing a lock manufactory, as the materials and some of the separate parts of the locks must be had from this district. The operatives, also, must be drawn from this town.

It is almost incredible that even in making "stock" locks at the present time, not a circular saw nor machinery of any kind is used. The cavity for the works of a double-handed lock (Steele's patent) is bored out with a hand auger and finished with a chisel, the block of wood being tightly screwed in a vice. The wood used for these locks is oak (pipe staves), and when Quebec timber is employed, from its hardness and roughness, the labour in working it by hand is very great, yet not a single maker has had the temerity to introduce the circular saw, which in other manufactures has produced such beneficial results. In making the *iron parts,* not even a press is used; all the holes being punched out by hand. The *plates* are cut out by hand also, and the *bolts* are all forged. The principal tools are the shears, file, and punch. The great waste of materials consequent upon such an antiquated system of manufacture is very considerable.

The patentee of a lock, who was not a lock-maker, and consequently had no feeling of attachment for the "things of old," came to Wolverhampton for the purpose of having his locks made, and called upon one of the principal manufacturers for that purpose. Part of the arrangement entered into comprised the purchase of a new and powerful press, which the manufacturer duly procured, and the patentee was shortly afterwards requested to

come and inspect it. He did so, and found to his amazement that it had been constructed out of three or more *separate* parts, bought at as many second-hand establishments. This is an apt illustration of the kind of enterprise the master locksmiths of Wolverhampton possess; and we feel assured that whatever *great* improvements are to be introduced into the trade generally, they will emanate from persons altogether unconnected with the manufacture. Such has been the case with nearly every other manufacture, the particular improvements in which have mostly been the work of inventors not belonging to the particular trade.

If our Manchester friends should become slack of orders we would recommend them to come and inspect the "antique" tools of the Wolverhampton locksmiths, and at once design the machinery which must some day cause a revolution in the lock trade.

The manufactories here are as antiquated as the tools, and are quite as susceptible of improvement. There is only one that has any pretensions to importance, and that is Messrs. Chubb's, in Horseley Fields, which was formerly the old Workhouse.

This, together with all the minor establishments (with one or two exceptions), are ill-contrived low buildings, badly lighted and worse ventilated. The workshops of the humbler masters are regular menageries, dogs being tied up under the bellows; bird-cages hung in the windows; rabbit-pens constructed under the work-bench; pigeons kept outside on the roof. The windows, which act as ventilators in summer, in winter form specimens of *marqueterie* work, made with paper, sheet iron, tinplate, &c. A pigsty under the workshop window and its accompanying tender—the wash tub—near it, with the accumulated dust and dirt of the floor, form the enchantments of a locksmith's shop.

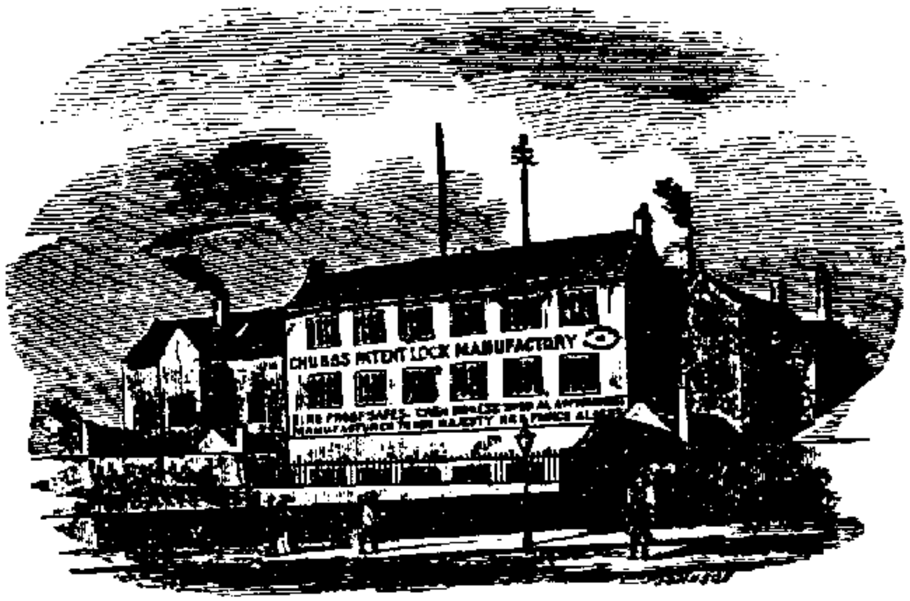


Figure 464. Chubb's Lock Manufactory, Horseley Fields, Wolverhampton. (Drawn November, 1856.)

Amongst the old buildings of the town the premises now occupied by Mr. Fleeming, chemist, High Green, possess considerable interest in connection with the lock manufacturers of this district, as the house was formerly a very celebrated inn, known as the "Angel," and it was this house that the locksmiths were in the habit of frequenting for the purpose of meeting the foreign merchants and country buyers. The Swan Hotel adjoining was originally an inn, at which the same class of masters and purchasers also assembled.

The custom appears to have been for the manufacturers to take up their standings outside and next to the doors of these two houses in the order in which they arrived. The American merchants were the principal customers, and it was usual for the latter in making a bargain to sell to the manufacturer a barrel of flour. Each seller had also to take a ticket from the innkeeper for a pint of ale, as a consideration for the accommodation afforded. It is stated that scarcely an instance occurred without the whole of the manufactured goods having been thus periodically disposed of. This custom prevailed till the enactment of the Corn Laws.

We have endeavoured to find out the period when the "factoring trade" was first established in this district, but our efforts have been unsuccessful That the sales of manufactured goods were formerly effected *direct* between the foreign merchants and country dealers and the producers is beyond question; and that

some of the foreign merchants had resident agents here, who bought the goods and shipped them off by canal, is also certain.

Some think that the factoring trade originated from the circumstance of the foreign merchants and the country buyers having "bantered" the manufacturers in the price of their goods, when the producers reduced the quality in proportion, and, as some say, sold them locks without keys, which, when discovered, caused a feeling of distrust on the part of the buyers, and made them afraid to purchase direct. They then employed a middleman to make their purchases, who was afterwards called a "Chapman," and subsequently "factor." In using the term "factor" in any other part of the kingdom to designate a trade, it would at once be asked what: cheese, butter, or bacon?

But in this district the term is synonymous with merchant, and is understood to mean only a wholesale dealer in hardware and other goods. Originally the chapmen, although wealthy, did not travel or send out representatives, and it is said they lacked the enterprise in this respect of their brethren of Birmingham, and allowed the chapmen of that town to get the start of them. Some, however, by degrees added the country to their foreign trade, whilst others continued alone, the latter business.

The representatives were then called, not as now by the dignified title of "commercial travelers" but "outriders," a very significant term, for they used to travel on horseback with their samples in their saddle-bags. The saddle-bags and horse afterwards gave place to the box and gig, and the latter is becoming in these railway times almost as great a novelty as the former.

Although the foreign merchants had from the circumstance before named ceased to come to the town, the manufacturers still expected them, and continued making stock in the anticipation of the whole being some day cleared off by these large buyers, when, after hoping against hope, they went and offered their goods to the factors, who told them that they (the factors) did not require such merchandise, but if they (the manufacturers) would reduce their respective prices five or ten percent, then they would purchase and take the goods into stock,.although they had no orders for them. This is said to have been the origin of the present system of discounts so universally adopted, not only in the lock-trade, but also in almost every other branch of the hardware manufacture.

Whether this would apply to all other trades we do not know, but that it was the case with the lock-makers we have every reason to believe, for several aged locksmiths recollect the time when discounts were unknown, and when locks which are now sold wholesale at a reduction from the original price of from 10 to 75 percent, were formerly sold net.

We have heard many droll anecdotes relative to the first establishment of these discounts. Some of the manufacturers, when it was first proposed to them, did not even understand the meaning of the word, whilst others, not only at that period, but even to the present time, from ignorance of the difference between discount and interest, have come to ruin, at the same time that they supposed themselves to be saving money; for so soon as the principle of discounts became a rule in the trade, the various manufacturers, as they invented new things or improved old ones, in calculating the price they could sell them at, would put on a certain amount of interest on the prime cost of the article, for the purpose of taking it off again to the factor; and this in most cases was reckoned thus: If the particular article had cost the manufacturer 3s. 9d., which, with his profit of 3d. added would make 4s., he would add to the latter amount 25 percent interest, for the purpose of allowing the same discount to the factor, which made the gross price 5s., and with 25 percent *discount* off, reduced it to 3s. 9d. net, which was, as stated before, the actual prime cost of the article.

We will illustrate this further by relating the following anecdote, which was told to us as a fact, and which we believe to be quite true: A small manufacturer, who had been started in business by a factor, kept so many journeymen, and on the Saturday night, after drawing his money from the factor for so many dozens of locks made and delivered, gave the amount, as is customary with this class of the commercial community, to his "better half" to pay the journeymen their wages. After paying most of them, and the good dame being requested by her lord and master to pay the remainder, she replied, and we think very prudently, "but Thomas we shall have no money left for ourselves." "How can that be?" replied the master; "I have made and drawn for so many dozen, and I reckon to get so much by each dozen after *putting on the discount;* there must be plenty left. "The good wife paid all the men, but the cash left was indeed "small and beautifully less" —it was simply the difference between putting on the discount and taking it off again."

All the *master* locksmiths, with a few exceptions, work at the vice themselves, and it is a rare circumstance to see one in the streets without his apron on. They have such an attachment to the apron that it is said some of them decline going to a place of worship, because they should have to "doff the apron."

The *journeymen* locksmiths, as a class, work hard when at their work, but are much addicted to drinking. Most of them are in a very degenerate state, and few seem inclined to better their condition. Little hope can be entertained of their improvement till the abominable system of hiring is abolished. The following extracts on this subject in Mr. Home's report before referred to, although written fifteen years ago, equally apply at the present time, and we insert them at length in the hope that they may arouse the philanthropic spirit of our townsmen to make an effort to abolish the system altogether. We hope the magistrates who adjudicate upon these cases will give the weight of their influence in assisting to do away with this system of English slavery. Its demoralizing effects cannot for one moment be doubted, and we feel convinced of the impossibility of improving the moral condition of this class of our working population till its eradication is complete and final:

"When a large master engages an adult, it is very common for the former to offer to lend the man money. This money is to be returned by weekly installments from the man's wages, and will generally require *at least* a twelve month term to be thus repaid at 1s. 6d. or 2s. per week. Hence the man indirectly hires himself for at least a twelve month period. Two years are a more common period by means of these kind of contracts, but as these weekly installments are very seldom strictly enforced, and never enforced when the man has paid up pretty regularly to a certain extent, it may well be expected that the man is far more glad to avail himself of the extra 1s. 6d. or 2s. a week than anxious to get out of debt. Thus, at the end of the year he is not again a free man, but is required to work as many more weeks as will pay up the balance by the installments. While doing this the master offers to lend him another sum of money on similar terms."

"The man cannot resist the temptation of having the means of a week's riot and debauchery, and he enters on a fresh contract of service for a year and a half, two years, or more, according to the amount of the sum and the weekly installment. It hence appears that the object of this loan of money from the master to the man is to create a debt which shall govern the period of service. A man, for instance, is engaged on the loan of £2 12s.

to work for a master until such sum shall be paid by weekly installments of 1s. Suppose a default is made in the payment of the installments, the *service* must continue until such payments are made in that particular way; which service would extend to the termination of the man's life if he continued a defaulter."

"That these contracts are sufficiently stringent on one side and loose on the other may be readily apprehended. They are drawn up by an attorney who is employed by the master. The following is from a copy of an agreement of this kind:—"

"First the said R.0— hereby agrees to hire himself to, and to work solely for the said J.H. his executors, administrators, and assign, for the term of one hundred and four weeks, at the work or trade of rim lock making, etc; and the said J.H-, his executors, administrators, and assigns shall be at liberty to retain out of the wages or earnings of the said R.O- the sum of two shillings and sixpence per week, till the sum of thirteen pounds is fully paid, which is now due and owing from the said R.O— to the said J.H-. If the said R.O— shall borrow any more money of the said J.H- while he is fulfilling his number of weeks as a contract servant, he shall in no *wise leave the service* of the said J.H-, his executors, administrators, and assigns, so long as he is indebted to them, etc."

The following clauses occur in a copy of another of these agreements:—

"And it is agreed by both parties that the acceptance by the said servant B.S—, at the usual reckoning times, *of any sum* as his wages, except expressly paid on account, shall be conclusive of a settlement; and it shall not be lawful for him again to dispute the amount, or open the account."

"That in case at any time the said master J.C- shall advance any sum of money to the said B. S beyond the wages then due, it shall be lawful for him to retain out of the wages from time to time to become due to the said B.S- by installments of [ ] shillings per week, until the whole of such advancement shall be paid: And this contract, and the term of service, shall extend and subsist until the sum be fully paid by such installment, notwithstanding anything herein to the contrary."

"These kind of contracts also contain other stringent clauses, such as compensation 'out of the wages' for work not well done or damaged. From the operation of this kind of

contract it happens in very few instances that a man is free, or has any definite period of service. The good of this system is that, if the master be a wise and benevolent man, the power he thus possesses over the servant may be beneficial to both parties. The evils of the system are these:— First, that as all masters are not wise and benevolent, it gives them a power which is liable to be abused in all the intricate ways of Tommy. Secondly, that it incites the man to a system of borrowing and of extravagant riot, in which the loans are almost always expended. Thirdly, it puts the means out of a man's power of availing himself of any opportunity that might occur for bettering his condition. The man has sold himself."

"Should a master and a man agree to part, the first question with a new master is, 'What do you owe your last master?' The new contract is founded upon the repayment of the last master by the new master (the former consenting to receive the sum of money) and an advance is again made to the man on the same terms, carrying on the whole debt. Hence the man is passed, with an accumulating debt upon his head, from one master's hands to the other. The man knows he shall never recover his freedom, and becomes reckless. Since a loan is made with every fresh engagement, he endeavours to change as often as he can."

"But very often the man breaks through the contract he has made with his master on account of money lent, and insists upon leaving the master. The master, not agreeing, insists upon the payment of the money remaining due to him by weekly installments, say £2, together with the current service. But suppose the man can raise the £2, he is still not free to leave upon paying it, for the master refuses to receive it, as not being according to the contract, which was by weekly installments from wages for work performed. The man refusing to fulfill this, the master instantly gets a warrant out against him; takes him before a magistrate and the man is forthwith sent to Stafford Jail. On his liberation he still has to fulfill his contract of service and payment of his debt by installments. In the course of the last four years there has been, on an average, other towns of the county inclusive, two hundred and forty individuals sent to Stafford Jail each year for this very offense. The expense to the county thus incurred is prodigious."

"I question the legality of the whole proceeding; for if the man offer to discharge the money debt at once, and the master refuse to accept it, then the remainder of his claim (except he can prove subatantial damages by the departure of the man at that

time) would surely be accounted, in equity, as frivolous and vexatious, and conspiring against the liberty of the subject. If a man agrees to work until he has paid his master fifty-two shillings by one shilling per week, this would be equivalent to a hiring for one year certain; and if, at the end of that year, any sum remained unpaid, I should conceive it would be a debt which, legally, had nothing to do with the service. But if the man engaged to *work* for the master *until* he paid him fifty-two shillings, that would be an indefinite contract as to time, and therefore voidable at any time. Now, in both cases, the magistrates enforce the service until the debts are discharged. They take no notice of the default of payment of any installment, (to which default it is probable the master has no objection), but only of the default of service while the debt is due."

Mr. Horne makes the following remarks relative to the physical labour of the locksmiths of Wolverhampton and Willenhall.

"With the locksmiths and key-makers the work becomes most injurious from the sameness of the position of the body and action of the arms, and the long protracted hours during which they stand filing at a vice."

"Physically injurious as these processes become here, [Wolverhampton] they are rendered far more so by the locksmiths and key-makers of Willenhall."

"The right shoulder-blade becomes displaced and projects, and the right leg crooks and bends inwards at the knee, like the letter K. It is the leg which is hindermost in standing at the vice. One of my witnesses who was accustomed to the sight could not help terming it 'hind leg,' so impressed was he with its similarity to that of a drudging animal."

"The right hand, also, has frequently a marked distortion. Almost everything it holds takes the position of the file. If the poor man carries a limp lettuce or a limper mackerel from Wolverhampton market, they are never dangled, but always held like the file. If he carry nothing, his right hand is in just the same position."

"I have heard several inhabitants of Wolverhampton declare they can recognize a Willenhall man whenever they see one in the streets. Probably this requires some qualification; at all events I believe I could do the same myself if he were a locksmith, almost at the first glance."

The hours of labour with the Willenhall locksmiths are less now than was universally the custom a few years ago. Since the opening of additional places of worship and the establishment of Sunday and day schools for the children of the working classes, and the gradual attainment of knowledge by the adult population, the operatives are not those drudges they were formerly. In proportion as they acquire useful knowledge, does the practice of long hours and excessive work lessen. Mr. Home, in the report before referred to, has drawn some very gloomy pictures of the moral condition of the locksmiths of Willenhall, but we are glad to state that since that period (1841) considerable improvements in this respect have taken place. The town also has much improved in its general appearance, as well as in a sanitary point of view. There are now both gas works and water works in full operation.

The following extracts will serve to give some idea of the social habits of these hard-worked and badly paid artisans:—

"Some years ago, a factor, who had projected a manufactory in Brussels, engaged some five-and twenty Willenhall men, whom he was at the expense of taking over. He gave them all work, and from hard-earned wages of from 9s. to last a week, these 'practiced hands' found themselves able to earn £3 a week and upwards. But they were not satisfied, and began to feel uncomfortable."

"First one left and returned home; then another, then one or two, till in the course of a few weeks every man had returned to Willenhall, resuming his slavery and his drunkenness, his low wages, dirty lanes, and destitution."

"About two O'clock on Saturday, some of those who did some work on Tuesday begin to appear in the streets; and large masses issue forth between four and five O'clock. The wives and elder girls go to market; the husbands and other adults to the beer-shops. By seven or eight O'clock the market is full; the streets are all alive; the beershops and gin-shops are full; and all the other shops are full. The [small] manufacturers are stretching their limbs, expanding their souls to the utmost, and spending their money as fast as they possibly can. No one ever thinks of saving a shilling."

We shall conclude this chapter by the following account of several small locks:—

Many minute locks and keys have been exhibited which are remarkable only for their smallness. Figure 465 represents a Barron's box lock and key, full size, made by Mr. Henry Yates. At the Exhibition of British Manufactures at Birmingham, in 1849, Mr. Chubb exhibited one of his patent detector locks, set in a gold finger-ring, the lock and key weighing but sixteen grains. At the Great Exhibition of 1851, Mr. Aubin exhibited a four-lever padlock 3/32 of all inch in diameter, or just small enough to go inside a hemp-seed husk. The key was a quarter of an inch long. The lock and key were made by two young boys, the sons of Mr. Aubin before named; but most of these locks are monstrously large in comparison with what were made nearly a century ago, as shown by the following extract from Shaw's History of Staffordshire:—

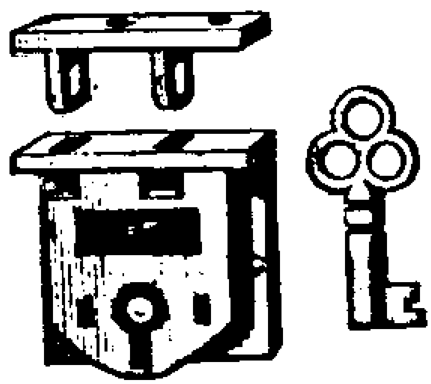


Figure 465

"June 13, 1776, James Lees, of Willenhall, aged 63 years and upwards, Showed me (Rev. T. Unett) a padlock, with its key, made by himself, that was not the weight of a silver two-pence. He at the same time showed me a lock that was not the weight of a silver penny; he was then making the key to it, all of iron. He said he would be bound to make a dozen locks, with their keys, that should not exceed the weight of a sixpence."

The illustration (figure **455**,) represents a Barron's portfolio lock made of a half-crown, and the hasp part of a four-penny piece, by Mr. Henry Yates, without at all injuring the faces of either coin by screws or rivets.

CHAPTER TWENTY-ONE: Useful Hints

in Connection with Iron Safes and Locks and Keys

1. We have stated before when noticing the *detector* locks, that these locks will frequently detect themselves, and it often happens that in the carriage of iron safes which are fitted with detector locks, when they arrive at their destination, from the above cause, they cannot be opened. Therefore we would recommend all persons not to jump to the conclusion that the lock is spoiled, but to turn the key in the same direction as in locking, which will release the detector, then turn the key and unlock, when if the throwing of the detector has been the cause of the lock not answering to its key, it will at once open.

2. Under no circumstances use violence when a lock does not act properly. Violence will always do harm, whilst a little patience in "humouring" it will, in nine cases out of ten, enable the key rightly to perform its office. The majority of locks, if they are to go well, are like watches, they must have some degree of careful treatment. Instances are not uncommon of persons who have iron safes, in the possible event of the lock "taking to go wrong," putting an instrument (as a piece of iron) through the bow of the key to act as a powerful lever, hoping by such violent means to make the key unlock it. In such cases the words "open sessamee" would be far more likely to produce the desired effect. The result of such violence is that the key-bit breaks in the lock, and then there is no alternative but to drill or cut open the door, and in many cases the safe has to be sent to the maker to be opened and refitted, thus entailing on the owner a very considerable expense.

3. Others, under similar circumstances, fill the lock with oil; and if this happens to be at all glutinous, it sticks the levers (in the lock) together, in which case, whatever security the lock previously possessed, is by that means destroyed.

4. It must be remembered that the lock is the lightest and weakest part of an iron safe, and in its transit from one place to another the jerks or jars it meets with are quite sufficient to somewhat disorder the internal parts of the lock, but a sharp rap with a hammer on that part of the door immediately over the small lock, we have always found sufficient to set all right

again.

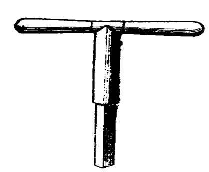
5. In some locks containing a "curtain," the latter will sometimes get *over* the keyhole and thus prevent the key from entering the lock; but it is easily moved from before the keyhole into its proper position by means of the blade of a penknife or any other similar pointed instrument.

6. We recommend in all cases in locking and unlocking any lock, to remove the key after performing either operation.

7. In those safes where the large bolts are thrown by a knob or handle and secured by a small lock, it is a good plan to throw the bolts with a swing, for unless the bolts are thrown quite "home," the bolt of the small lock cannot enter the slot in the arm of the large bolts, by which all are secured. From not understanding the construction of the locks on the doors of iron safes, persons frequently attempt to lock the small lock without even turning the handle to first throw the large bolts, and the key is thereby sometimes broken.

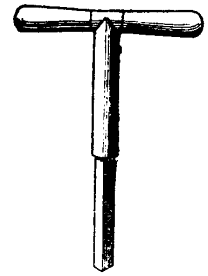
8. When iron safes are made true and square, they require to be carefully fixed; and it is advisable to use a spirit level to set them, otherwise the doors will not open and shut freely, and in double-door safes the bolts of the locks cannot be thrown.

9. In double-door safes, first close the left-hand door, and then throw the bolts with the knob by turning it from right to left; then close the right-hand door, and throw the bolts of it by turning the handle *in the same direction,* then insert the key in the small lock, turn it round, and withdraw it; and to make sure that it is locked, try the handle of the right-hand door, as in unlocking. To open the safe, the same operation must be performed, but of course in the reverse order.



10. When safes are required to be sent abroad or removed from place to place, it is advisable to remove the handle and other *outside* fittings, placing them inside, and then with any square instrument which will answer the purpose of a spindle, or what is called a

answer the purpose of a spindle, or what is called a T-key (figure 466), throw the bolts, lock the small lock, and send the key by post or otherwise. We have adopted this plan for several years and have never had an accident, and it dispenses with the use of a packing-case. The *direction* or a piece of blank paper should be gummed or pasted over the key and spindle holes, to prevent dust or dirt getting either into the lock or into the interior of the safe.



Figure

11. In most small locks the main-bolt, even in brass ones, is usually made of iron, which in damp situations is sure to rust and will therefore *stick,* and when this is so, great care must be used to move it, otherwise the key-bit is apt to break in the lock. In consequence of this liability of the iron bolt to oxydise, we have for some time had all our locks constructed with *brass bolts,* and we recommend all lock-makers to use as little iron in the internal mechanism of their locks as possible.

12. Although it may be thought unnecessary, yet we must remind those who have iron safes to invariably have a duplicate key, which should not, as is so frequently the case, be placed *inside the safe,* but should be kept in some secret place, so that in the event of the other key being lost, the reserve key may be put in requisition to open the safe, when the combination of the lock can be altered, and new keys made at a trifling expenses so that, if the former key has dropped into improper hands, it would fail to open the safe. Instances have been of frequent occurrence where an individual has lost the one key, haling the other locked up in his safe, the result being, that *the door* has had to be cut or drilled open, and a new lock put on at a considerable cost.

13. We have before observed, and it may be well to repeat it here, that in fixing detector locks in which the detector has to be released by an *extra* shoot of the bolt, a space of from one-eighth to a quarter of an inch should always be allowed in the depth of the *bolt-hole* to allow for it, otherwise when the detector is thrown, and no play is left for the extra shoot, the lock cannot of course be unlocked.

14. Never leave your keys in the locks, or indeed out of your own hands. This precaution will effectually prevent a dishonest employed from taking an impression of them, or of tampering with them in any way, and for this reason use small or moderate sized locks with corresponding keys.

Several years ago a bank was robbed in America, and a clean sweep made of all the cash, although the iron safe was secured by an unpickable lock. On an enquiry being instituted, the manager recollected leaving the key in an unlocked wooden desk.

The great gold robbery from the South Eastern Railway Company in May, 1855, appears to have been consummated through an employed leaving the duplicate master key of the iron chest, whilst his back was turned only for a few minutes, in an unlocked repository. This circumstance suggests the propriety of using spring locks more generally so that all doors or drawers could be fastened in an instant merely by closing them. This robbery has proved beyond all question the possibility of making a key that will open a Chubb lock, by simply taking an impression of the original; and we now think it necessary still further to caution all persons against carelessly leaving their keys in a public or in an unsafe depository. The composition used for the purpose of taking impressions is composed of bees' wax, powdered charcoal, and oil; and a sufficiently accurate impression can be thus obtained of the key of almost every patent lock made, from which a perfect key can be fabricated.

We should recommend all such specie chests for regular transit between one place and another to be secured by two or even three locks, each lock in its construction to be as dissimilar from the others as possible, as well as the keys. Had this plan been adopted, this robbery could not have been effected by the means stated to have been employed in the evidence taken before the Lord Mayor, at the Mansion House London, in November, 1856.

15. Pipe keys should occasionally be examined, and any foreign matter that may have got inside the pipe or drill-hole should be removed.

16. Should the levers in lever locks be found to "grate" or to make a whistling noise when in action, take a fine needle and dip it in olive or best sweet oil, and with it touch very slightly all the long steps of the key-bit, and then apply the key to the lock in the usual way; such grating is caused by the springs being made unnecessarily strong. The short steps seldom or never require any oil, as the lifts of these levers being short, produce but little friction.

17. In ordering cabinet furniture, be particular in stipulating that a certain quality of lock shall be used, as it is the custom both with first-class as well as inferior makers to use inferior

or common locks. We would recommend architects also in their specifications to name particularly the quality of locks to be employed, whether warded locks, lever locks, &c.; and if the latter, how many levers the lock is to contain.

18. As most of the traveling and writing cases, despatch boxes, &c. sold are fitted with common locks, many of which, as we have stated before, can be readily picked by a quill, we strongly recommend commercial travelers and others who use such articles to satisfy themselves of the real quality and security of the locks before entrusting cash or private papers to their custody.

19. Some makers call an iron doors and frames fire-proof, whereas in some there is no fire-proof composition in their construction, therefore architects should always specify that the back of the lock-chamber should contain a certain thickness of composition. We know of several instances where one maker has estimated for a genuine fire-proof door, and the order has been given to another maker, because his estimate was some little lower; but when the door came to hand, it was found to be of the former kind, i.e., without any fire-proof composition at all in its construction. The difference in price between a fire-proof door and one not fire-proof is from two to five pounds, according to the size of the door.

20. The bolt of a right-hand lock always shoots from left to right, and a left-hand lock from right to left, *as you stand on the* OUTSIDE *of the door.* Mistakes with respect to the *hand* of locks are of daily occurrence. What the carpenter calls a *right-hand* lock, the locksmith calls a *left-hand,* and *vice versa.* In order to prevent such mistakes in future, we have thought it as well to illustrate the difference by the following diagrams represents a door which would require a right-hand lock. Figure 468 represents a door which would require a left-hand lock.

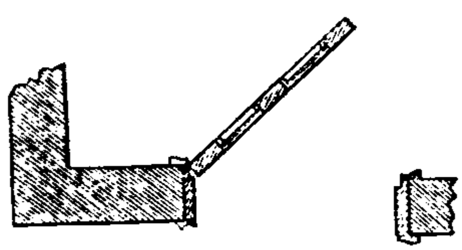


Figure 467. This door requires a *right* hand rim or mortise lock.

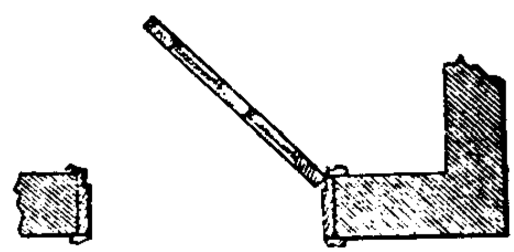


Figure *468. This* door requires a *left* hand rim or mortise lock.

Figure 469 represents a pair of folding cupboard, book-case, or

wardrobe doors, which would require a left-hand lock. Figure 470 represents a cupboard with a single door, which would require a right-hand lock. By observing these figures the reader will perceive that the hand is found by standing on the *outside* of the door, and locking the lock by turning the key in the right-hand locks to the right, and in the left-hand locks to the left; if the bolt comes out to the left it is a left-hand lock; if to the right it is a right-hand lock. This is the locksmiths' rule. We recommend all parties when ordering such locks to give a sketch of the previous figures, or quote the number of the particular figure or figures before described.

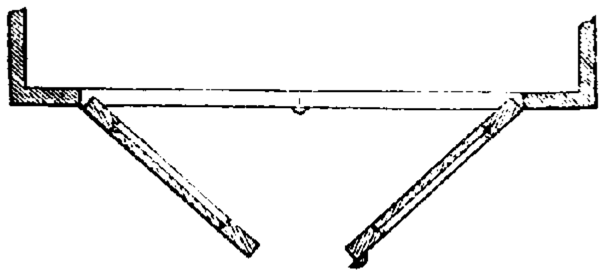


Figure 469 Pair of folding cupboard, book-case, or wardrobe doors, which require a left-hand lock.

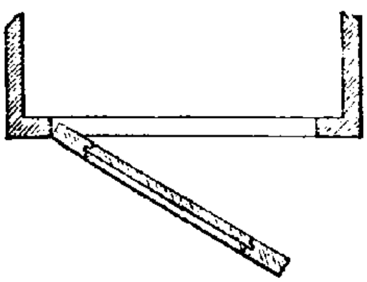


Figure 470 Single cupboard door which requires a right-hand lock.

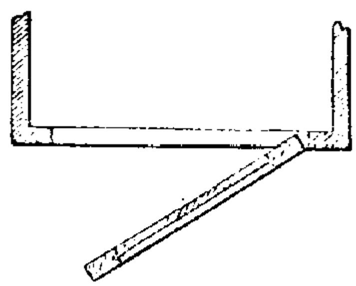


Figure 471 Single cupboard door which requires a left-hand lock.

It may be well to notice that for a closet in a room in which the door of the closet is constructed to pull *towards you,* if a rim lock be required to be fixed on such a door so as to be *inside* the closet when the door is closed, the bolt of the lock or latch would require to be bevelled just the contrary way to the ordinary locks, as in closing the door you push the lock away from you, instead of pulling it towards you. Such a lock is called by locksmiths a reverse-bolt lock, and it requires to be fitted with a striking-plate for the door-case instead of the ordinary box-staple of the other locks.

21. The length and width of the lock required (if of importance)

together with the thickness of the door should always be given in ordering any door lock.

22. If the knob or the keyhole are required to be any particular distance from the edge of the door, always measure from the centre of the spindle hole and the centre of the keyhole respectively.

23. In ordering locks never run down the price, because whatever reduction you may get from the regular end fair prices, is certain to be made out to you in so much less security, so much less strength, and so much less finish. By the adoption of such a system, however much you may think you have saved, the maker will have got more, as there is always more profit, in proportion, attending the manufacture of a common article, than one of a superior quality.

24. Before purchasing either an iron safe or a lock, we recommend buyers to compare the productions of one maker with those of another, examine their several merits and judge for themselves. It is to assist them in this object that this work has been published. Let them not be entrapped by the present unscrupulous means adopted by some persons to increase their business. Even the *professors* of religious truth in these days are guilty of conduct most reprehensible in this respect. The old proverb "let everything stand on its own bottom," seems to be altogether ignored. One manufacturer thinks no means too unworthy or disreputable to employ to raise his own wares and to lower those of his competitors in the estimation of the public. Another by the most unblushing falsehoods in the shape of puffing advertisements seeks thus to increase his business. Another knowing the credulity of the general public, seeks to produce an impression on their minds of the vastness of his establishment, by exhibiting and publishing drawings of manufactories or shops that never had an existence, or the true buildings so increased in size, in number, or in the accessories to complete the picture, that the original is altogether lost in the supposed representation.

25. Many robberies take place through the want of due care with respect to cash boxes and other portable depositories. The former useful articles, even when containing convertible property of great value, are frequently locked up at night in a wooden desk or cupboard. A few weeks ago we read an account of the robbery of a cash box from a carrying firm at Bradford. The thieves had only to prize open the lid of the desk, and there was the cash box

containing about £40 with which they got clear off. Another careless practice is, to have the cash box lying about the counting-house or office. The following robberies which occurred lately will show the necessity of either keeping such valuable property in the drawer of an iron safe, or locking-up the cash box in one. Robberies similar to the above are of almost every day occurrence; and yet although the accounts of them appear in the newspapers, few take warning, till they have been taught the necessity of it by dear experience. When the horse is stolen, the stable door is locked.

The latter remark applies quite as much in respect to the carelessness manifested by many persons in reference to the preservation of books and papers from fire. In colliery offices, many of which are mere hovels, the books are almost invariably kept in wooden receptacles, amongst all sorts of articles used in the colliery, some of which as cotton waste, oil, &e., are calculated to cause spontaneous combustion. Last year a fire took place in an office of this description, in the neighbourhood of Willenhall, which of course consumed the wooden desk and the books it contained. We need not say, that after the books were thus destroyed, the proprietors of the colliery purchased an expensive fire-proof safe, whereas, had they expended but half the amount previously in a safe receptacle for their books, they would have saved some scores of pounds, as they had to trust to the honor of their customers as to what amounts they respectively owed them.

"DARING HOUSE ROBBERY AT CAMP HILL. On Sunday evening last, a daring robbery was effected in the house occupied by Mr. Foster, Trinity Place, Camp Hill. The thieves, taking advantage of the temporary absence of the inmates at Church, comparative seclusion of the locality, broke into the premises by means of *skeleton* keys, and making, as it would appear, direct to the bed room, carried off a *cash* box containing £5 and £10 notes on the Coventry Bank, to the amount of £80; also a gold watch, seals, and key, a silver snuff box, a gold ring, purse, silver toothpick, and other valuable trifles, amounting with the notes, to about £105. The cash box was found early on the following morning, empty, of course, in an entry in Hill Street; but the thieves have not yet been traced by the police. It is to be hoped that this notice may serve as a caution to householders, many of whom, notwithstanding the frequent instances of housebreaking during Church time on Sabbath evenings, leave their premises not only unwatched, but in many cases entirely unsecured."

Aris's *Birmingham Gazette.*

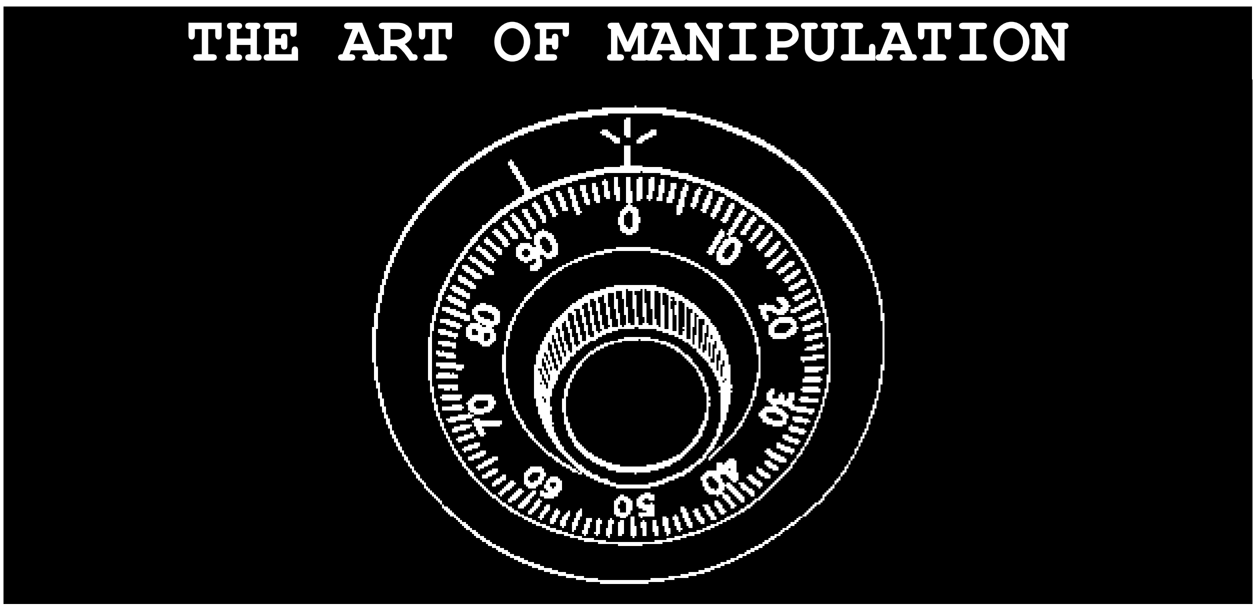
"Thirty Thousand Pounds stolen. Early on Friday morning, as one of the Borough Constables of Sunderland was patrolling his beat, be observed two young boys endeavouring to avoid him, upon which be crossed the street to see what they were about. They at once ran off but the officer succeeded in taking one of them into custody, who confessed that be and his companion bad just broken into the counting-room of Mr. J. H. Brown, rope manufacturer, and stolen a *cash* box, the contents of which were of great value. The boy who escaped, he said, had the box with him and the officer having ascertained the address of the fugitive, apprehended him, also in a few hours, and ascertained from him that be had buried the box in the Town Moor. The spot indicated was then dug up, and the box found; and on its contents being reckoned up, they were found to amount to £87 in cash, and £2,460 in cheques and bills. The boy who was first taken into custody was employed in Mr. Brown's office, and on Saturday he confessed to robbing his master of a £50 note about six weeks ego."

Manchester Guardian.

"A daring robbery was effected at the shop of Mr. Sotheron, bookseller, York, on Friday se'nnight. During the dinner hour of the assistants and the errand boy, two respectably dressed men entered the shop and requested to be shown certain articles. Mr. Sotheron was in attendance, and produced several books, but one of the men particularly wished to see a 'History of the Bible,' which was lying in the window. To obtain this Mr. Sotheron had to open a folding sash, one side of which was covered with prints, and which when thrown back concealed part of the shop from his view. Under the pretext of facilitating the search, the taller of the men went outside the shop, and pointed through the window to the book in question, as well as to another which he pretended to want. In the meantime his accomplice went into the counting-house behind the shop, and stole Mr. Sotheron's cash box, containing a quantity of gold and silver (including a double sovereign of the reign of George IV.), a promissory note for £200, a £10 Bank of England note, a £5 ditto, several York and West Riding notes, two bankers' deposit notes for £50 each, some bankers' receipts for railway cars, and other documents. The books pointed out having at length been found, the man who had stolen the cash told his companion that he should walk on, and accordingly left the shop, The other fellow requested Mr. Sotheron to make a neat parcel of the books he had selected, and promised to call for it in about an hour. Nothing more, however, was seen of him by Mr. Sotheron, who in the course of the afternoon went to his desk for the cash box, and found it was gone. The thieves have not been detected."

Aris's *Birmingham Gazette, November* 10th, 1856.

In closing this chapter, we would beg to draw especial attention to a little pamphlet by Mr. George Cruikshank entitled "Stop Thief," in which he suggests some most excellent and innexpensive concontrivances for securing doors and windows against burglars. The house-breakers' implements and method of breaking in are also explained, in order to give the house-keeper a through knowledge of the plan of attack, so that he may apply such fastenings as may frustrate the operation of the thief.



Clyde Lentz and Bill Kenton
First Edition, 1955

Introduction to Second Edition.

The original printing of ***The Art of Manipulation*** was in 1955. Although small in size, it was the first printed work to detail and describe the step by step theory and process of manipulation by practitioners in the trade. I think it is fair to say that the manual has been purchased by almost every safe and vault technician, since its original printing.

Because of its longevity and wide acceptance, it has been included within **LSS+**, as an added reference to the materials

presented in **Chapter 36.** The text and graphics have been edited and revised by the author to enhance understanding of the material. The basic concepts, however, have not changed, although the design of some Group 1 and Group 2 locks certainly have been altered and improved.

When Kenton and Lentz (referred to as "the authors") first published their manual, computer-based systems were not even a dream. Thus, the X-07, X-08, and competing products were not even contemplated. There were no robot dialers or other sophisticated forms of manipulation machines. Microprocessors had not been invented, nor the advanced devices that exist today to open combination locks.

It is hoped that the revision of the original edition provides an enhanced understanding of the subject, and offers another perspective to the Art of Manipulation.

MWT

MASTER EXHIBIT SUMMARY

CHAPTER ONE: Introduction to Manipulation

This chapter introduces the reader to manipulation, providing a summary of how and why locks can be opened by touch, feel, and sound. Specific definitions, the jargon of manipulation, are also presented. The reader is directed to Chapter 36 of Locks, Safes, and Security for a more thorough treatment of the subject.

DEFINITION of Manipulation

MANIPULATION is the art of opening combination locks:

- ***Without prior knowledge or information as to the present combination;***
- ***Does not require the use of force or tools;***
- ***Does not cause damage to any part or component; and leaves no evidence of entry.***

The technician learns:

- **To move each wheel in order to indicate their position in relation to the fence;**
- **To determine the relationship between wheels, gates, and fence by sight, Sound, and feel;**
- **To utilize electronic or mechanical devices as an aid to manipulation; however, they are not necessary but in some cases may be beneficial.**

NOMENCLATURE OF COMPONENTS

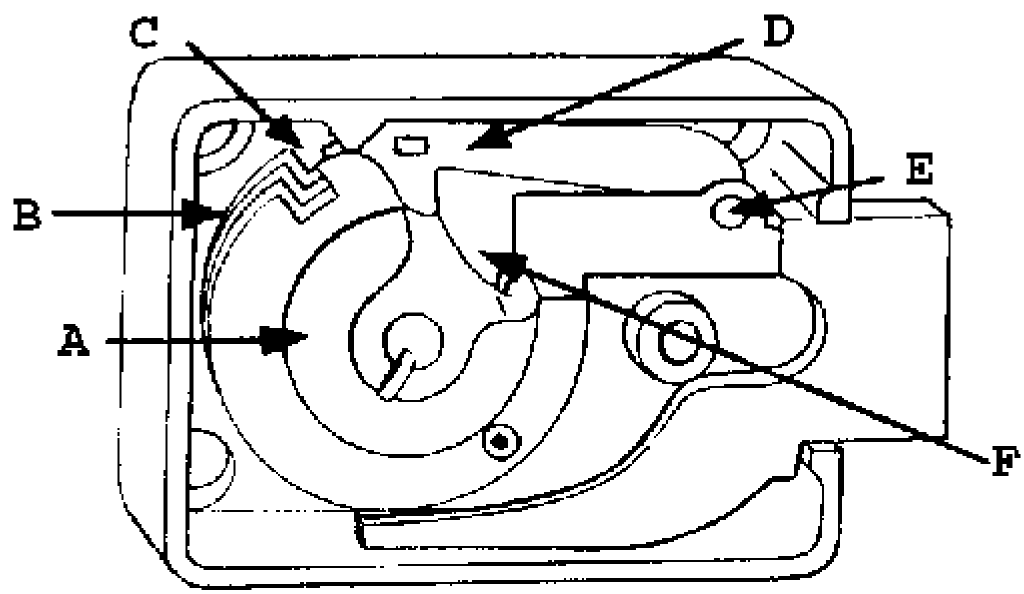


Figure M01 (A) drive cam, (B) tumblers or wheels, (C) wheel gatings, (D) lever fence, (E) lever screw or pin, (F) drive cam opening.

Why Manipulation Is Possible

There are eight primary conditions resulting from manufacturing tolerance errors that permit manipulation:

1. Differences in widths of gating in each individual wheel and in the drive cam;

2. Variations in the wheel post diameter for each wheel;

3. Eccentricity of each of the wheels;

4. General inaccuracy in and failure to maintain tolerances in the manufacturing process.

In machine-produced parts there must be a certain degree of tolerance or clearances for the proper movement and functioning of components. The same requirements exist for traditional key locks, and forms the basis of picking and impressioning theory. For example, the inside diameter of the wheels must be approximately .005” larger than the wheel post to allow free

rotation on the post.

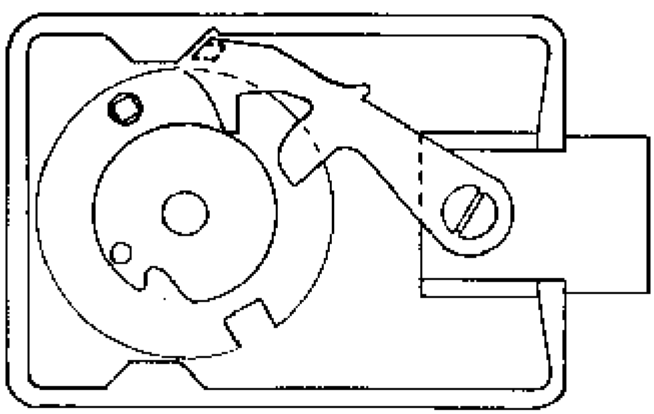
5.Differences in distance between nose of the lever and fence. The picking and decoding of lever locks closely parallels this parameter.

6.Differences in the diameter of the drive cam.

7.Squareness in wheel gatings and mating fence.

8.Tolerances in the lever Fence locks. The lever is secured to the bolt by a screw or pin, and in some locks is equipped with a lever spring, so that the lock can be mounted in different positions (Vertical up, Vertical down, Right or Left hand.) In order for the lever to work freely on the bolt screw or pin, the inside diameter of the hole in the lever must be considerably larger than the outside diameter of the actual bolt screw or pin.

The requirement for this tolerance can be understood from the illustration; Note how the play between lever and bolt creates a different position of the fence.



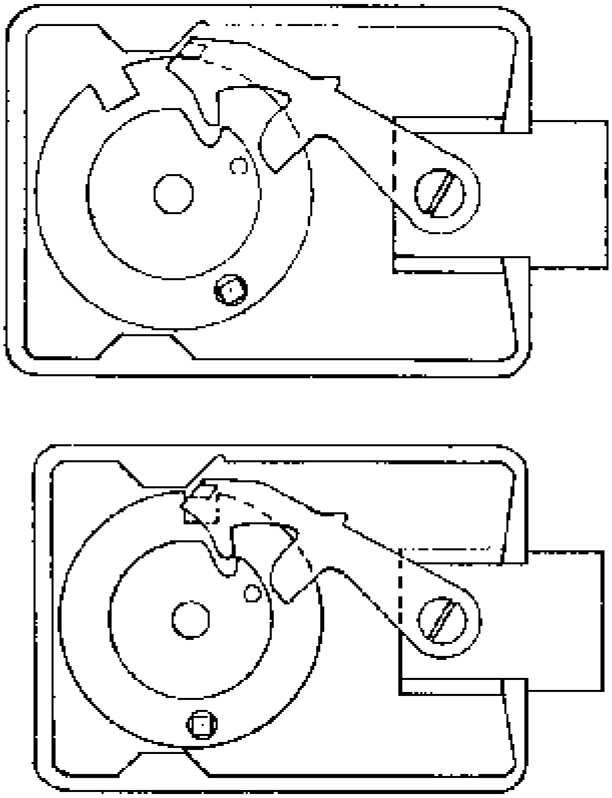


Figure M02. These diagrams demonstrate the different positions of the fence and nose of the lever during the manipulation process. In (top left), the fence and nose ride on the drive cam. In (top right) the fence is resting on the wheels with the nose of the lever in the drive cam opening. In (bottom), with No. 3 wheel-gating lined up with the fence and lever nose in the drive cam opening, the fence rests on No. 1 and No. 2 wheels, allowing the fence to tilt into the gating of No. 1 wheel and the nose of the lever to drop further into the drive cam opening.

A better understanding of the following procedures can be achieved by mounting a three-wheel lever fence lock, such as the S&G 6730, so that it may be manipulated throughout the remainder of this text. Cutaway locks may also be purchased from Lockmasters, MBA, and other vendors. After mastering the concepts to allow successful manipulation of the S&G lever fence design, it is suggested that similar products of different manufacturers and different basic designs be utilized.

Later in the text, variations upon the technique of manipulation will be explained, for different basic lock designs. Although there is a variance in procedures resulting from mechanical designs, the fundamental theory of all manipulation remains

constant.

Categories of Locks that are Subject to Manipulation

The authors have identified six primary classifications of combination locks that can be manipulated within the Group 2, or unlisted categories. Opening procedures vary according to each category, and are described in the chapters that follow.

- ***Gear-driven rotary fence***
- ***Rotary fence, spring-actuated***
- ***Lever fence***
- ***Straight tail-piece***
- ***Bottom drop***
- ***Off-set gear driven***

CHAPTER TWO: Manipulation Procedures for Lever Fence Lock

Introduction

The worldwide prevalence and acceptance of the lever fence combination lock makes this mechanical configuration the obvious choice for use as a model for teaching manipulation within this text. Variances in opening procedures for the other forms of locks previously identified are described in later chapters.

Manipulation Procedures for Lever Fence

There are two contact points in this mechanical configuration, and as with the Rotary fence lock, the sloping side of the drive cam provides a better indication of each wheel. Because the lever fence is so popular, detailed information will be provided as to the procedures that should be employed for a successful opening.

Overview of the Manipulation process

In order to determine the combination for a lever fence lock, the following critical actions must be accomplished:

Step 1: Determine the total number of wheels

Step 2: Determine the location of the contact points
Step 3: Find the low area of each wheel
Step 4: Determine which wheel is indicating

Detailed Manipulation Procedure

Each of the following steps must be successfully completed in sequence.

STEP 1: Determine the number of wheels in the Wheel Pack

It is critical to determine the number of wheels or tumblers within the lock to be opened. Obviously, if only three wheels of a four-wheel mechanism are tested, success can never be achieved. This information can also become invaluable for service calls where a mechanical malfunction has developed, such as stuck flys, tumblers sticking together, loose back plate screws, and other problems.

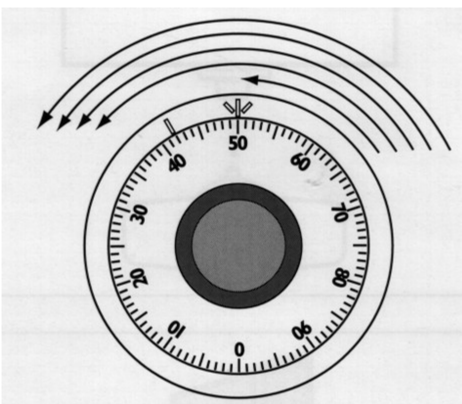


Figure M03. All wheels are rotated in one direction several complete revolutions, in order to insure th wheels are picked up.

In order to determine the number of wheels, all of the discs are rotated in one direction for several revolutions, so that all of the flys and drive pins are engaged, and all of the wheels within the wheel pack are rotated together. Direction of rotation is then reversed, so that an accurate count can be made as each wheel is picked up in succession.

Detailed Procedure for Counting Wheels

- **Turn the dial to the right (clockwise) six times stopping on 60;**

- **Turn left (counterclockwise) slowly to 50 then rapidly continue left past 60, listening and feeling as the wheel closest to drive cam is picked up. One wheel has now been counted;**

- **Continue turning left to 50 then rapidly past 60, listening and feeling as the next wheel is picked up. The count is now two wheels;**

- **Continue turning left to 50, then rapidly past 60, listening and feeling, as you pick up the next wheel. Three wheels have now been counted;**

- **Continue turning left to 50, then rapidly past 60, listening and feeling for an additional wheel. At this point, if there was no indication of another wheel, the lock only contains three discs.**

- **If an indication of a fourth wheel was received, then the lock must be tested for a fifth wheel;**

- **Continue turning left to 50 then rapidly past 60, listening and feeling as another wheel is tested. If so, then the lock contains five wheels within the wheel pack.**

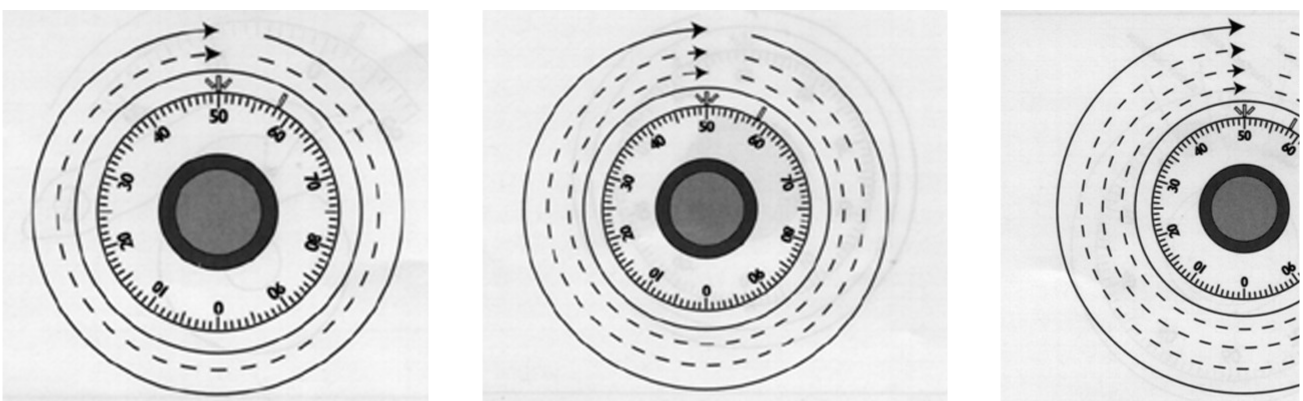
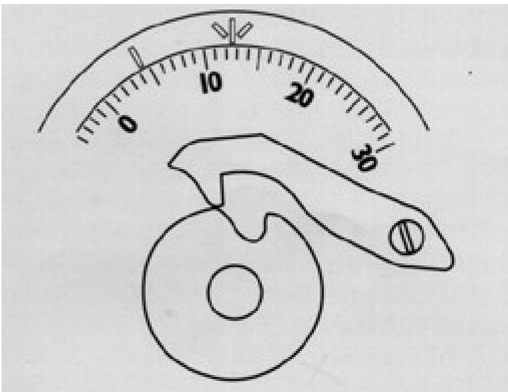


Figure M04. After parking, wheels are rotated so that each complete turn picks up another disc.

STEP 2: Determining the Location of the Contact Points

This is probably the most critical function to perform, because

it will provide you with the data (readings) from which all manipulation theory is based, and which is required to allow graphing of the geometry of each wheel. From the contact readings, the low areas for each disc can be determined, and ultimately, the gate position for each wheel is correlated.



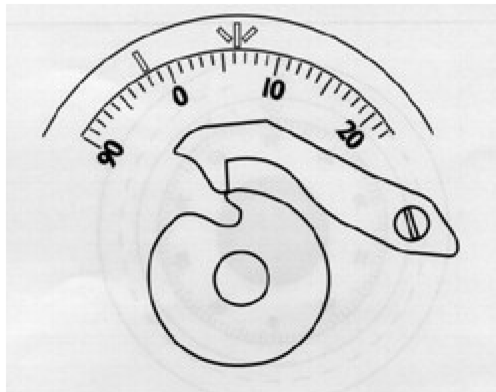


Figure M05. Contact points are shown for left (12.2) and right (8.1)

Detailed Procedure to Locate Contact Points for Lever Fence

Rotate the dial four times to Right, stopping at 60 (five times on a four wheel lock), turn left and attempt to feel and hear when the lever touches each side of the gateway of the drive cam.

Do this by oscillating over an area of approximately ten numbers at a time until you have determined the precise location of the two contact points. The **drop in area** is equivalent to locating each side of the drive cam opening or drop in point.

After finding the two contact points, lightly grasp the dial between thumb and forefinger and rotate the dial lightly between the contact points and note the exact location on the dial where the lever contacts the drive cam on the left and right side.

In the case of our test lock (using the sloping side on the drive cam), the contact point reads 12; the sharp side of the gate will provide a contact reading of 2. If the number-three wheel is lined up with the fence, and the **right** contact is read, then the fence reading improves as the nose of the lever drops further into the drive cam opening. In this event, the reading will be closer to 11.

Locating Contact Points for Spring Actuated Rotary Fence Lock

In the spring-actuated rotary fence lock, the fence is mounted on

a post secured to the lock case. In order for the fence to move freely on the post, it must have a considerable amount of tolerance. This type of mechanism will react in the same way as the lever fence, during manipulation.

Readings and contact indications can only be obtained when the dial is rotated to the left, because of the mechanical design of this category of lock. This results from a design that allows the fence to touch the drive cam only when it is rotated in the counterclockwise direction.

Locating Contact Points for Gear Driven Rotary Fence Lock

The fence in this lock works in conjunction with a gear, which in turn is actuated by the drive cam. This design differs from the spring-actuated mechanism because the fence only touches the drive cam when rotating the dial to the left; thus, there is only one contact point.

Determine which of the two contact points is to be used to obtain indications or readings on the dial. In some cases it is better to use the sloping side (right contact) of the drive cam opening because it will give a better indication when a wheel gating lines up with the fence. In other cases it makes no difference which contact point is selected, because the drive cam opening has the same contour on either side.

STEP 3: Finding Low Areas of each Wheel

The essence of successful manipulation is the determination of the lowest spot on each wheel, which must correlate to the position of the gating. Throughout the process, the goal is to cause the fence to drop further and further into the wheel pack. This is based upon the assumption that the lowest spot may be either a wheel gating or a dip in the edge of the wheel geometry that will allow the fence to contact the edge of the next lowest wheel. *The critical requirement, then, is to keep working toward the lowest spot within the wheel pack at all times.*

As the surface of each wheel is tested for each dial division or group of divisions, the contact readings are charted or graphed in order to provide a true representation of the geometry of the precise circumference of each disc. When all of the wheels have been graphed, a correlation can be made as to the location of each gate, and the combination is thus derived.

Documenting Contact Readings

Illustration graphs are provided for a three-wheel lever fence lock. Standard graph paper or preprinted forms from Lockmasters or other vendors can be utilized. Although some safe and vault technicians do not often chart their readings due to the time required, the practice is in large measure dependent upon the type of lock, and its tolerances. Students should chart all readings until proficiency is achieved.

Charting Procedure

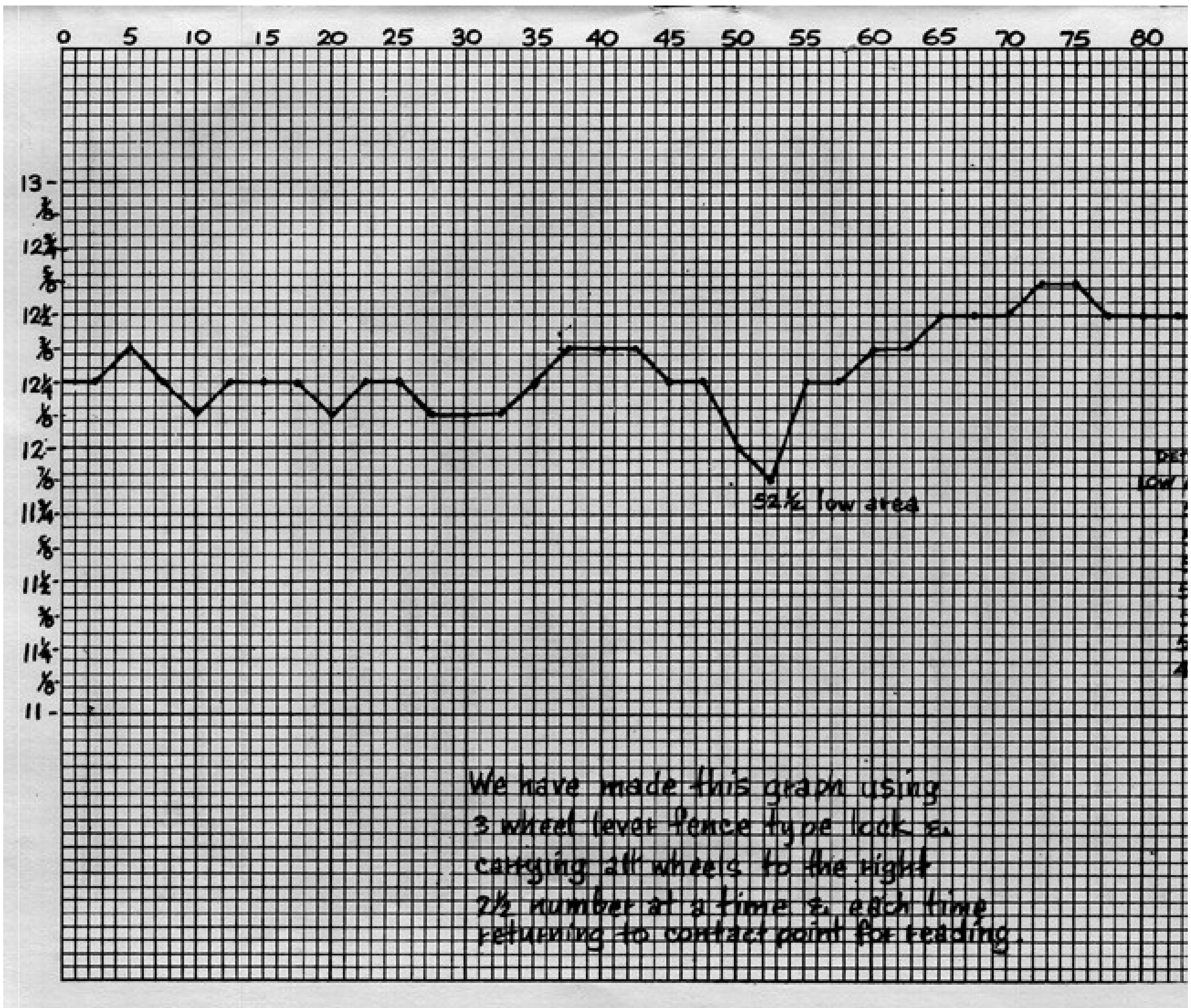


Figure M06. Graph #1

Turn the dial four times right, carrying all wheels to “0”. Turn the dial left to the contact point. It is important to grasp the dial with a very light touch when turning to a contact point. This is a critical issue, because the validity of the reading depends upon the nose of the lever barely touching the gate area. If the nose is over-driven, then the reading will be skewed and in error. Remember, manipulation is based upon tolerance errors of a few thousandths of an inch. This correlates to an extremely minute change within the dial marker indication as the relative location of the nose within the lever changes.

- **Turn dial to the right, moving all wheels to 97 1/2;**
- **Turn dial to the left to contact point, take reading, and record on graph;**
- **Turn the dial to the right, moving all wheels to 95;**
- **Turn the dial left to contact point, take reading and record on graph;**
- **Turn the dial to the right, moving all wheels to 92 1/2;**
- **Turn the dial left to contact point, take reading and record on graph;**
- **Turn the dial to the right, moving all wheels to 90;**
- **Turn the dial left to contact point, take reading and record on graph;**
- **Turn the dial right, moving all wheels to 871/2,**
- **Turn dial left to contact point, take reading and record on graph.**
- **Before taking each reading at the contact point, oscillate the dial right and left over the drive cam opening, in order to float or work the fence to the lowest possible point. This will give you a closer reading.**

Follow the above procedure for every 2.5 number divisions, moving all wheels completely around the dial, taking readings and making

recordings on the graph.

The number of divisions for each sample is in part based upon the tolerance of the lock and the interaction of the gate and fence. A contact reading may be taken every number, if desired. This will provide more qualitative data from which to chart wheel geometry. However, every 2, or 2.5 division is sufficient for most Group 2 locks.

In the first edition of this manual, the authors did not address the issue of “parking” of each wheel during contact readings. This concept is important, and is addressed more fully in **Chapter 36** of Locks, Safes, and Security. Parking describes the practice of isolating each wheel, so that a determination can be made as to which is indicating. This is required in order to derive the correct combination sequence, and to insure that only one wheel is analyzed at any one time.

Parking simply requires that the first, second, or third wheel (in a three wheel lock) is rotated through the contact area, while the other wheels remain in one position. This is accomplished at the beginning of the reading sequence, when all wheels are rotated left or right to pick up all flys and drive pins. Depending upon which wheel is to be tested, the **first**, or **first and second** wheels are set to an imaginary number on the dial.

If the first wheel is to be tested, then after all wheels are rotated left for several revolutions, the dial is turned right, for example, to take contact readings. If the second wheel is to be tested, then after AWR or AWL, the first wheel is set to an imaginary number as if the combination were being entered. The rotation direction of the dial is reversed and the second wheel is moved through the contact area, division by division. If the third number is to be tested, then this process is repeated as if the first and second imaginary numbers were dialed; the third number being tested for contact readings. In this manner, each of the wheels can be tested individually.

Remember that as the wheels are moved to the right and pass the contact point, there is only a short rotational clearance remaining to the other contact point in order to take reading. Do not rotate completely around the dial. To illustrate, our contact point is approximately 12, so as we pass 12 and go to 10 with all wheels, we only turn back left two divisions to the contact point to obtain a reading.

When finished taking samples of each dial division group, examine graph for:

Sharp drops and rises
Gradual drops or rises

Identify all apparent low areas on the graph. These indications represent **potential** gate areas on each wheel, although they may also represent production errors in the stamping of each disc. It must also be understood that a failure to identify a low area may be due to a problem known as shadowing, whereby an adjacent wheel is blocking a reading of the next gate.

In our example graph, the *apparent* location of the gate is at 52. However, this is not a precise measurement but rather an approximation. The exact drop in point must now be determined.

Finding Exact Drop In Point

This is accomplished by first rotating the dial four times right, stopping at 56. Then,

- **Turn the dial left to contact point and record reading;**
- **Turn the dial right, moving all wheels from 56 to 55;**
- **Turn the dial left to contact point and record reading;**
- **Continue every number to 49, each time moving the wheels only one division at a time, and record the readings.**
- **By checking recordings, we find 52 gives the best reading or indication, so we assume 52 is one of the combination settings.**

The use of graphs in learning manipulation is most important, and the authors advise making a graph on every lock that is manipulated until proficiency is achieved. A graph will provide an overall picture of low areas of the wheel pack and in some cases will indicate two numbers of the combination setting.

Always study your graphs thoroughly, not only for sharp declines which likely indicate a gate, but also for gradual declines over

several numbers. Occasionally, a sharp decline will not be recorded; therefore the number-one and number-two wheels will have to be set in this gradual low area, and then attempt to obtain a better reading or indication of the number-three wheel.

To illustrate, assume that the gradual low area is between 37 and 52. The authors outline the following procedure to determine the precise location of the gate:

- **Turn the dial right four times, stopping at the center of the low area (approximately 43);**
- **Turn the dial left one complete revolution, picking up the number-three wheel at 43 and stop at 45;**
- **Turn the dial right to the contact point, take reading and record them on the graph;**
- **Turn the dial left to 45, picking up the number-three wheel and stop at 47;**
- **Turn the dial right to the contact point, take a reading and record it on the graph. Continue moving the number-three wheel every two divisions (numbers) completely around the dial; Determine which wheel is giving the lowest reading or best indication. By the process of elimination, find which wheel is giving the low or best indication;**
- **Turn the dial to the right four times, stopping at 52;**
- **Turn the dial left, causing only the drive cam to rotate. No discs are affected until reaching 52, where the number-three wheel (the one closest to the drive cam) is picked up. Stop at 62;**
- **Turn the dial right to the contact point and take a reading. At this time, the number-one and number-two wheels are at 52 the number-three wheel is on 62.**
- **If a good reading or indication is lost, it is likely that the number-three tumbler is the one that is giving the good reading. If there is still a good indication, then rotate the dial left to 62, picking up the number-three wheel; continue**

left and pick up number-two wheel at 52 and stop at 62.

- **Rotate the dial right to the contact point and take a reading. If a good reading or indication is lost, it is probable that the number-two tumbler is the one providing the good reading or indication. If there is still a good indication, then the number-one wheel must be the one being tested.**

This process is a modified form of "parking" which was noted earlier. Its purpose is to isolate and identify the indicating wheel, by eliminating the other two (or three) tumblers during the taking of readings.

We are actually moving one wheel at a time off the number that is giving the best indication, beginning with the disc that is nearest to the drive cam, or the number-three wheel in a three wheel lock (number-four wheel in a four wheel mechanism). Assuming that the number-three wheel was actually the one giving the good indication, we know that the third number of our combination is 52.

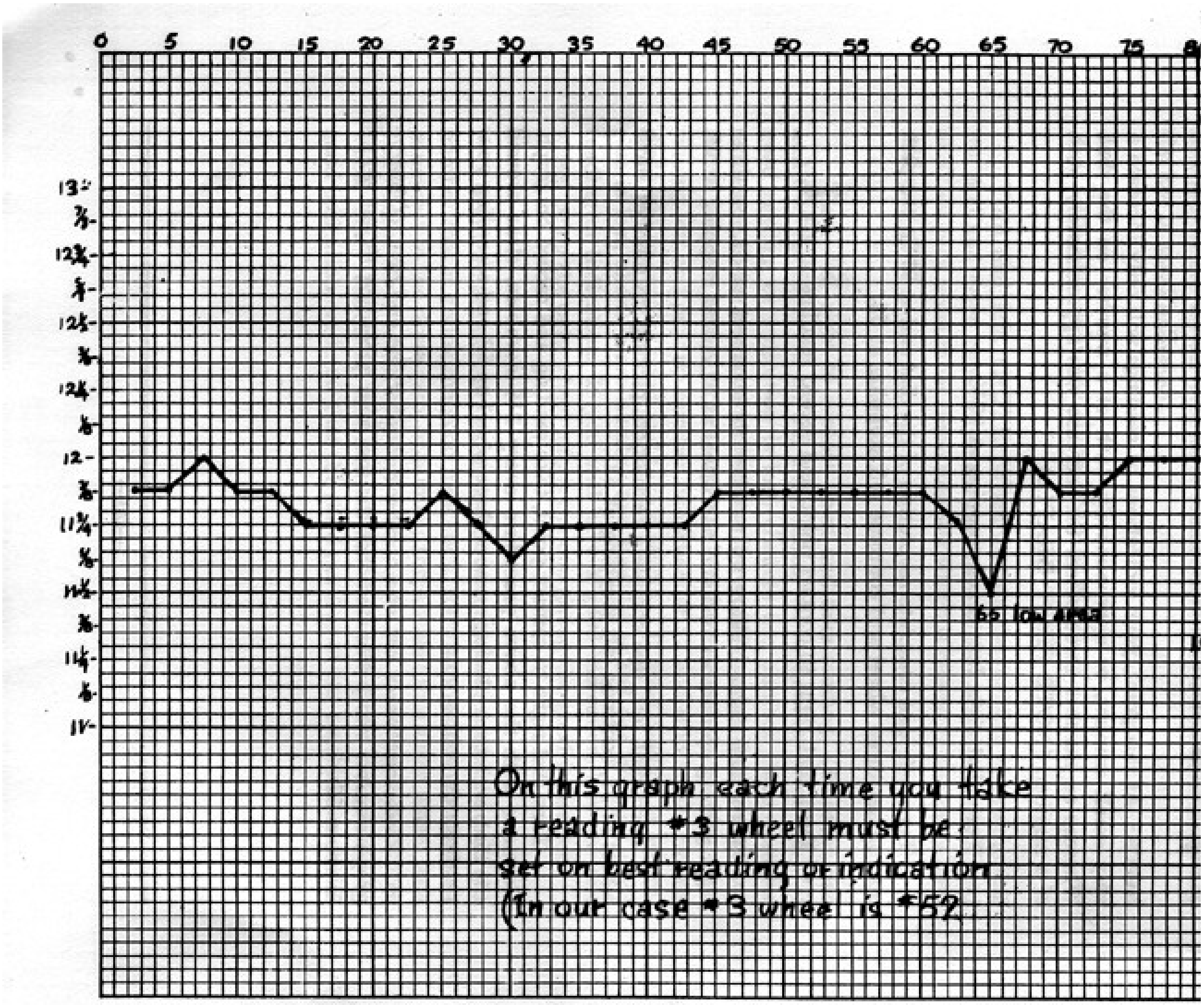


Figure M07. Graph #2.

- **Determine the low area or drop in point of tumblers number-one or two. A graph should be prepared for readings of these wheels;**

- **At this point, the indications or readings will increase a very small distance; approximately 1/8th of a dial marker division. In contrast, the change in the number-three wheel indication was approximately 1/4th of a marker division. Refer to the first graph;**

- **Turn the dial right four times, stopping at 97 1/2;**

- **Turn to the left one complete revolution, picking up the number-three wheel at 97 1/2, continuing left and stopping at 52;**

- **Turn the dial right to the contact point and record the reading on the graph;**

- **Turn the dial right, picking up the number-three wheel at 52;**

- **Continue right while picking up the number-two and number-one wheel at 97 1/2 and stopping at 95;**

- **Turn the dial left for one complete revolution, picking up number-three wheel at 95. Continue left, stopping at 52;**

- **Turn the dial right to the contact point, take a reading and record on the graph. Continue to take samples for every 2 1/2 numbers, completely around the dial. For each reading, place the number-three wheel on 52 and record the readings;**

- **Determine the exact low area of wheel number-one and number-two, by examining the second graph. We find that it is probably at about 65;**

- **Turn the dial right four times, stopping at 68;**

- **Turn the dial to the left one complete revolution, picking up number-three wheel at 68, and stopping at 52;**

- **Turn the dial right to the contact point, take a reading and record it;**

- **Turn the dial to the right and pick up the number-three wheel at 52, then continue right, picking up the number-one and number-two wheels at 68, stopping at 67;**

- **Turn to the left one complete revolution, picking up the number-three wheel at 67, continuing left and stopping at 52;**

- **Turn right to the contact point, take a reading and record the**

data Continue moving the number-one and number-two wheels to the right, one marker division at a time through 62, while placing the number-three wheel on 52 and returning to your contact point for a reading. From the graph we find that the exact low area of the number-one and number-two wheels is 64, and with number-three wheel on 52, we obtain the best indication or reading.

Isolating Individual Wheels

It can be seen from the first graph (number one) that when we were carrying all three wheels to the right and taking readings, that the position of the marker for number 52 read 11 7/8 on the dial. Now, on graph number two with the number-one and number-two wheels on 64 and number-three wheel on 52, our best reading was 11 1/2. So, how is it possible to determine which wheel is giving a good indication at 64, because it could be either the number-one or number-two wheel?

Isolating the Number-two wheel

- **Turn the dial right four times to 64. Turn the dial left for one complete revolution, picking up the number-three wheel at 64 and continuing left one more revolution to pick up the number-two wheel at 64 and stopping at 74;**

- **Turn the dial right one complete revolution, picking up the number-three wheel at 74 and stopping at 52;**

- **Turn left to the contact point, and take a reading. If a good indication has been lost, chances are that the number-two wheel, which is set on 64, was the one giving the good indication or reading. If a good indication remains, then the number-one wheel was providing the reading. In our case, the good indication was lost, thus demonstrating that 64 is the number-two wheel, or the second number of the combination.**

We have now derived what we believe to be two of the three numbers of the combination: those for the number-two wheel (at 64) and the number-three wheel (at 52). By the process of elimination we must now find the combination setting of wheel number-one.

- **Turn to the right four times stopping at 97 1/2;**
- **Turn to the left three times to 64;**
- **Turn to the right two times to 52, left to the drive cam opening, and oscillate the dial back and forth between contact points. Rapid oscillation after trying each combination setting will yield information from the sound and feel of the dial as the gate of the number one wheel is reached. If the true gate position is one or two divisions off from that shown on the graph, the fence can be worked into the gating by this method, thereby deriving the exact reading;**
- **Turn right four times stopping at 95.**
- **Turn left three times to 64. Turn right two times to 52.**
- **Turn left to the drive cam opening, and oscillate the dial back and forth between contact points. Continue moving the number-one wheel every 2 1/2 divisions, each time placing the number-two wheel on 64 and the number-three wheel on 52, until the lock is open. In most cases,the number-three wheel usually indicates first.**

Within the imperfect world of combination locks, **any** wheel can provide the initial indication. In the following example, the number-two wheel has been verified as giving the first positive reading. Now, the gate position of the number-three wheel should be determined, because it is usually the easiest to move.

Isolating the Number-Three Wheel

It is critical to correctly be able to isolate and identify each indicating wheel. Three examples are presented in the following pages to demonstrate the correct procedure. In these exercises, we wish to target wheel number-three.

Example 1

In our first example, we find that a good indication is at 36, which we have proven to be the number-two wheel. In the following exercise, the position of the number-one and number-two wheels will remain at 36, and they will not be disturbed.

- **Turn the dial right four times stopping at 36;**

- **Turn the dial to the left for one complete revolution, picking up the number-three wheel at 36 (leaving the number-one and number-two wheels at 36), and stop at 37 1/2;**

- **Turn the dial right to the contact point, take a reading, and record on the graph;**

- **Turn the dial to the left, picking up the number-three wheel at 37 1/2 and stopping at 40;**

- **Turn the dial right to the contact point, take a reading and record on the graph. Continue moving the number-three wheel every 2 1/2 numbers completely around the dial, each time taking a reading and recording it on the graph. Remember, as the number-three wheel is moved through the contact area, only a slight rotation of the dial will be required in order to take a reading;**

Example 2

Another example is provided, where the contact point is 3 1/4, with the number-one and number-two wheels on 36. The number-three wheel is moved left every 2 1/2 divisions past the contact point, stopping at 5.

- **Turn the dial to the right only 1 3/4 numbers to the contact point, which is at 3 1/4, and take a reading and record the information;**

- **Turn the dial to the left and at 5, pick up the number-three wheel and move it to 7 1/2;**

- **Turn the dial to the right only 4 1/4 numbers to the contact point, take a reading, and record the data. Continue moving the number-three wheel to 35;**

- **Check your graph for the lowest area and determine the exact low point of the number-three wheel by moving the number-three wheel over this area, one division at a time. What if you found the number-three wheel to be set on 82. You already**

have the combination setting of the number-two and number-three wheels. Follow the same procedure as before by moving the number-one wheel 2 1/2 divisions for each reading, and for each sample, set the number-two wheel on 36, and the number-three wheel on 82, until the lock is open.

Example 3

- **Turn right four times to 97 1/2;**
- **Turn left three times to 36;**
- **Turn right two times to 82;**
- **Turn left to the contact point or drive cam opening, and oscillate dial.**

Example 4: Number-One Wheel Indicates First

We will now explain what to do if the number-one wheel indicates first. In most cases when this occurs, the number-two wheel will indicate next.

In this example, you have determined the exact location of the low point for the number-one wheel from your graph, at 27. Proceed as follows to isolate the indicating wheel.

- **Turn the dial right four times, stopping at 27;**

- **Turn the dial to the left two complete revolutions, picking up the number-three wheel on the first revolution at 27, and the number-two wheel on the second revolution at 27, and moving them both to 30;**

- **Turn the dial to the right to the contact point, take a reading and graph the data;**

- **Turn the dial to the left, picking up the number-three and number-two wheels at 30, and stopping at 32 1/2;**

- **Turn the dial to the right to the contact point, take a reading and record the data;**

- **Continue moving the number-three and number-two wheels to the left every 2 1/2 divisions**

completely around the dial to 25, each time taking and recording the reading. These actions have been accomplished without moving the number-one wheel that we left set at 27;

- **Determine the exact low point of the number-two wheel (assuming it to be at 47), and use the process of elimination for the number-three wheel. This is quite simple, because the wheel is easily moved without disturbing the others;**
- **Turn the dial right four times to 27;**
- **Turn the dial left three times to 47;**
- **Turn the dial to the right one revolution, picking up the number-three wheel at 47 and stopping at 45;**
- **Turn the dial to the left to the contact point and oscillate back and forth over the drive cam opening;**
- **Turn the dial to the right, picking up the number-three wheel at 45, then move to 42 1/2;**
- **Turn the dial left to the contact point and oscillate back and forth over drive cam opening.**
- **Continue moving the number-three wheel to the right every 2 1/2 divisions until the lock is open.**

In this example, the number-three wheel has been moved around the dial without disturbing the position of the number-one or number-two wheels, which were left on 27 and 47 respectively.

CHAPTER THREE: Manipulation of Mechanisms other than the Lever Fence

Introduction

In the preceding chapter, detailed procedures and examples demonstrated the methods to manipulate the lever fence lock. In the materials that follow, information will be presented regarding the techniques that are employed for the rotary fence gear-driven, rotary fence spring-loaded, straight-in tail piece, bottom-drop, and off-set gear driven mechanisms. Although the fundamental principles are the same, the methods required in obtaining accurate readings or indications will differ.

Manipulation(539) Procedures for Rotary Fence Gear-driven Locks

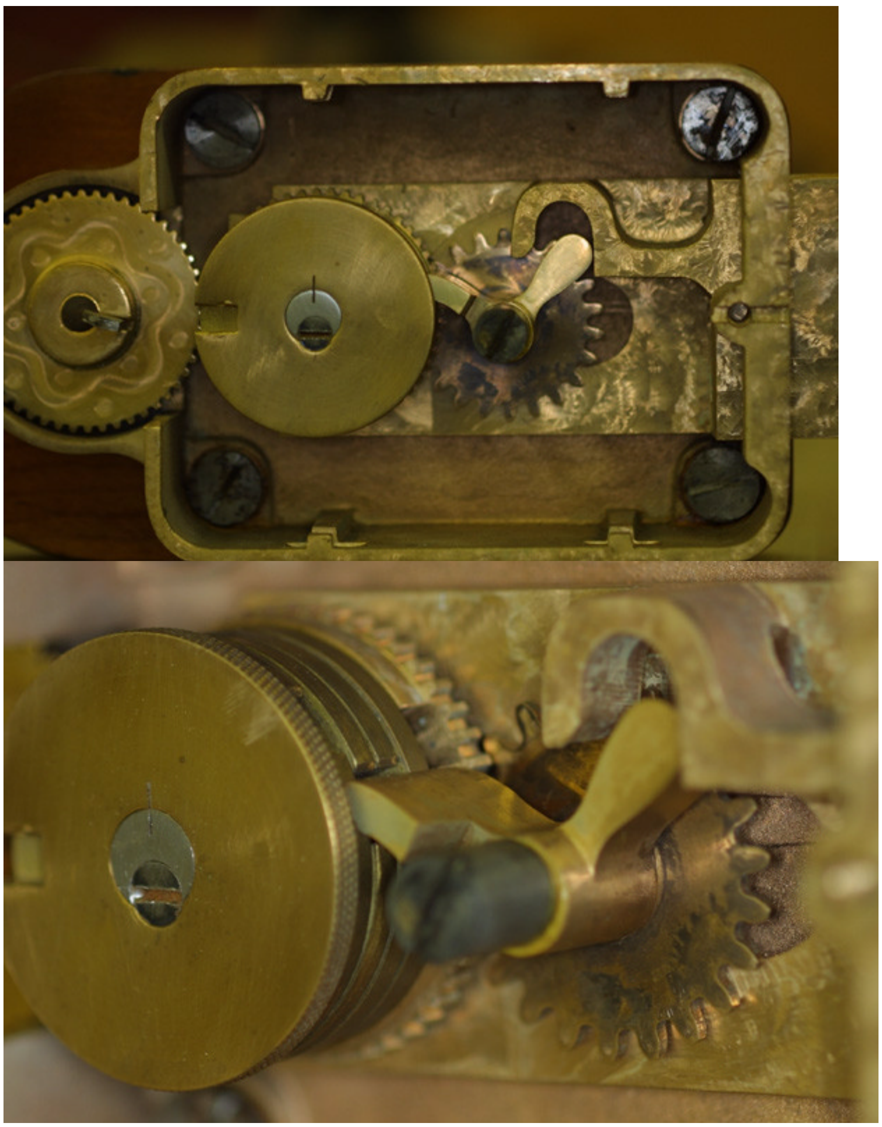


Figure M08. Rotary fence, gear driven lock.

It will be recalled that the lever fence mechanism offers two contact points that can provide data as to each wheel, although the sloping side of the fence offers more qualitative information. In the rotary fence gear-driven lock, readings can only be taken by rotating the dial counterclockwise. This is due to the mechanical design of the lock: as the dial is turned to the right, the friction between the gear and the fence moves the fence away from the drive cam and wheels.

If the dial is rotated to the left, however, the fence moves **toward** or against the drive cam and wheels, allowing the taking of readings at the drive cam opening.

Occasionally, due to variances in manufacturing, the drive cam is smaller than the wheels, thus allowing the fence to ride on the tumblers. By slowly and carefully turning the dial to the left, the gatings can sometimes be heard or felt as they rotate past the fence.

Manipulation Procedures for Spring-Loaded Rotary Fence





Figure M09. Yale OC9 spring roller fence lock.

This lock is manipulated in the same manner as the lever fence mechanism, described earlier.

Manipulation Procedure for Straight-in Tail Piece

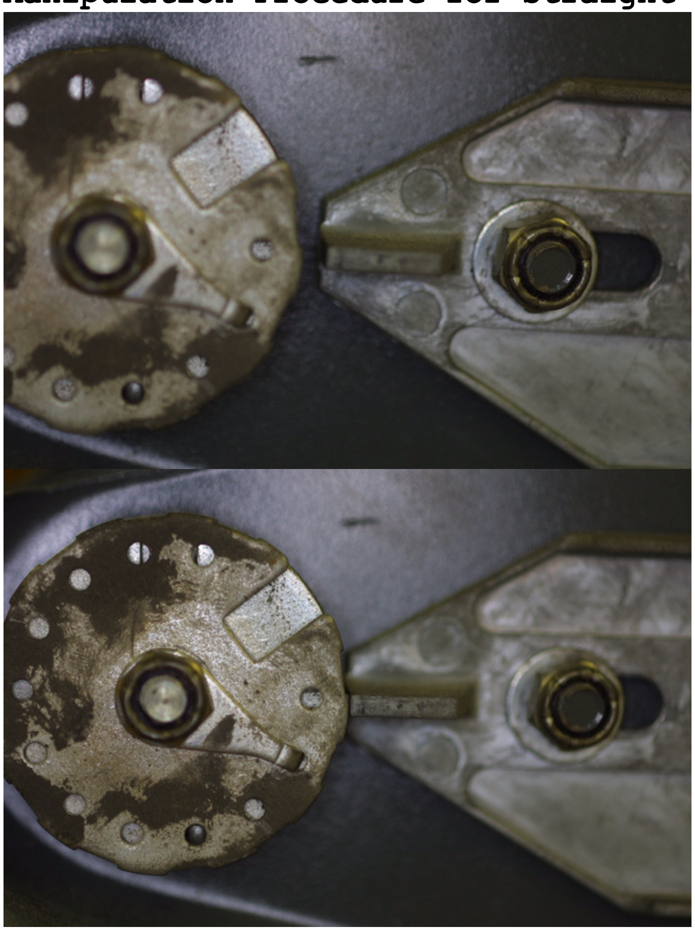






**Figure M10. Straight tail piece. Pressure can be applied directly against the wheel
pack to determine gate position.**

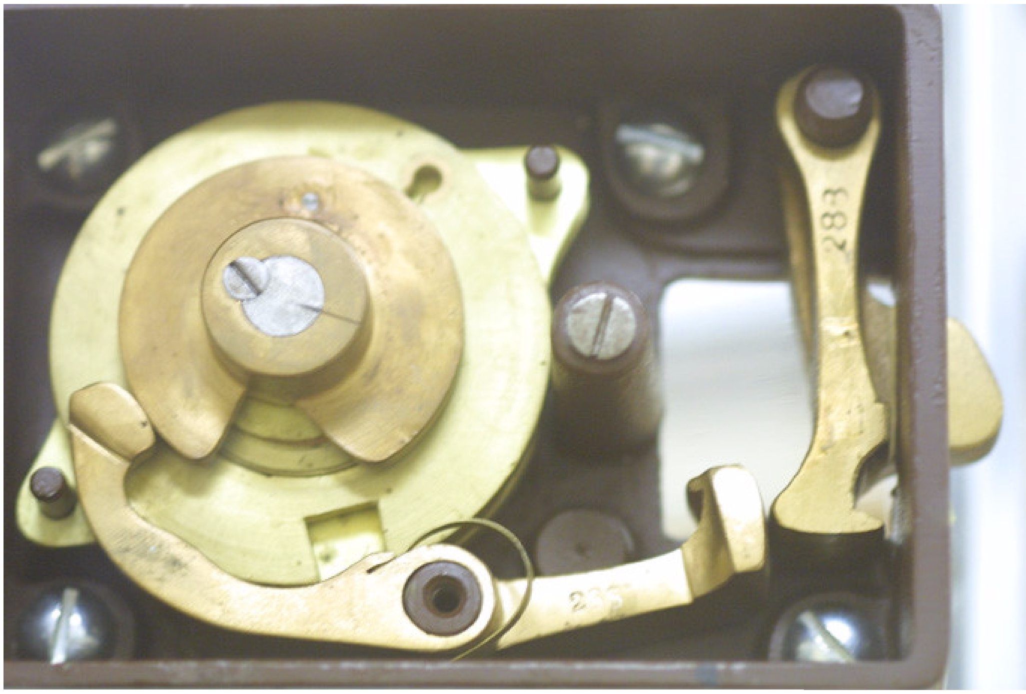
The mechanical design of this lock differs from all other types, and requires that contact indications and readings must be taken and charted from the **handle**, rather than from the dial.

To provide contact indications, a pointer must be constructed of approximately twelve and eighteen inches in length, and affixed to the handle of the safe. Located at the tip of this pointer, a sheet of paper is taped to the door and marked with graduations of 1/16”, to simulate the dial divisions for position data.

Once the pointer is in place, determine the drive cam opening. Often, there are false gatings in several places around the drive cam, although the true gating is usually narrower. By rotating the dial with pressure on the handle, a determination can usually be made as to which is the true gating or drive cam opening by the amount of play in the dial, when held by the handle tail-piece.

Once the location of the drive cam opening has been ascertained, follow the same procedure as described for the lever fence lock, with the exception that readings are derived from the pointer attached to the handle.

Manipulation Procedure for Bottom-Drop Mechanism



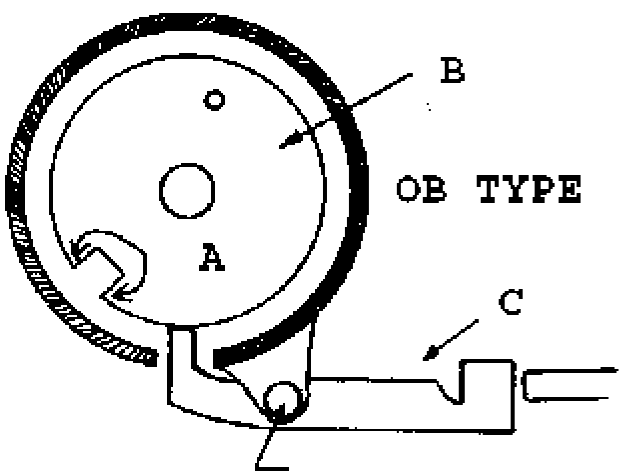


Figure M11. Bottom drop mechanism. In the diagram, (A) are the contact points, (B) is the drive wheel or cam,
(C) is the lock dog or fence.

There are two different designs incorporated in this type of mechanism: **gravity fence**, and **handle pressure actuated fence.** These locks have two contact points; either will usually provide the same indications and readings.

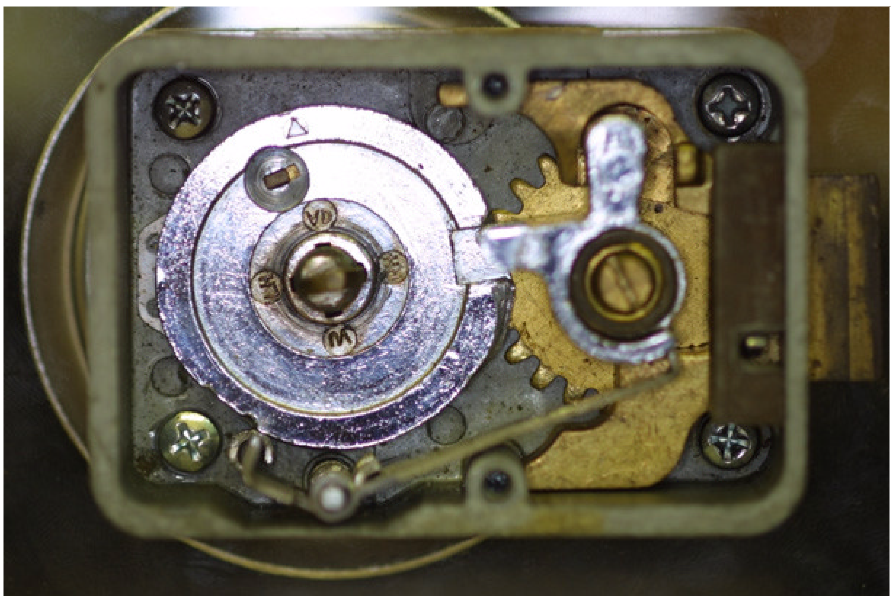
A. Gravity Fence

This lock is manipulated in the same manner as the lever Fence.

B. Fence Actuated by Handle Pressure

These devices are manipulated in the same manner as the lever fence, except that the handle must be turned to raise the fence so that it will contact the drive cam opening and wheels in order to take readings or indications.

Manipulation Procedures for Offset Gear-Driven Locks



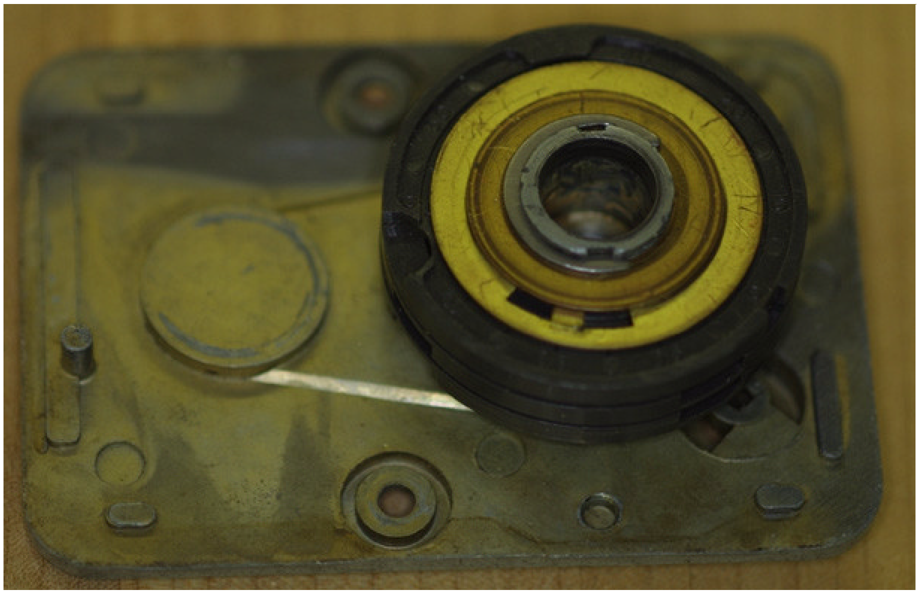
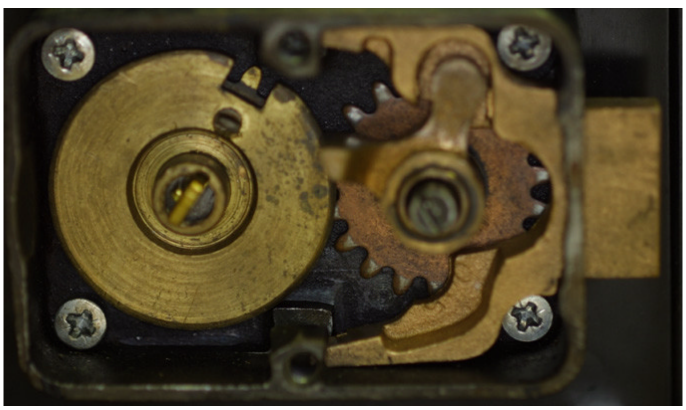
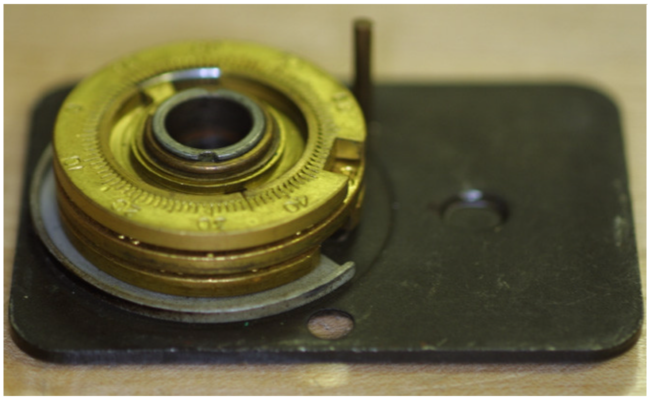


Figure M12. Yale B30 Manipulation resistant 1950 vintage UL 1R label.

Manipulation is accomplished in the same manner as with the direct drive locks described above; however, they are more difficult to read, due to the slack in the gears. The technique requires greater practice to become proficient.





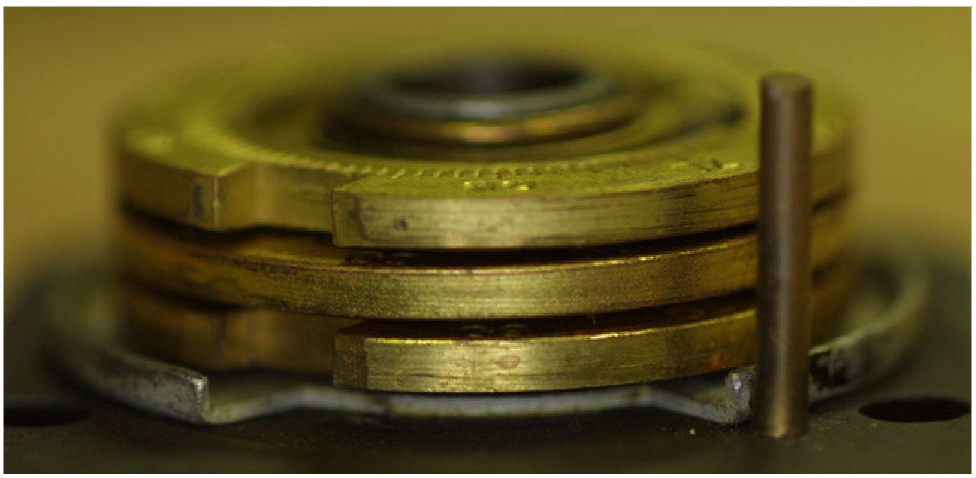


Figure M13. Yale OC5 geared roller fence. Only the left contact is read.

CHAPTER FOUR: Manipulation Resistant (MP) Locks

As with traditional key locks that boast that they are pick-proof, so also, there is a class of mechanical combination locks, designated as Group 1 devices, that are manipulation-resistant. Although most key and combination locks can be manipulated in one form of another: it is simply impractical with certain high-security and Group 1 designs. Since the original edition of this manual was written almost fifty years ago, the introduction of sophisticated microprocessors such as employed in the unique Mas-Hamilton X-07 and X-08, have created a class of locks that simply cannot be manipulated.

Mas-Hamilton has developed a highly sophisticated system called the Soft Drill, that actually performs manipulation on several popular combination locks, through the use of sound and mechanical feedback from the lock. The information from surface sensors is fed through a microprocessor and displayed on a laptop computer. The system will open many Group 2 locks. The reader is referred to **Chapter 36** for additional information.

Certain MP and MR Group 1 combination locks can theoretically be manipulated, and thus, information is presented here regarding the technique. The author utilizes the term "theoretically" to describe these manipulation processes because, although impractical, it is possible.

Rotary Fence Gear Driven MP Locks

This lock is almost identical to the older design, except for an additional lever that has been added to hold the fence away from the drive cam and tumblers until the proper combination has been run. It then drops into a narrow gating in all of the wheels, and allows the fence to contact the drive cam and open the lock.

This piece will be referred to as the manipulation-resistant lever. Instead of taking readings at the regular drive cam opening and fence, all of the indications will be derived from this lever, together with the small gatings in the tumblers and the slight depression in the drive cam into which this lever drops when the lock is opened.

The point of contact will be approximately 2 or 3 on the dial, where this manipulation-resistant lever contacts the edge of the depression on the drive cam, as the dial is rotated to the left. Although this lock has four tumblers, they often are only set on three numbers.

As an aid in obtaining readings or indications, it is usually necessary to mount a good magnifying glass or reading glass over the dial, in order to see the indications, as they are very slight. Also, a large pointer, twelve to eighteen inches long, may be attached to the dial, as in the case of the safe handle on the straight tail-piece.

This will increase the slight variations in indications to an extent that they will be more easily read. Otherwise, the lock is manipulated in the same manner as the regular rotary fence

gear driven device.

Lever Fence Mechanism

This lock is similar in outward appearance to the conventional version for the same manufacture. After dialing the combination setting, turn the dial to 100 and push in, allowing the lever to drop into the drive cam opening and rotate the dial to the right, retracting the bolt. The dial is spring loaded and can only be pushed in at 100.

In order to manipulate this lock, it is necessary to secure a machinist's dial indicator and mount it on the front of the safe, with the tip of the indicator touching the outermost point of the dial knob.

The manipulation procedure is the same as a regular lever fence lock, except that each time a reading is obtained the dial is set on 100, and pushed all the way in, allowing the lever and fence to drop down on the wheels. Then slowly let the dial come out until the lever contacts the beveled edge of the drive cam; take a reading on the dial indicator at this time. The lesser reading on the dial indicator will possibly be a combination setting. Although possible, this is a highly impractical procedure, due to the time required. It will be remembered that the applicable UL standards for manipulation-resistant locks require a minimum of 20 man-hours of manipulation resistance. See **Chapter 37**.

Conclusion

Manipulation requires a great deal of practice to become proficient. Attention to detail and perseverance, together with the technical understanding of the lock, and mechanical aptitude are prerequisite to mastering the Art of Manipulation.

Endnotes

1 (Popup - ART OF MANIPULATION)

The Art of Manipulation was first published in 1953, by Clyde Lentz and Bill Kenton.

2 (Popup - A Treatise on Fire & Thief-Proof Depositories and Locks and Keys)

A Treatise on Fire & Thief-Proof Depositories and Locks and Keys, Written by George Price, and published in London by Simpkin, Marshall, and Co., 1856.

3 (Popup - LOCKS AND SAFES: The Construction of Locks)

LOCKS AND SAFES: The Construction of Locks, compiled from the papers of A. C. Hobbs, Esq. of New York, and edited by Charles Tomlinson, Esq.

Reprinted 1970: Published by Kingshead Reprints, Kingshead Square, Bath, England; first published in 1868 by Virtue and Company, London.

4 (Popup - LOCKS, SAFES, AND SECURITY)

Locks, Safes, and Security: A Handbook for Law Enforcement Personnel, was originally published in 1970.

Charles C. Thomas Publishers is located at 2600 South First Street, Springfield, Illinois, 62704. Telephone: 217.789.8980. They maintain a website at www.ccthomas.com

5 (Popup - SECURITY.ORG)

http://www.security.org is the website maintained by the author to provide supplementary materials for the bound edition of Locks, Safes, and Security, and for LSS+. For additional information, please contact the author at Investigative Law Offices, 1.605.334.1155, or at e-mail address marc@security.org.

6 (Popup - SUPPLEMENTARY MULTIMEDIA INFOBASES)

A series of supplemental disks will be supplied with **LSS+**. Depending upon security level (1,2,3) you will be provided with disks in the **LSS100**, **LSS200**, and **LSS300** groups. These will be continually updated as new materials are added. You will be responsible for purchasing additions to the Infobase.

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Security Level 1: LSS100 GROUP

LSS101

LSS101: Interview with Jeremy Bramah

LSS101: Ikon factory, Berlin, Germany: How locks are made.

LSS101: Scanning electron microscope Part I: Michael Platek

LSS101: Scanning electron microscope Part II: Michael Platek

LSS101: Scanning electron microscope Part III: Michael Platek

LSS101: Discussion of safe design by Bill Sherlock.

LSS101: Discussion of the X-07 and X-08 with Joe Cortie

8 (Popup - SUPPLEMENTARY MULTIMEDIA INFOBASES)
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select the file directly. You may open more than one infobase at a time. Thus, the **LSS+** infobase as well as the linked multimedia infobase (such as LSS101, for example) can both be active. To close the multimedia infobase, select [FILE] [CLOSE]. This will close the second infobase and return you to the **LSS+** infobase.

Security Level 2: LSS200 GROUP

LSS201

LSS201: Procedure for making keys with a clay mold. Courtesy of MSC.

LSS201: Making keys by silicone impression, Courtesy of MSC

LSS201: MSC Assortment of tension wrenches, courtesy of Mahmod Abu Shanab

LSS201: MSC "Sputnik" bypass tool, courtesy of MSC.

LSS201: MSC Lock Force tool, courtesy of MSC

LSS201: Forced entry tools produced by Sigma. Courtesy of Ian Bauchop.

LSS201: A primer on the burglary of safes, Courtesy of Bill Sherlock.

LSS201: Forensics and locks, Courtesy of Bill Sherlock.

LSS201: Mark Bates on Manipulation

LSS201: Mark Bates on the Soft Drill

LSS202

LSS202: Broco Thermic lance description and use, by Tom Joos.

LSS202: Steve Mattoon on the use of explosives to gain entry.

LSS202: Kaba-Ilco Quattrocode key machine, Courtesy of Steve Fish.

LSS202: The Ultracode key machine, Courtesy of Steve Fish.

LSS202: The Kaba-Ilco Triax key machine, Courtesy of Steve Fish.

LSS202: Kaba-Ilco RW2 Transponder system, Courtesy of Steve Fish.

LSS202: Forensic investigation and the locksmith, by Don Shiles

LSS202: The use of the "bump key" or "999" key, by Hans Mejlshede.

LSS202: Ross Anderson on smart card technology

LSS202: Ross Anderson on security engineering

LSS202: Ross Anderson on biometrics

LSS203

LSS203: The forensic investigation of locks and keys, by Hans Mejlshede.

LSS203: HPC BlueSHARK third generation key cutting machine.

LSS203: Rosengrens RKL10 assembly procedure

LSS203: Matt Blaze on shimming a cylinder to determine all pin segments

LSS203: Brian Chan on TMK extrapolation

LSS203: Harry Sher on the decoding of a top level master key

LSS203: Matt Blaze on the extrapolation of a top level master key

LSS203: Harry Sher on covert methods of entry

LSS203: Demonstration of the use of a loid, by MSC

LSS203: Demonstration of the MSC cross pick on a lock with four rows of tumblers

LSS203: Demonstration of the MSC electropick on a profile cylinder

LSS203: Easy entrie key machine demonstration

LSS203: MSC Acoustic picking tool demonstration

LSS204

LSS204: Owe Bengtsson on opening safes

LSS204: Owe Bengtsson introduction to opening safes

LSS204: Owe Bengtsson on the forced entry opening of safes

LSS204: Owe Bengtsson on the opening of high security safes

LSS204: Owe Bengtsson on picking lever locks and utilizing markings on the levers.

LSS204: Owe Bengtsson on picking the Kromer Convar lock

LSS204: Owe Bengtsson on picking the Kromer Novum lever lock

LSS204: Owe Bengtsson on picking the Stuv lever lock.

LSS204: Owe Bengtsson on opening the Rosengrens ABN1 lever lock.

LSS204: Owe Bengtsson on opening the Rosengrens RKL10 high security lever lock

LSS204: MSC Sputnik II with audio probe

LSS204: Harry Sher on picking axial pin tumbler locks

LSS204: Brian Chan on the use of system keys.

LSS204: Brian Chan on positive and negative locking.

LSS204: Brian Chan on lubrication of locks

LSS204: Brian Chan on the Sequence of Progression

LSS204: Brian Chan on assumptions regarding master keying

LSS204: Brian Chan discussing old style master keying and pinning.

LSS204: Brian Chan on the disassembly of a lock and derivation of the TMK

LSS204: Brian Chan discussing the pinning of a Best IC lock

LSS204: Brian Chan on master keying rules

LSS204: Brian Chan discussing balanced drivers

LSS204: Demonstration of the Keyway King, by Greg Brandt

LSS205

LSS205: Gale Johnson on key codes

9 (Popup - SUPPLEMENTARY MULTIMEDIA INFOBASES)

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Security Level 3: LSS300 GROUP

LSS301

LSS301: Foil impressioning system, by John Falle

LSS301: Abus decoder, by John Falle

LSS301: European lever lock decoder, by John Falle

LSS301: Ford Galaxy decoding system, by John Falle

LSS302

LSS302: Medeco lock decoding system, by John Falle

LSS302: Universal pin lock decoder, by John Falle

LSS302: European lever lock pick, by John Falle

LSS302: Axira lock decoding system, by John Falle

LSS302: BMW lock decoder system, by John Falle

LSS303

LSS303: Analysis of bypass techniques, by John Falle

LSS303: Pin and cam system for CISA and other European locks, by John Falle

LSS303: BiLock decoder system, by John Falle

LSS303: Abloy decoder system, by John Falle

LSS303: Universal pin and cam system, by John Falle

LSS304

LSS304: Universal belly reader system, by John Falle

LSS304: Key turning system for lever locks, by John Falle

LSS304: DOM Diamond decoder and pick system, by John Falle.

LSS304: DOM Dimple foil impressioning system, by John Falle

LSS304: Chubb AVA pick and decoder system, by John Falle

LSS305

LSS305: EVVA 3KS pick and decoder system, by John Falle

LSS305: Pin lock decoder system with pin and cam technology, by John Falle.

10 (Popup - LSS400)

A series of supplemental disks will be supplied with **LSS+.** Depending upon security level (1,2,3) you will be provided with disks in the **LSS100, LSS200, LSS300,** and **LSS400** groups. These will be continually updated as new materials are added. You will be responsible for purchasing additions to the Infobase.

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infobase (such as LSS101, for example) can both be active. To close the multimedia infobase, select [FILE] [CLOSE]. This will close the second infobase and return you to the **LSS+** infobase.

Security Level 3: LSS400 GROUP

ALARMS GROUP

LSS401

LSS401: E Field protection

LSS401: Buried Cable sensors

LSS401: Fence alarm system

LSS401: Microwave sensor systems

LSS401: Outside passive infrared sensors

LSS401: Photoelectric sensors

LSS401: Thermal imaging and sensing

LSS401: Video logging and capture systems

LSS401: Alarm contact devices, including magnetic switches

LSS401: Discussion regarding pressure mats

LSS401: Embedded screen wires

LSS401: Alarm foil

LSS401: Grid wires in alarm systems

LSS401: Ribbon switch material as a sensor

LSS402

LSS402: Shock sensors for glass break detection

LSS402: Other types of shock detection sensors

LSS402: Trip wires in alarm systems

LSS402: Alarm monitoring systems

LSS402 Defeat techniques for different sensor technologies

LSS402: Glass break sensors and how they work

LSS402: Issues with microwave sensors

LSS402: Alarm sounders and notification devices

LSS402: Ultrasonic alarm sensors

LSS402: Proximity sensor technology

LSS402: Alarm defeat methods for dual technology devices

LSS402: Passive infrared sensor technology

LSS403

LSS403: Fiber optic fence sensors

LSS403: Shock sensors utilized to protect fences

LSS403: Magnetic point sensors

LSS403: Dual technology devices utilized in outside environments

LSS403: Ross Anderson on alarm system monitoring

LSS403: Magnasphere technology

LSS403: DOE on perimeter sensors and their defeat

LSS403: DOE on alarm assessment

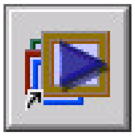
LSS403: DOE on sensor technology

LSS403: DOE on layers exterior protection

LSS403: DOE on a typical plan of attack on a facility

LSS403: Defeat of magnetic switches, including BMS

11 (Popup - MULTIMEDIA LINKS)

 This icon appears before any audio or video link contained within this infobase, where the material is contained on the Infobase CD. It denotes the use of Windows Media Player, which can be downloaded from Microsoft. Most of the multimedia clips are contained on separate CD/ROMS, due to their size. They will be referenced by security level and disk number as well as the icon shown below. Please note that you may notice a synchronization error between audio and video on certain long sengments. This is usually due to buffering problems on your computer, or lack or resources, combined with the encoding process for streaming video.

This Icon denotes video links to other CDs in the LSS+1xx, LSS+2xx, LSSx3xx, or LSSx5xx series. Note the difference in background color. You must have these disks as well as the appropriate security clearance to view the material.

The following coding shall be utilized in all versions of **LSS+** and **LSS+/x** to indicate the infobase to be opened:

LSS-**1xx**   **Public access level, no restrictions on access**
LSS-**2xx**   **Restricted distribution to locksmiths and safe technicians**
LSSx-**3xx** **Restricted to government agencies only, and certified safe technicians**
LSSx-5xx Restricted to government agencies only. This material deals specifically with SWAT team operations and the use of explosives for breaching.

Security level is shown in red; disk series is shown in green. The combined identifier is the name of the Infobase where the multimedia clip is contained.

The designation following the security level denotes the disk number, beginning with 01, and will be issued in sequential order, as material is added to the Infobase.

NOTE: You will be required to open the infobase on the designated disk, and link to the file in order to view or listen to the clip.

There are hyperlinks contained within this CD/ROM to www.security.org, and many other websites. You must be on-line for these links to function properly. Please contact the site administrator at security.org to advise of any problems or invalid links.

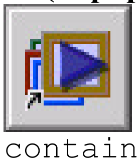
A master index of multimedia content can be found at the beginning of each chapter, and in the Master Exhibit listing at the beginning of the book.

Note that in certain cases that there are links within the Master Exhibit listing to both images and multimedia. The icon always is utilized to link to
audio and video files; the text (in green) links to images, if available.

NOTE REGARDING MULTIMEDIA LINKS: These Infobases are extremely large (in excess of 600 MB) and therefore require a great deal of RAM to run properly. If your computer has less than 256 MB. of RAM, you will find that the system will take a long time to load linked materials on LSS Infobases. You may go directly to the indicated disk and launch the multimedia material directly, rather than waiting for the system to locate and load the file.

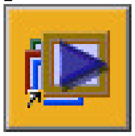
SPECIAL NOTE REGARDING ISP EXHIBITS: There are special identification numbers for all exhibits from the Illinois State Police. These are identified as ISP-12-3456, where ISP = Illinois State Police, 12 = the photograph ID as it appears on the original Kodak PhotoCD translation, and 3456 is the CD reference number for internal use. Many of the audio clips associated with the ISP exhibits refer to the reference numbers denoted in the captions. Appreciation is expressed to Bill Sherlock, retired Chicago Police Department Forensics Examiner. He is currently assigned to the Illinois State Police Forensics Laboratory in Chicago. Bill Sherlock and Art Paholke worked together for many years, and were the pioneers in the development of forensic analysis of locks.

12 (Popup - MULTIMEDIA LINKS)



This icon appears before any audio or video link contained within this infobase, where the material is contained on the Infobase CD. It denotes the use of Windows Media Player, which can be downloaded from Microsoft. Most of the multimedia clips are contained on separate CD/ROMS, due to their size. They

will be referenced by security level and disk number as well as the icon shown below. Please note that you may notice a synchronization error between audio and video on certain long sengments. This is usually due to buffering problems on your computer, or lack or resources, combined with the encoding process for streaming video.



This Icon denotes video links to other CDs in the LSS+1xx, LSS+2xx, LSSx3xx, or LSSx5xx series. Note the difference in background color. You must have these disks as well as the appropriate security clearance to view the material. You can insert the required disk and click on the link directly, rather than waiting for your computer to load the linked Infobase. If your computer does not have sufficient RAM, this is preferred because of the loading time required.

If you receive an **error message** that a media link cannot be executed, it is likely due to the default program setting for opening video or audio files. You must have the default set for mp3 and video files to Windows Media player. See the on-line tutorial as to how to determine the default program setting for these types of files.

The following coding shall be utilized in all versions of **LSS+** and **LSS+/x** to indicate the infobase to be opened:

LSS-**1xx** **Public access level, no restrictions on access**
LSS-**2xx** **Restricted distribution to locksmiths and safe technicians**
LSSx-**3xx** **Restricted to government agencies only**
LSSx-5xx Alarm system information Restricted to government agencies only.

Security level is shown in red; disk series is shown in green. The combined identifier is the name of the Infobase where the multimedia clip is contained.

The designation following the security level denotes the disk number, beginning with 01, and will be issued in sequential order, as material is added to the Infobase.

NOTE: You will be required to open the infobase on the designated disk, and link to the file in order to view or listen

to the clip.

There are hyperlinks contained within this CD/ROM to www.security.org, and many other websites. You must be on-line for these links to function properly. Please contact the site administrator at security.org to advise of any problems or invalid links.

A master index of multimedia content can be found at the beginning of each chapter, and in the Master Exhibit listing at the beginning of the book.

Note that in certain cases that there are links within the Master Exhibit listing to both images and multimedia. The icon always is utilized to link to
audio and video files; the text (in green) links to images, if available.

NOTE REGARDING MULTIMEDIA LINKS: These Infobases are extremely large (in excess of 600 MB) and therefore require a great deal of RAM to run properly. If your computer has less than 256 MB. of RAM, you will find that the system will take a long time to load linked materials on LSS Infobases. You may go directly to the indicated disk and launch the multimedia material directly, rather than waiting for the system to locate and load the file.

SPECIAL NOTE REGARDING ISP EXHIBITS: There are special identification numbers for all exhibits from the Illinois State Police. These are identified as ISP-12-3456, where ISP = Illinois State Police, 12 = the photograph ID as it appears on the original Kodak PhotoCD translation, and 3456 is the CD reference number for internal use. Many of the audio clips associated with the ISP exhibits refer to the reference numbers denoted in the captions. Appreciation is expressed to Bill Sherlock, retired Chicago Police Department Forensics Examiner. He is currently assigned to the Illinois State Police Forensics Laboratory in Chicago. Bill Sherlock and Art Paholke worked together for many years, and were the pioneers in the development of forensic analysis of locks.

13 (Popup - OVERVIEW OF LOCKS, SAFES, AND SECURITY)

The Electronic Infobase of ***Locks, Safes, and Security*** (Second Edition) combines the data within the hardbound edition and extensive multimedia and supplementary references. The first edition of Locks, Safes, and Security was published in 1970, and achieved recognition within the law enforcement community for its detail and thorough coverage of topics relevant to law

enforcement. Thirty years later, the second edition was released, in December 2000. The text is extremely comprehensive, and provides the reader with an understanding of the subject matter relating to locks, safes, and security. The book was specifically written for law enforcement investigators, criminalists, and intelligence agencies. Its secondary audience is the professional locksmith and safe technician.

14 (Popup - THE ART OF MANIPULATOIN)

This manual was originally published in 1955, and was the first real description of the manipulation process. The author has rewritten the text and added photographs for clarity. Although the work was relatively short in length, thousands of copies have been sold to locksmiths throughout the world.

15 (Popup - A TREATISE ON FIRE & THIEF-PROOF DEPOSITORIES AND LOCKS AND KEYS)

PREFACE to the SECOND EDITION

George Price wrote an extremely comprehensive work on the history and development of locks and safes during the time of the Great Exhibition in London. This was a period of significant advancements in the design of locks, safes, and vaults. His treatise provides a rich insight into the state of security technology of his day. When I was first introduced to this work by Horace Smith in England, I was fascinated by the chronicle of historical development of the forerunners to modern locking systems.

It was immediately obvious that this work should be updated and integrated into the Electronic edition of ***Locks, Safes and Security***. Although I have taken license to change some of the traditional English verbiage in order to enhance readability in our modern world, I have also attempted to insure that the excitement, intrigue, and ingenuity of the era and its pioneers remains intact.

The Electronic Infobase Edition of ***Locks, Safes, and Security*** allows the flexibility to link and combine the information within these two books with a third by Alfred C. Hobbs. I hope that this allows the reader to gain a deeper understanding of how locks and safes were developed, and the difficulties that were encountered by the craftsmen in Wolverhampton, Willenhall, and throughout Europe and America. Links to other areas of the Infobase are designated by **[**brackets**]**.

One of the video segments that can be found within this infobase was shot in London with Jeremy Bramah, a distant relative of Joseph Bramah. I believe that the reader will find that this provides more insight into the era of the Great Exhibition and complements the work of George Price.

Mr. Price provided a timeless and valuable chronicle of events that ultimately resulted in the security principles and devices of the twentieth century. I hope that the availability of his work furthers an understanding of the locksmith profession, and an appreciation of the difficulties in bridging the forty centuries from the first Egyptian lock, to the modern highly technical world of security and its practitioners.

16 (Popup - LOCKS AND SAFES: THE CONSTRUCTION OF LOCKS)
The author has rewritten the original edition of LOCKS AND SAFES: THE CONSTRUCTION OF LOCKS, and released it as a second edition. A. C. Hobbs was both a lawyer and locksmith. He is credited with the bypass of the Bramah lock at the Great Exposition in London in 1851, thereby causing a cascade of inventions and improvements in locks, safes, and security hardware. His book provides a different perspective from that of the Price book, also contained within this Infobase. All of the original graphics have been reproduced.

MWT

PREFACE

THE reader is entitled to know the origin of the small work which he holds in his hands.

In August 1852, being about to write a short article on Locks for a Cyclopedia of Useful Arts, of which I am the editor, I consulted my esteemed and lamented friend, the late Professor Cowper, of King's College, as to the desirability of explaining to the general reader the defects of some of our English locks, which, previous to the celebrated "lock controversy" of 1851, had borne a high character for skilful construction, beauty of workmanship, and undoubted security.

Professor Cowper expressed his strong conviction that by exposing the effects of our locks, the cause of mechanical science, as well as the public in general, would be benefited; that if our locks were defective, inventors would be stimulated to supply the

defects, and the art of the locksmith would be raised accordingly.

He considered that Mr. Hobbs had made a considerable step in advance in the constructive details of his art, not only in having detected the weak points of some of our best English locks, but also in having introduced two or three new locks, which appeared to be more secure than any of those previously produced.

Professor Cowper gave me an introduction to Mr. Hobbs, who placed at my disposal a variety of literary materials relating to the history and construction of locks, and stated his intention at some future time of bringing out a small book on the subject, if he could meet with a publisher. I recommended him to offer the work to Mr. Weale, for insertion in his series of Rudimentary Works. This was accordingly done, and I was invited to prepare the work; but as my engagements did not leave me sufficient leisure to write the book, I requested my friend Mr. George Dodd to put the materials together, and to search for more.

Mr. Dodd acceded to my request; and having completed his part of the work, I subjected it to a careful revision, and added various details which seemed to be necessary to completeness, at least so far as the narrow limits of a small rudimentary work would admit of completeness. The manuscript was then sent to press.

Each sheet as it was received from the printer was submitted to Mr. Hobbs, who read it with care, and made his annotations and corrections thereon. Mr. Hobbs and I then had a meeting, when the additions and corrections were read and discussed, and admitted or rejected as the case might be. The sheet having been thus corrected was sent to press.

It should also be stated that, during the progress of the work, Mr. Weale, at my request, wrote to Messrs. Bramah, and also to Messrs. Chubb, informing them that a Rudimentary Treatise on the Construction of Locks was being prepared, and requesting them to state in writing what alterations or improvements they had made in their locks since the date of the Great Exhibition. The communications which we have received from these celebrated firms are inserted verbatim, in their proper places, in the present work.

Such is the mode in which this small volume has been prepared. I have endeavored to perform an editor's duty conscientiously,

without entertaining the feeling of a partisan in the matter. My chief object in superintending the production of this book (an object in which the Publisher fully participates) is to advance the cause of mechanical science, and to supply a deficiency in one of the most interesting portions of its English literature.

C. TOMLINSON.
July 1853.

17 (Popup - REVISIONS FOR LSS+)
The following material applies to all release versions of **LSS+.** Changes, deletions, and additions are referenced by the release version number contained on the **CD/ROM.**

The **LSS+ CD/ROM** has been greatly expanded and updated since the printing of the second edition of ***Locks, Safes, and Security*** in December, 2000. The Electronic Infobase edition contains material which could not be included within the hardbound edition, due to space limitations. A master listing of all additions to the electronic edition is contained within this pop-up screen.

The additions to the second edition of the text include color graphics, additional photographs to more thoroughly describe the topic, exploded views within photographs, and audio and video clips to enhance understanding by the reader.

Full-text patents, as well as links to materials contained within the Infobase at **www.security.org**, are accessible within this CD/ROM.

You will note that figures that have been added to the electronic Infobase edition are labeled with a separate **LSS+** number, to distinguish them from illustrations within the hardbound edition. All of the figures contained within this CD/ROM are indexed in a Master Exhibit Listing at the beginning of the text, as well as at the beginning of each chapter.

You can search for any chapter and section heading by entering the chapter_section number, separated by an underscore, within the query dialog box.

MASTER UPDATE SUMMARY FOR LSS+ Version 4.05.

Chapter One

Add text to section 1_3.0

Illustrations added.

Figure LSS+102 Examples of pin tumbler locks from different cultures.
Figure LSS+103 A Pin tumbler lock found in Northern Africa.
Figure LSS+104 A 17th Century Persian padlock.
Figure LSS+105 An early Roman padlock.
Figure LSS+106 An early European padlock.
Figure LSS+107 An early warded lock.
Figure LSS+108 An early warded lock mechanism.
Figure LSS+109 A warded lock produced between the 15th and 18th century.
Figure LSS+110 An example of a Roman lock.
Figure LSS+111 A warded door lock.
Figure LSS+112 An example of a Barron lock
Figure LSS+113 An analysis of the movement of the bolt within the Barron lock.
Figure LSS+114 The Appointment by the Queen of the Bramah Lock Company.
Figure LSS+115 The Pillard time lock.
Figure LSS+116 Hobbs and Hart lever lock
Figure LSS+117 Map of England
Figure LSS+118 The Bramah lock that was successfully opened by Alfred Hobbs.
Figure LSS+119 Bramah lock, view of sliders.

LSS101: Interview with Jeremy Bramah

Alfred Hobbs was able to bypass the Bramah lock. Courtesy of Hans Mejlshede.

Locksmith training in Denmark, in comparison to the United States. Courtesy of Hans Mejlshede.

Chapter Three

Illustrations and new definitions added.

Figure LSS+301 Axial pin tumbler lock
Figure LSS+302 Arc ring
Figure LSS+303 Auxiliary deadlock latch bolt
Figure LSS+304 Blade of key
Figure LSS+305 Blank key
Figure LSS+306 Cam and cam lock
Figure LSS+307 Case ward
Figure LSS+308 Change key for combination lock

Figure LSS+309 Code cut original key, direct reading code
Figure LSS+310 Connecting bar
Figure LSS+311 Corrugated key for warded padlock
Figure LSS+312 Cut root for pin tumbler key
Figure LSS+313 Deadbolt
Figure LSS+314 Dimple key for Sargent Keso lock

Chapter Four

Illustrations added, and the following sections:

Add Section 4_2.4 Automobile Entry Tools
Add Section 4_2.5 bypass Tools
Add Section 4_2.6 Bypass tools for Safes and Vaults
Add Section 4_4.2.7 Forensic Investigative Tool Set
Figure LSS+401 Single and double cut files.
Figure LSS+402 Two file sets produced by HPC.

Macro lens, Courtesy of Hans Mejlshede.

Data back for documentation of images. Courtesy of Hans Mejlshede.

Photographic equipment requirements. Courtesy of Hans Mejlshede.

Ring strobe is a necessity for forensic photography. Courtesy of Hans Mejlshede.

Forensic marks and their observation with proper lighting. Courtesy of Don Shiles.

Chapter Five

Illustrations and definitions added.
Figure LSS+501, Periodic table.

Chapter Six

Figure LSS+601 Back-cut key
Figure LSS+602 Laser track keys from Volvo and Mercedes
Figure LSS+603, Pin tumbler key, showing steeples
Figure LSS+604, Keyway wards
Figure LSS+605, John Falle comb pick
Figure LSS+606, Ikon paracentric keyway
Figure LSS+607, Key head identifying markings (Sargent)
Figure LSS+608, Key head identifying markings (Ilco and Silca)
Figure LSS+609, Milled key blank

Chapter Seven

Figure LSS+701a Design of a key
Figure LSS+701b Key component design
Figure LSS+701c Code cut key, showing symmetry of design
Figure LSS+702a Improper alignment between cuts of a key and pin chambers
Figure LSS+702b Correct registration of key between cuts and pin chambers
Figure LSS+703 Bow of key
Figure LSS+704 Shoulder of key
Figure LSS+705 Depth and spacing diagram
Figure LSS+706 Depth and spacing of keys
Figure LSS+707 These diagrams show an example of different pin lengths utilized by Schlage.

Conversation with Chuck Murray, Kaba-Ilco, regarding keys and their production.

Chapter Eight

Illustrations and supplementary materials added to sections on clay and silicone casting.
Add Section 8_7.1.4.1 Add Impressioning of stamped numbers on metal
Figure LSS+801 An HPC SKM-2D key micrometer for direct reading of bitting depths
Figure LSS+802 An HPC HKD-75 key gauge for reading bitting depths
Figure LSS+803 An HPC axial lock depth gauge TKPD-1
Figure LSS+804 A factory original key with a direct code that correlates with bitting depths for each cut
Figure LSS+805 The mold is prepared for clay impression of a key
Figure LSS+806 Talc or other lubricant is applied to allow release of the source key from the clay
Figure LSS+807 Excess clay is trimmed from the edge of the mold
Figure LSS+808 The source key is positioned within the mold
Figure LSS+809 The key is impressed into the clay mold
Figure LSS+810 The mold is closed with the key inserted to create an impression
Figure LSS+811 The mold is opened after an impression is taken
Figure LSS+812 Source key is removed from the mold
Figure LSS+813 A channel is made in the clay for the escape of gasses created during impressioning
Figure LSS+814 The mold is secured in a locked position
Figure LSS+815 Low temperature metal is heated and poured into the mold
Figure LSS+816 The mold is allowed to cool and opened

Figure LSS+817 The target key is removed from the mold
Figure LSS+818 Silicon is poured into a container to make an impression of a source key
Figure LSS+819 The silicone is cut in half to show the details of an impression
Figure LSS+820 A source and target key produced by silicone impressioning
Figure LSS+821 HPC 747xu tubular key duplicator
Figure LSS+822 HPC 1200 key duplicator
Figure LSS+823 HPC handheld key code computer (HP720)
Figure LSS+824 HPC KM-60 micrometer
Figure LSS+821 HPC 747xu tubular key duplicator
Figure LSS+822 HPC 1200 key duplicator
Figure LSS+823 HPC handheld key code computer (HP720)
Figure LSS+824 HPC KM-60 micrometer
Figure LSS+825 The HPC 1200 mechanical punch cutter can be utilized anywhere.
Figure LSS+826 The Codemax was one of the original HPC computerized code cutters.
Figure LSS+827 The Kaba-Ilco Triax-e.code key machine.
Figure LSS+828 The Ilco Ultracode computerized key machine.

LSS201: Procedure for making keys with a clay mold. Courtesy of MSC.

LSS201: Making keys by silicone impression, Courtesy of MSC

LSS202: Kaba-Ilco Quattrocode key machine, Courtesy of Steve Fish.

LSS202: The Ultracode key machine, Courtesy of Steve Fish.

LSS202: The Kaba-Ilco Triax key machine, Courtesy of Steve Fish.

LSS202: Kaba-Ilco RW2 Transponder system, Courtesy of Steve Fish.

Keys can be copied through the use of clay molds. Courtesy of Hans Mejlshede.

Chapter Nine

Add text and photographs to section 9_5.3.1.4.1
Figure LSS+901 Shimming open a lock
Figure LSS+902 Rapping open a lock
Figure LSS+903 Examples of flat keys

Forensic implications of using a shim to open a lock prior to analysis. Courtesy of Hans Mejlshede.

Chapter Eleven

Add text to 11_8.3.7

Figure LSS+1101 Master key design

Figure LSS+1102 Master wafer too thin

Figure LSS+1103 Master wafer too thin, allows key jiggling to open the lock

Figure LSS+1104 Change key diagram

Figure LSS+1105 Great grand master key diagram

Figure LSS+1106 MACS-Maximum adjacent cut specifications

Figure LSS+1107 Master key

Figure LSS+1108 Master key single and two step progression

Figure LSS+1109 Master key differ chart demonstrates loss of security

Figure LSS+1110 Master wafer creates different shear lines

Figure LSS+1111 Top master key diagram

Figure LSS+1112 Master key design parameters

Chapter Twelve

Add section 12_2.7 Lock and Bolt Guards

Figure LSS+1201 Yale night latch lock

Figure LSS+1202 Yale rim lock

Figure LSS+1203 HPC cylinder guard

Figure LSS+1204 Example of a mortised lock, and the mechanism for holding the cylinder.

Figure LSS+1205 Various HPC door guards produced to protect narrow aluminum doors.

Figure LSS+1204 Example of a mortised lock, and the mechanism for holding the cylinder.

Figure LSS+1205 Various HPC door guards produced to protect narrow aluminum doors.

Figure LSS+1206 Rim cylinder (left) and mortise cylinders (right) in two standard sizes.

Figure LSS+1207 Key in knob lock.

Figure LSS+1208 Examples of deadbolts in different configurations.

Figure LSS+1209, examples of single and double-locking night latches.

Figure LSS+1210, a guard ring assembly protects the cylinder from attack.

Figure LSS+1211 Internal and external support hardware to increase resistance to attack.

Figure LSS+1212 Improved strike box and plate.

Figure LSS+1213 After-market hardware to protect door and frame from attack.

Chapter Thirteen

Chapter Fourteen

Add Section 14_2.1.1 European Lever Locks

Chapter Fifteen

Chapter Sixteen

Add text to section 16_4.2.1

Figure LSS+1601 Pin stack

Figure LSS+1602 Broach is used to create a keyway

Figure LSS+1603 Top pins and drivers

Figure LSS+1604 The shear line

Figure LSS+1605 Calculating pin tumbler lock differs

Figure LSS+1606 Re-pinning a lock

Figure LSS+1607 Re-pinning process with all pins loaded

Figure LSS+1608 Formation of a plug at Ikon factory

Figure LSS+1609 The broaching process

Figure LSS+1610 How a plug is broached

Figure LSS+1611 A plug that has been partially and fully broached

Figure LSS+1612 An Ikon profile created by a broach

Figure LSS+1613 The driver and lower pins in their three states.

Figure LSS+1614 Sectional view of the location and function of the mushroom tumblers.

Figure LSS+1615 The status of driver and bottom pins in the locked and plug rotating unlocked position.

Figure LSS+1615 The status of driver and bottom pins in the locked and plug rotating unlocked position.

The use of a pin tray or set-up tray is required for forensic disassembly of a lock. Courtesy of Hans Mejlshede.

Producing pins for cylinders. Courtesy of Hans Mejlshede.

Forensic issues regarding the bypass of security and mushroom tumblers. Courtesy of Hans Mejlshede.

LSS101: Ikon factory, Berlin, Germany: How locks are made.

Chapter Seventeen

Add section 17_6.1.3.5 Medeco BiLevel

Add section 17_2.5A IKON WSW System

Figure LSS+1701 The Evva 3KS sidebar lock showing the sidebar in an unlocked and locked position.

Figure LSS+1702 The Evva 3KS is a modular system. Shown is one cylinder in a locked position.

Figure LSS+1703 A BiLock key is distinctive in its dual bitting configuration.

Figure LSS+1704 Medeco BiLevel key and internal sidebar design.

Figure LSS+1705 The IKON WSW Lock system

Abloy master keying theory, Courtesy of Hans Mejlshede.

Forced entry of Abloy locks, and forensic indications, Courtesy of Hans Mejlshede.

The Peter Field (Medeco) patent for a security tumbler. Courtesy of Hans Mejlshede.

Forensic analysis of the Medeco cam lock. Courtesy of Hans Mejlshede.

Chapter Twenty-One

Add section 21_1.4 IKON CLIQ
Figure LSS+2101 The EVVA ELMO system
Figure LSS+2102 The IKON CLIQ System

Chapter Twenty-Three

Add text and photographs to section 23_2.1
Add text to section 23_2.3.1
Add section 23_2.3.1.1 S&G 8077 padlock series
Add section 23_2.3.1.2 S&G 8088 padlock series
Add section 23_2.3.1.3 S&G 8065 padlock series

Rename section 23_4.2 to 23_4.2A General Motors VATS
Add section 23_4.2 Vehicle Electronic Protection Systems
Add section 23_4.4.2 National Automobile Altered Numbers File
Add section 23_4.4.3 National Vehicle Identification Number Standard File
Add text to section 23_4.2A
Add text to section 23_4.3
Add text to section 23_7.1
Add section 23_7.1.1 History of Post Office Locks
Add section 23_7.1.2 Post Office locking systems
Add section 23_7.1.3 Post Office lock patents
Figure LSS+2301 **The English thumbscrews developed in the seventeenth century**
Figure LSS+2302 **Early Scandinavian padlock design.**
Figure LSS+2303 **Examples of Persian padlocks 17-18th century, and 1966 model of the same lock.**
Figure LSS+2304 **An early Chinese padlock.**
Figure LSS+2305 **Example of seventeenth century Spanish padlock and key.**
Figure LSS+2306 Puzzle locks
Figure LSS+2307 **A French padlock from the seventeenth century.**
Figure LSS+2308 Flemish padlock, sixteenth century
Figure LSS+2309 German padlock, seventeenth century
Figure LSS+2310 Screw action padlock
Figure LSS+2311 Italian screw design, seventeenth century
Figure LSS+2312 Screw design, nineteenth century
Figure LSS+2313 Various screw action padlock designs
Figure LSS+2314 Padlock and key, eighteenth century
Figure LSS+2315 Ball padlock

Discussion of transponder theft. Courtesy of Hans Mejlshede.

Bypass of push button locks. Courtesy of Don Shiles.

Chapter Twenty-Four

A forensic investigation involving the theft of a BMW automobile. Courtesy Hans Mejlshede.

Doing research on different bypass techniques is important for the forensic investigator. Courtesy of Don Shiles.

Analysis of a case involving forensics. Courtesy of Don Shiles.

Case example, burglary investigation. Courtesy of Don Shiles

Case example of hotel lock bypass. Courtesy of Don Shiles.

Case example, Courtesy of Hans Mejlshede.

Analysis of a case involving forensic locksmithing. Courtesy of Don Shiles.

Mail slot bypass device. Courtesy of Hans Mejlshede.

Keys can be copied by taking a 1:1 image using a copier machine. Courtesy of Hans Mejlshede.

Master key records. Courtesy of Hans Mejlshede.

Investigative clues that develop during a case. Courtesy Jim Bickers.

Pickability or ease with which a lock can be picked. Courtesy of Hans Mejlshede.

Chapter Twenty-Five

Add text to section 25_1.1.1
Add text to section 25_1.1.2
Add section 25_1.2.2 Queries During Analysis of Locks and Keys
Add text to section 25_1.3.1
Add section 25_3.0 Forensic Experts in Locks and Keys
Add section 25_3.1 I.A.I.L. Qualifications for Forensic Locksmiths
Add section 25_3.2 Crime Scene Processing
Add section 25_3.2.1 Securing and Examining the Crime Scene
Add section 25_3.2.2 Documentation
Add section 25_3.2.3 Collection and Preservation of Evidence
Add section 25_3.2.4 Presentation of Findings
Add section 25_3.2.5 U.S. Department of Justice Handbook of Forensic Science
Add section 25_3.3 Tool Marks
Add section 25_3.4 Forensic Photography
Add section 25_3.5 Admission of Evidence
Add section 25_3.5.1 Court Rulings and Federal Rules on Admissibility
Add section 25_3.6 Specialized Forensic Investigations
Add section 25_3.7 Forms and Reports
Add section 25_3.8 Bibliography for Forensic Locksmiths

Figure LSS+2501 Forensic investigation forms
Figure LSS+2502 Forensic evidence log-in report by Hans Mejlshede
Figure LSS+2503 Sample forensic analysis form by Hans Mejlshede

Art Paholke is the father of modern forensic locksmithing. Courtesy of Hans Mejlshede.

Many car thefts are simulated for insurance claims. Courtesy of Hans Mejlshede.

It is essential to save the pins from a lock that has been the subject of a burglary attack. Courtesy of Hans Mejlshede.

Pressure will often be applied to the forensic locksmith during the course of an investigation to change the results of a report. Courtesy of Hans

Mejlshede.

A clean work area for the forensic locksmith is a necessity. Courtesy of Hans Mejlshede.

Care must be exercised in cleaning of components. Courtesy of Hans Mejlshede.

The Forensic locksmith is often called upon to investigative covert entry. Courtesy of Hans Mejlshede.

The forensic investigator must prepare detailed reports. Courtesy of Hans Mejlshede.

Evidence in car theft investigations. Courtesy of Don Shiles.

Analysis of vehicle locks. Courtesy of Hans Mejlshede.

Analysis of vehicle theft cases. Courtesy of Hans Mejlshede.

Simulation of vehicle theft. Comments on investigation. Courtesy of Hans Mejlshede.

Investigations involving vehicle fires. Courtesy of Hans Mejlshede.

Analysis of marks produced by a slimjim bypass tool. Courtesy of Hans Mejlshede.

Use of rubber or silicone-coated tweezers. Courtesy of Hans Mejlshede.

Discussion regarding microscopes for use in forensic analysis. Courtesy of Hans Mejlshede.

Issues regarding crime scene sketches. Courtesy of Don Shiles.

Evidence handling techniques. Courtesy of Don Shiles.

Methods of forensic analysis. Courtesy of Don Shiles.

The investigative locksmith as a witness. Courtesy of Don Shiles.

Required background of the forensic locksmith and investigator. Courtesy of Don Shiles.

Definition of a forensic locksmith.

Use of photograph. Courtesy of Don Shiles

What is an investigative locksmith? Courtesy of Don Shiles.

An introduction and summary of forensic locksmithing. Courtesy of Hans Mejlshede.

Forensic locksmithing history and the role of Art Paholke. Courtesy of Hans Mejlshede.

Was the lock picked? Courtesy of Don Shiles.

Macro lens, Courtesy of Hans Mejlshede.

Data back for documentation of images. Courtesy of Hans Mejlshede.

Photographic equipment requirements. Courtesy of Hans Mejlshede.

Ring strobe is a necessity for forensic photography. Courtesy of Hans Mejlshede.

Use of plastic tweezers. Courtesy of Hans Mejlshede.

Recovering stamped numbers from keys and locks. Courtesy of Hans Mejlshede.

Opinions of examiner, and certainty of their opinions. Courtesy of Hans Mejlshede.

Logging receipt of evidence. Courtesy of Hans Mejlshede.

Issues regarding investigative reports. Courtesy of Hans Mejlshede.

It is difficult to bypass laser track locks through the use of jiggle keys. Courtesy of Hans Mejlshede.

Definition of an Investigative locksmith. Courtesy of Don Shiles.

Forensic marks and their observation with proper lighting. Courtesy of Don Shiles.

The investigative locksmith gets involved in insurance fraud cases. Courtesy of Hans Mejlshede.

Marks on the back of the lock from bypass. Courtesy of Hans Mejlshede.

Use of WD-40 to clean and lubricate. Courtesy of Hans Mejlshede.

Oxidation and dating of marks in a forensic examination. Courtesy of Don Shiles.

Forensic implications of using a shim to open a lock prior to analysis. Courtesy of Hans Mejlshede.

An attempt may be made to mask pick marks so that the perpetrator is not identified. Courtesy of Hans Mejlshede.

Obtaining all keys that fit a particular cylinder. Courtesy of Hans Mejlshede.

Removal of cylinder and its analysis must be done correctly. Courtesy of Hans Mejlshede.

Changing or removal of top pins. Courtesy of Hans Mejlshede.

Preliminary issues in the examination of a lock. Courtesy of Don Shiles.

Examination of a lock and disassembly. Courtesy of Don Shiles.

Examination of a lock and marks that are visible. Courtesy of Don Shiles.

Information during a forensic investigation. Coutesy of Don Shiles.

Opening a lock using a blank key and a shim. Courtesy of Don Shiles.

LSS202: Forensic investigation and the locksmith, by Don Shiles

Chapter Twenty-Six

Add section 26_1.5.1.A, Method of Examination for Tool Marks
Add section 26_1.5.1.B, Results of Testing
Add section 25_1.5.5.A Markings on Wafers: General Issues
Add section 26_2.4.1 SEM Issues Regarding the Analysis of Pick Marks
Add section 26_2.4.2 Issues Regarding Metal Transfer

Figure LSS+2601 Cutaway view of plug, showing location of pick and tension wrench marks

Figure LSS+2602 A cylinder that has been picked and raked (left) and picked, then a forced entry tool was utilized.

Figure LSS+2603 An electric pick gun was utilized to open the lock on the left; impressioning and picking was utilized to open the lock on the left.

Figure LSS+2604 Impression, rake picking marks in plug

Figure LSS+2605 Normal use marks, and those from impressioning

Figure LSS+2606 Forensic marks from picking within lock body

Figure LSS+2607 Forensic marks on, normal pin from the factory

LSS101: Scanning electron microscope Part I: Michael Platek

LSS101: Scanning electron microscope Part II: Michael Platek

LSS101: Scanning electron microscope Part III: Michael Platek

LSS203: The forensic investigation of locks and keys, by Hans Mejlshede.

Forensic indication of the use of a "999" or "bump key", Courtesy Hans Mejlshede

The age of picking marks can sometimes be determined through the analysis of corrosion within the lock. Courtesy of Hans Mejlshede.

Destructive analysis of locks is often required in an investigation. Courtesy of Hans Mejlshede.

Analysis of marks within the plug after it has been cut apart. Courtesy of Hans Mejlshede.

Marks left from a turning wrench. Courtesy of Don Shiles.

Use of a scanning electron microscope (SEM). Courtesy of Hans Mejlshede.

The use of pick guns with profile locks. Courtesy of Hans Mejlshede.

Forensic analysis of pick gun marks. Courtesy of Hans Mejlshede.

Pick gun marks and order of picking. Courtesy of Hans Mejlshede.

Dust motes, visible in forensic analysis. Courtesy of Don Shiles.

Marks on wafers from picking. Courtesy of Hans Mejlshede.

Pick marks may appear on surface of wafers. Courtesy of Hans Mejlshede.

Analysis of presence of grease on wafers in forensic investigation. Courtesy of Hans Mejlshede.

Marks produced from turning wrenches are identifiable. Courtesy of Don Shiles.

Forensic indications of the use of an electric pick gun. Courtesy of Hans Mejlshede.

Cylinders may be opened by rapping them. Courtesy of Hans Mejlshede.

A forensic examination takes five minutes or less. Courtesy of Hans Mejlshede.

Forensic investigations involving locks that have been impressioned. Courtesy of Hans Mejlshede.

Forensic analysis of gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

Marks on Ford wafer locks produced by gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

Wear information and tests on pins. Courtesy of Hans Mejlshede.

Wear marks on pins. Courtesy of Hans Mejlshede.

Markings on components by manufacturers. Courtesy of Don Shiles.

Milling marks on pins during manufacture. Courtesy of Don Shiles.

Forensic marks and their observation with proper lighting. Courtesy of Don Shiles.

Bypass techniques must be known to the forensic investigator. Courtesy of Hans Mejlshede.

An analysis of latches and bolts may be required. Courtesy of Hans Mejlshede.

Loids may be utilized to bypass latches and bolts. Courtesy of Hans Mejlshede.

Virgin areas of the plug will provide an indication that the locks was picked. Courtesy of Hans Mejlshede.

Normal appearance of pins and what type of marks appear. Courtesy of Hans Mejlshede.

Forensic marks from the use of a lock pick. Courtesy of Hans Mejlshede.

Pickability or ease with which a lock can be picked. Courtesy of Hans Mejlshede.

Turning wrench or torque wrench will leave identifiable tool marks. Courtesy of Hans Mejlshede.

Tool mark comparison. Courtesy of Hans Mejlshede.

Picking marks on wafers from vehicle locks. Courtesy of Hans Mejlshede.

Marks produced by raking. Courtesy of Don Shiles.

Marks produced from keys making contact with pins. Courtesy of Don Shiles.

Different marks are created from various lock picks. Courtesy of Don Shiles.

Chapter Twenty-Seven

Figure LSS+2701 Schlage 922 wafer lock diagram and photograph
Figure LSS+2702 A milled blank is made to fit a restricted keyway

Bypass of a Schlage 922 series wafer lock. Courtesy of Don Shiles.

Metal filings at the scene of a safe burglary. Courtesy of Don Shiles.

Investigations may require a determination of whether a key has been copied. Courtesy of Hans Mejlshede.

Marks from key duplication. Courtesy of Don Shiles.

Chapter Twenty-Eight

Add text to section 28_3.2

Discussion of different bypass techniques. Courtesy of Don Shiles.

Bypass of an American Padlock Series 700. Courtesy of Don Shiles.

Forensic analysis of gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

Marks on Ford wafer locks produced by gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

External bypass of a solenoid using a magnetic field. Courtesy of Don Shiles.

LSS303: Analysis of bypass techniques, by John Falle

Chapter Twenty-Nine

Change section name for 29_6.4 to 999 or Code 12 Rapping Keys
Add text to section 29_6.4
Add text to section 29_7.3.1.2
Add section 29_7.3.3 Safe Opening tools

Figure LSS+2901 Application of torque when picking
Figure LSS+2902 HPC Flip-it tool, proper use
Figure LSS+2903 Insertion of pick into the lock
Figure LSS+2904 Comb pick by John Falle
Figure LSS+2905 MSC (Hamburg) produces different shaped torque wrenches
Figure LSS+2906 MSC produces a spring-loaded tension wrench like HPC
Figure LSS+2907 Warded lock diagram of keys and lock
Figure LSS+2908 Warded keys used to open locks, including burglars skewer
Figure LSS+2909 Warded skeleton keys
Figure LSS+2910 An axial cylinder, picked and locked
Figure LSS+2911 Axial pick and decode tool setup
Figure LSS+2912 Axial pick tool inserted into a lock
Figure LSS+2913 Axial lock picked and decoded
Figure LSS+2914 MSC Sputnik picking and decoding tool
Figure LSS+2915 MSC Sputnik detail of construction
Figure LSS+2916 MSC Sputnik tool; the wires drive individual pins
Figure LSS+2917 MSC Sputnik tool, internal detail of wire guides
Figure LSS+2918 MSC Sputnik tool, wires protruding to control

pins
Figure LSS+2919 MSC Sputnik tool, one wire protruded
Figure LSS+2920 MSC Sputnik tool, pins can be moved to any position
Figure LSS+2921 The John Falle pick set detail
Figure LSS+2922 The John Falle two-in-one wheel pick set and two locks that it will open. Courtesy of John Falle.
Figure LSS+2923 A set of "jiggers" to bypass lever locks. Courtesy of John Falle.
Figure LSS+2924 A variety of lever lock picking tools are produced by John Falle.
Figure LSS+2925, Diagram showing order of picking, and the misalignment of the five chambers.
Figure LSS+2926 Plug partially picked.
Figure LSS+2927 John Falle comb pick set
Figure LSS+2928 Safe opening tools for lever locks
Figure LSS+2929 The theory of lock picking
Figure LSS+2930 The use of a comb pick

The theory behind the use of the 999 key, Courtesy of Hans Mejlshede.

The proper technique for the use of the 999 or bump key, Courtesy of Hans Mejlshede.

Residue may be present when a dimple lock has been bypassed. Courtesy of Hans Mejlshede.

Order of picking. Courtesy of Hans Mejlshede.

The use of pick guns and forensic analysis of locks. Courtesy of Hans Mejlshede.

Use of a pick gun requires skill. It also leaves forensic indications. Courtesy of Hans Mejlshede.

LSS201: MSC Assortment of tension wrenches, courtesy of Mahmod Abu Shanab

LSS201: MSC "Sputnik" bypass tool, courtesy of MSC.

LSS202: The use of the "bump key" or "999" key, by Hans Mejlshede.

Chapter Thirty

Add text to section 30_4.5.1
Add text and exhibits to section 30_12.2.3.3
Add text to section 30_4.4.3
Figure LSS+3001 The impressioning light box allows viewing of keys during

covert operations

Figure LSS+3002 Use of a pippin file for impressioning
Figure LSS+3003 John Falle self-impressioning system for lever locks
Figure LSS+3004 Falle foil impressioning system for specific dimple locks
Figure LSS+3005 Foil impressioning system for dimple locks by John Falle
Figure LSS+3006 Special dies for the Foil dimple impressioning system

A clever device for impressioning lever locks has been developed in Bulgaria. Courtesy of Hans Mejlshede.

The usefulness of the impressioning technique. Courtesy of Hans Mejlshede.

LSS301: Foil impressioning system, by John Falle

LSS304: DOM Dimple foil impressioning system, by John Falle

Chapter Thirty-One

Add section 31_4.4.1.8.1.A Fichet H series Lock
Add section 31_4.4.2.5 Evva 3KS Laser Track Lock
Add section 31_4.4.1.3.3 Chubb Battleship
Add section 31_4.6.3.1 Axira Radial Pin Decoder
Add section 31_4.4.2.6 Dom Diamond Decoder
Add section 31_4.4.2.7 Ford Galaxy Decoder
Add section 31_4.6.3.2 Picard Decoder
Add section 31_4.4.1.9A Key turn system
Add section 31_4.6.1.2.2 Pin and Cam Pin Lock Decoder system

Figure LSS+3101 John Falle pin and cam system principle
Figure LSS+3102 British lever locks that can be decoded by Pin and Cam system
Figure LSS+3103 European lever locks
Figure LSS+3104 CISA double locking cylinder system
Figure LSS+3105 MCM pin and cam key detail
Figure LSS+3106 Chubb/Lips lever lock
Figure LSS+3107 Ingersoll variable key system by John Falle
Figure LSS+3108 Fichet Monopole lock
Figure LSS+3109 Fichet H decoder system by John Falle
Figure LSS+3110 Fichet H version sidebar detail
Figure LSS+3111 Fichet H version sidebar detail
Figure LSS+3112 John Falle Fichet Pump 787 decoder system
Figure LSS+3113 Mottura key
Figure LSS+3114 Abloy DiscLock models
Figure LSS+3115 Chubb Ava padlock
Figure LSS+3116 John Falle for Chubb Ava, variable key generation system

Discussion of endoscope and borescope. Courtesy of Hans Mejlshede.

The John Falle lever decoder system. Courtesy of Hans Mejlshede.

Bypass of laser track or sidewinder locks. Courtesy of Hans Mejlshede.

Master key records. Courtesy of Hans Mejlshede.

A discussion of reading the belly of a lever. Courtesy of Hans Mejlshede.

Forensic implications of the bypass of lever locks. Courtesy of Hans Mejlshede.

Forensic implications of picking or decoding the Abloy lock. Courtesy of Hans Mejlshede.

LSS301: Abus decoder, by John Falle

LSS301: European lever lock decoder, by John Falle

LSS301: Ford Galaxy decoding system, by John Falle

LSS302: Medeco lock decoding system, by John Falle

LSS302: Universal pin lock decoder, by John Falle

LSS302: European lever lock pick, by John Falle

LSS302: Axira lock decoding system, by John Falle

LSS302: BMW lock decoder system, by John Falle

LSS303: Pin and cam system for CISA and other European locks, by John Falle

LSS303: BiLock decoder system, by John Falle

LSS303: Abloy decoder system, by John Falle

LSS303: Universal pin and cam system, by John Falle

LSS304: Universal belly reader system, by John Falle

LSS304: Key turning system for lever locks, by John Falle

LSS304: DOM Diamond decoder and pick system, by John Falle.

LSS304: Chubb AVA pick and decoder system, by John Falle

LSS305: EVVA 3KS pick and decoder system, by John Falle

LSS305: Pin lock decoder system with pin and cam technology, by John Falle.

Chapter Thirty-Two

Add section 32_3.3 Pounding, Driving, Prying, Fracturing
Add section 32_3.10.1.1.1 Addition of Broco Operations Manual
Add text to section 32_4.4
Add text to section 32_4.4.1

Add text to section 32_3.5.3 Addition to text
Add section 32_3.5.4 Core Removal Tool,
Add text to section 32_4.4.3 Basic tool mark examinations
Add section 32_5.0 Forced Entry Tools for Motor Vehicles
Add section 32_6.0 Hybrid Entry Tools for Locks and Doors
Add section 32_7.0 Specific Entry Problems for Doors, Gates, and Windows

Figure LSS+3201 Sigma Baby ram

Figure LSS+3202 Explosive Wall Breaching System

Figure LSS+3203 Sigma Firecracker ram

Figure LSS+3204 Sigma Mitts

Figure LSS+3205 Sigma Ripper

Figure LSS+3206 Power actuated tool

Figure LSS+3207 External - Right hand inward opening timber door with standard Yale type lock; Internal - Left hand inward opening steel gate in confined area armed with single deadlock. Courtesy Ian Bauchop.

Figure LSS+3208 External - Left hand outward opening solid timber door with two locks; Internal - Left hand inward opening steel grille. Confined space with one deadlock and two sliding bolts

Figure LSS+3209 Internal concertina mild steel window grilles behind 6 mm float glass casement window

Figure LSS+3210 Right hand inward opening solid timber door with multipoint locking system

Figure LSS+3211 External - Right hand outward opening steel gate, slightly recessed with single lock and cover plate down lock side on two rising butt hinges; Internal - Right hand inward opening timber door

Figure LSS+3212 External - Steel cage protecting front door with right hand outward opening single lock with now cover plate. External steel grilles protection windows; Internal - Inward opening solid timber door

Figure LSS+3213 Right hand inward opening flush solid timber door with one visible lock

Figure LSS+3214 Internal view of LSS+3213 detailing timber braces and additional deadlock and night chain

Figure LSS+3215 Right hand inward opening solid timber door with four individual locks. Attack made with chain saw on hinge side

Figure LSS+3216 External - Right hand opening steel gate with single lock, full cover plate and rising butt hinges; Internal - Right hand outward opening solid timber door, locks unseen

Figure LSS+3217 External - Right hand outward opening steel gate, single lock, no cover plate and standard butt hinges; Internal - Right hand inward opening solid timber door, one lock visible

Figure LSS+3218 External - Right hand outward opening timber and glass door with single lock; Internal - Right hand opening timber and glass paneled door with two locks

Figure LSS+3219 Recessed Left hand inward opening solid timber door with multipoint locking system, set in steel frame plus additional top lock

Figure LSS+3220 External - Flush with building right hand outward opening steel paneled gate with steel mesh and full cover plate; Internal - Standard timber door with glass panel

Figure LSS+3221 Left hand outward opening recessed solid timber fire door with steel panel

Figure LSS+3222 External - Heavy duty right hand outward opening steel gate proud of building line with single lock and no cover plate; Internal - Right hand inward opening timber door, locks unseen

Figure LSS+3223 External - Recessed right hand outward opening steel gate with three standard butt hinges and no cover strip; Internal - Right hand inward opening timber paneled door with two locks visible

Figure LSS+3224 A sigma forced entry team shows the technique for breaching a door.

Figure LSS+3225 MSC Lock Force tool is similar to that produced by SIGMA

Figure LSS+3226 There are various dies for the MSC LOCK FORCE tool to fit different profiles

Figure LSS+3227 The use of the MSC LOCK FORCE tool is straightforward
Figure LSS+3228 The BROCO thermic lance is a small self contained package
Figure LSS+3229 The BROCO control nozzle and chemical self starter for the thermic lance
Figure LSS+3230 The KIBB security lock and strike system makes bypass difficult
Figure LSS+3231, an attack on a file cabinet safe with a variety of tools.

Figure LSS+3232 A hole saw can be used to ream out the entire plug.

Figure LSS+3233 A new shear line is created by drilling the plug.

Figure LSS+3234 The mounting for the cylinder is cast and can be fractured, allowing removal of the lock.

Figure LSS+3235 Knob locks should not be used as the sole protection on exterior doors.

Figure LSS+3236 Rim locks must be mounted properly to increase their resistance to attack.

Figure LSS+3237 Cylinders can be pried loose if not mounted properly.

Figure LSS+3238 The cylinder was pounded through the mounting.

Figure LSS+3239 A pipe wrench can be utilized to twist loose a key-in-knob or cylinder lock.

Figure LSS+3240 The ease by which a cylinder can be removed by shearing the set screw.

A wrench attack on cylinders can be very effective. Courtesy of Don Shiles.

Figure LSS+3241 A diagram showing the principle of jamb spreading.

Figure LSS+3242, examples of burglary tools found at the scene of a safe job.

Cylinders can be forcibly removed by applying torque and destroying internal set screws. The set screws can also be removed during business hours

to allow the cylinder to be unscrewed at a later time. Courtesy of Don Shiles.
Figure LSS+3243, a special drill bit for removing plugs, called a rotary pick.
Figure LSS+3244 A lock can be drilled by raising all drivers above shear line.
Figure LSS+3245 A lock can be drilled to create a new shear line.
Figure LSS+3246 A lock can be drilled and then shimmed with a fine wire.

Sigma analysis of the Kibb interlocking strike plate, with Ian Bauchop.
Demonstration of different forced entry techniques on doors utilizing the Kibb interlocking strike plate design.
A wrench attack on cylinders can be very effective. Courtesy of Don Shiles.
Forensic evidence of forced entry. Courtesy of Hans Mejlshede.
Opening a padlock by bouncing the locking dog. Courtesy of Don Shiles.

LSS201: MSC Lock Force tool, courtesy of MSC
LSS201: Forced entry tools produced by Sigma. Courtesy of Ian Bauchop.
LSS202: Broco Thermic lance description and use, by Tom Joos.

Figure LSS+3243, a special drill bit for removing plugs, called a rotary pick.

Chapter Thirty-Three

Figure LSS+3301 A seventeenth century German strongbox
Figure LSS+3302 German chest lock, seventeenth century and a French chest, sixteenth century
Figure LSS+3303 German chest locks, seventeenth century, and fifteenth century.
Figure LSS+3304 Record safe with internal component layout.
Figure LSS+3305 The money safe and internal view.
Figure LSS+3306 Examples of composite safe, claded safe, and combination safe.
Figure LSS+3307, an example of a floor safe and SMNA labels

for fire and burglary rating.
Figure LSS+3308 Examples of fire protected file cabinets.

LSS101: Discussion of safe design by Bill Sherlock.

Chapter Thirty-Four

Add text to section 34_1.1
Add section 34_4.1.1.1 Other combination locks
Add section 34_7.2.1.1 Sargent & Greenleaf Model 6600 Series
Add section 34_7.2.1.2 Sargent & Greenleaf Model 8400 Series
Add section 34_7.2.1.3 Sargent & Greenleaf Model 8500 Series
Add section 34_7.2.1.4 Mosler Model 300-400 and 301-401 MR Series Locks
Add section 34_7.2.1.5 Mosler Model 302-402 MR and 302-402 MRK Series
Add section 34_7.2.1.6 LaGard Model 1980
Add section 34_7.2.1.7 Mas-Hamilton X-07
Add text to section 34_7.2.3
Add text to section 34_8.0 Changing Combinations, including new section
Add section 34_8.1 Procedures for Changing Combinations
Add text to section 34_9.0 Time Locks

Figure LSS+3401 S&G Model 6600 Series (1950Version)
Figure LSS+3402 S&G Model 6600 Series (1960Version)
Figure LSS+3403 S&G 6600 SERIES (1960 VERSION) DISASSEMBLED
Figure LSS+3405 Diagram of disassembled lock
Figure LSS+3406 Mosler 302 MR Hand Change Lock
Figure LSS+3407 Mas-Hamilton Group X-07 Electromechanical Lock
Figure LSS+3408 Diebold Model 180 Series
Figure LSS+3409 Puzzle locks, 18th and 19th century
Figure LSS+3410 Tobacco box and lock
Figure LSS+3411 Yale and S&G three wheel locks, circa. 1948
Figure LSS+3412 Hand-change combination lock procedure
Figure LSS+3413 Hole-change combination lock procedure
Figure LSS+3414 Screw-change combination lock procedure
Figure LSS+3415 Metal and plastic wheel pack in combination locks
Figure LSS+3416 S&G 6700 MP combination lock
Figure LSS+3417 S&G 6730 MP combination lock
Figure LSS+3418 S&G 6700 MP combination lock
Figure LSS+3419 S&G 8400 combination lock
Figure LSS+3420 S&G 8470 combination lock diagram
Figure LSS+3421 S&G 8550 combination lock
Figure LSS+3422 LaGard 1980 combination lock
Figure LSS+3423 Pillard time lock
Figure LSS+3424 UL tolerances for Group 1 and Group 2 combination

locks

Chatwood Invincible Key Lock

Dalton Permutation

Damon's Patent Lock

Day and Newell Parautoptic Safe Key

Dodds MacNeale & Urban's "Excelsior"

W.B. Dodds

Hall's Double Dial Premier (mid-size) with Consolidated Time Lock

Hall's Premier (mid-size)

Hall's Crescent

Hall's Crescent

Hall's Safe Lock

Hall's Single Dial Premier (mid-size) with Consolidated Time Lock

Herring, Farrel, and Sherman Double Dial

Herring Grasshopper Key Lock

H.C. Jones Patent Combination Lock

"Hobnail" (Early American) Safe Key

Lillie (attributed) Click Lock with Key

Lillie (attributed) Dial Lock w/Knob

Lillie (Lewis) "Click Lock" Safe Key

Miller Combination Lock Patent Model

Rosengrens Safe Lock

Safe Deposit Lock-1

Sargent's Magnetic Lock #2 (early)

Sargent & Greenleaf #3 Fire Proof Lock

Sargent & Greenleaf #1 Vault Door Lock

T. J. Sullivan

Yale Double Dial Bank Lock Earliest pat. Date-July 14, 1857

Yale Double Dial Split-Bolt Vault Lock

Yale Pin Dial Time Lock (56 hour, 2 movement)

Yale 101-1/2 Double Dial

Yale Quadruplex Safe Key

LSS101: Discussion of the X-07 and X-08 with Joe Cortie

Chapter Thirty-Five

Add text to section 35_1.6.2.2 Tear gas
Add text to section 35_4.2.1
Add section 35_4.2.2A Prying and Wedging
Add section 35_4.2.2B Pulling
Add section 35_4.2.2C Pounding
Add section 35_4.2.2D Wedging
Add section 35_4.2.7.7 Definition of Conventional Explosives
Add text and graphics to section 35_10.1
Add text to section 35_10.2.3
Add audio segments to section 35_10.2.7

3563-15
3563-16
3563-17
3563-1819

Figure LSS+3501 Chemical composition of tear gars
Figure LSS+3502 Tear gas canister
Figure LSS+3503 Table of Explosives
Figure LSS+3504 Emergency dials
Figure LSS+3505 Fire and record safes
Figure LSS+3506 Money safes
Figure LSS+3507 Cash safes
Figure LSS+3505 Fire and record safes
Figure LSS+3506 Money safes
Figure LSS+3507 Cash safes

Figure LSS+3508. Punching involves the wheel pack being forced inward

Figure LSS+3509, diagram showing how a safe is peeled by gaining an access point to remove layers of metal.

Figure LSS+3510. In this figure, peeling was accomplished from the corner using a cold chisel.

Figure LSS+3511 This was a peel and punch attack to access the bolts (left). A classic peel attack is shown (right)

Figure LSS+3512, examples of peeling of the outer skin on the top of the container and the rivets popped.

Figure LSS+3513 Prying and wedging.

Figure LSS+3514 A safe that has had the door pulled loose by the application of extreme pressure.

Figure LSS+3515, (ISP 38-3563 left, and 39-3563 right). The result of pounding of components.

Figure LSS+3516, Bolts were sheared from shock waves through the use of the welded bar to the front of the door.

Figure LSS+3517. Example of punching. Pressure was applied to the hinge side.

Figure LSS+3518. This was a pound attack. The door was pounded with many hits.

Figure LSS+3519, An attack by the use of a wedge to pry apart and separate portions of the container.

Figure LSS+3520, The top of the safe was cut into to provide access to the bolt works.

Figure LSS+3521 Attacks by torch. In the middle picture, an inept attempt to open the safe by cutting through the side.

Figure LSS+3522. Attack using a torch where there was obviously no knowledge of where to cut.

Figure LSS+3523 Additional examples of the use of a torch. In the photographs, the lock box is burned out.

Figure LSS+3524 Lines scored by an oxy-acetylene torch in the outer shell of a Chubb safe.

Figure LSS+3525, examples of torch attack. Incorrect tools were utilized on the side of the safe.

Figure LSS+3526, attack by torch that did not result in an opening.

Figure LSS+3527, A torch attack where burglars cut a portion from the door for access.

Figure LSS+3528, Examples of attack by oxyacetylene.

Figure LSS+3529. The thermic lance develops high temperature and can be utilized virtually anywhere.

Figure LSS+3530 An example of a safe attacked with a thermic lance.

Figure LSS+3531 An example of arc welding with cutting rods.

Figure LSS+3532, A free-standing Chubb safe was attacked with explosives.

Figure LSS+3533 A safe was open with explosives, after being filled with water.

Figure LSS+3534 A fixed drill rig.

Figure LSS+3535 A burglary where it is suspected that a drill rig caused the fracture of the outer skin of the door.

Figure LSS+3536 Core drill can produce a large hole for

access to the bolt works or lock box.

Figure LSS+3537 Critical drill points are shown. This is a rear view, with the lock case removed.

Figure LSS+3538 (ISP 23-2963) Deflector plates made of angle iron are added to deter drilling.

Figure LSS+3539 (ISP 104-3563) The bolt is punched out of the way in order for the handle cam to be rotated.

Figure LSS+3540 Burglars drilled into the side of the safe to punch and drive the bolt out of the way.

Figure LSS+3541 A scope is inserted to obtain a view of the wheel pack.

Figure LSS+3542 The fence is a prime target for drilling, either the soldered link or the actual fence material.

Figure LSS+3543 Progression of movement of the fence into the gate of the wheel pack.

Figure LSS+3544 A 90 degree angle view with a borescope using a mirror on a Mosler MR 302.

Figure LSS+3545 Locating the fence for drilling.

Figure LSS+3546 A lever fence that has been drilled, and then removed.

Figure LSS+3547 Drilled relockers and zoom view.

Figure LSS+3548 Mosler MR-302 point of penetration.

Figure LSS+3549 Hole drilled through cover plate.

Figure LSS+3550 Side drilling and scoping the lock case.

Figure LSS+3551 Floor safe that has been angle drilled to view wheel pack.

Figure LSS+3552 Safe drilled from the top of safe to lock box to view the wheel pack.

Figure LSS+3553 Many burglaries are simulated.

Figure LSS+3554 The burglar uses a drill without much knowledge of the safe.

3563-15 Individual must have knowledge

3563-16 Tool knowledge of the burgar

3563-17 Time limit for burglary

3563-1819 Proficiency in burglarizing types of safes

LSS201: A primer on the burglary of safes, Courtesy of Bill Sherlock.

LSS201: Forensics and locks, Courtesy of Bill Sherlock.

LSS202: Steve Mattoon on the use of explosives to gain entry.

Chapter Thirty-Six

Add text to 36_3.1.2

Figure LSS+3601 Mas-Hamilton Soft Drill system

Figure LSS+3602 Soft Drill display screens during manipulation

Figure LSS+3603 Parallax error can cause problems during manipulation

2963-42 The use of robot dialers

Use of ultra violet to determine which keys have been depressed on a keypad. Courtesy of Don Shiles.

LSS201: Mark Bates on Manipulation

LSS201: Mark Bates on the Soft Drill

Chapter Thirty-Seven

Add text to section 37_12.0 from case citations.

Add text to §1716a Nonmailable locksmithing devices and motor vehicle master keys

Figure LSS+3701 UL Label

Figure LSS+3702 UL Label designations and nomenclature

Figure LSS+3703 SMNA Label designations

Chapter Thirty-Nine

Figure LSS+3901 Kwikset key-in-knob bypass tool

Hinges and forensic evidence. Courtesy Don Shiles.

Case example: removal of sliding glass door. Courtesy of Don Shiles.

Chapter Forty

Add section 40_1.1.1 Operational Requirements
Add section 40_2.1.1.1 Sensor Applications
Add section 40_2.1.1.2 Detection Factors
Add section 40_2.1.6 Power Supply
Add section 40_3.0.0 Performance Characteristics
Add section 40_3.0.2 Environmental Considerations
Add section 40_3.1.1 Balanced Magnetic Switch
Add section 40_3.1.8 Taut wire
Add section 40_3.2.3.A Fence Vibration
Add section 40_3.2.3.B Strain Sensitive Cable
Add section 40_3.2.3.C Fiber optic Fence
Add section 40_3.2.4 Wall Vibration
Add section 40_3.2.5 Fiber Optic Wall
Add section 40_3.2.6 In-ground fiber optic
Add section 40_3.2.7 Ported Coax Buried Line
Add section 40_3.2.8 Balance buried pressure
Add section 40_3.2.9 Buried Geophone
Add section 40_3.4.1 Electric Field
Add section 40_3.5.1.2 Radar
Add section 40_3.5.2.1 Passive Infrared
Add section 40_3.5.2.2 Active Ultrasonic
Add section 40_3.5.2.3 Audio Sensors
Add section 40_3.5.2.4 Acoustic Detection (Air Turbulence)
Add section 40_3.6.A Interior Active Infrared
Add section 40_3.6.B Exterior Active Infrared
Add section 40_3.7.1 Video Motion Detection

Add text to section 40_2.1.1 System Integration
Add text to section 40_3.0 Sensor Categories
Add text to section 40_2.1 Technology Solutions
Add text to section 40_2.1.2 Alarm Monitoring Systems
Add text to section 40_2.1.5 Alarm Assessment
Add text to section 40_2.1.1.2 Sensor Integration
Add text to section 40_2.1.4 Communications
Add text to section 40_1.1.1 Cost Considerations
Add text to section 40_3.1 Mechanical Switch
Add text to section 40_3.1.1 Magnetic Switch
Add text to section 40_3.2.2 Glass Break
Add text to section 40_3.3 Photo Electric Beam
Add text to section 40_3.5 Microwave
Add text to section 40_3.6 Passive Infrared
Add text to section 40_3.5.1.1 Dual Technology Passive IR/Microwave

Add text to section 40_3.4 Capacitance

Figure LSS+4041 Interior intrusion sensors

18 (Popup - REVISIONS FOR LSS+)
The following material applies to all release versions of **LSS+.** Changes, deletions, and additions are referenced by the release version number contained on the **CD/ROM.**

The **LSS+ CD/ROM** has been greatly expanded and updated since the printing of the second edition of ***Locks, Safes, and Security*** in December, 2000. The Electronic Infobase edition contains material which could not be included within the hardbound edition, due to space limitations. A master listing of all additions to the electronic edition is contained within this pop-up screen.

The additions to the second edition of the text include color graphics, additional photographs to more thoroughly describe the topic, exploded views within photographs, and audio and video clips to enhance understanding by the reader.

Full-text patents, as well as links to materials contained within the Infobase at **www.security.org**, are accessible within this CD/ROM.

You will note that figures that have been added to the electronic Infobase edition are labeled with a separate **LSS+** number, to distinguish them from illustrations within the hardbound edition. All of the figures contained within this CD/ROM are indexed in a Master Exhibit Listing at the beginning of the text, as well as at the beginning of each chapter.

You can search for any chapter and section heading by entering the chapter_section number, separated by an underscore, within the query dialog box.

MASTER UPDATE SUMMARY FOR LSS+ Version 4.05.

Chapter One

Add text to section 1_3.0

Illustrations added.

Figure LSS+102 Examples of pin tumbler locks from different cultures.
Figure LSS+103 A Pin tumbler lock found in Northern Africa.
Figure LSS+104 A 17th Century Persian padlock.

LSS101: Interview with Jeremy Bramah

Alfred Hobbs was able to bypass the Bramah lock. Courtesy of Hans Mejlshede.

Locksmith training in Denmark, in comparison to the United States. Courtesy of Hans Mejlshede.

Chapter Three

Illustrations and new definitions added.

Chapter Four

Illustrations added, and the following sections:

Add Section 4_2.4 Automobile Entry Tools
Add Section 4_2.5 bypass Tools
Add Section 4_2.6 Bypass tools for Safes and Vaults
Add Section 4_4.2.7 Forensic Investigative Tool Set
Figure LSS+401 Single and double cut files.
Figure LSS+402 Two file sets produced by HPC.

Macro lens, Courtesy of Hans Mejlshede.

Data back for documentation of images. Courtesy of Hans Mejlshede.

Photographic equipment requirements. Courtesy of Hans Mejlshede.

Ring strobe is a necessity for forensic photography. Courtesy of Hans Mejlshede.

Forensic marks and their observation with proper lighting. Courtesy of Don Shiles.

Chapter Five

Illustrations and definitions added.
Figure LSS+501, Periodic table.

Chapter Six

Figure LSS+601 Back-cut key
Figure LSS+602 Laser track keys from Volvo and Mercedes
Figure LSS+603, Pin tumbler key, showing steeples
Figure LSS+604, Keyway wards
Figure LSS+605, John Falle comb pick
Figure LSS+606, Ikon paracentric keyway
Figure LSS+607, Key head identifying markings (Sargent)
Figure LSS+608, Key head identifying markings (Ilco and Silca)
Figure LSS+609, Milled key blank

Chapter Seven

Figure LSS+701a Design of a key
Figure LSS+701b Key component design
Figure LSS+701c Code cut key, showing symmetry of design
Figure LSS+702a Improper alignment between cuts of a key and pin chambers

Conversation with Chuck Murray, Kaba-Ilco, regarding keys and their production.

Chapter Eight

Illustrations and supplementary materials added to sections on clay and silicone casting.
Add Section 8_7.1.4.1 Add Impressioning of stamped numbers on metal

Figure LSS+821 HPC 747xu tubular key duplicator
Figure LSS+822 HPC 1200 key duplicator
Figure LSS+823 HPC handheld key code computer (HP720)
Figure LSS+824 HPC KM-60 micrometer
Figure LSS+821 HPC 747xu tubular key duplicator
Figure LSS+822 HPC 1200 key duplicator
Figure LSS+823 HPC handheld key code computer (HP720)
Figure LSS+824 HPC KM-60 micrometer
Figure LSS+825 The HPC 1200 mechanical punch cutter can be utilized anywhere.
Figure LSS+826 The Codemax was one of the original HPC computerized code cutters.
Figure LSS+827 The Kaba-Ilco Triax-e.code key machine.
Figure LSS+828 The Ilco Ultracode computerized key machine.

LSS201: Procedure for making keys with a clay mold. Courtesy of MSC.

LSS201: Making keys by silicone impression, Courtesy of MSC

LSS202: Kaba-Ilco Quattrocode key machine, Courtesy of Steve Fish.

LSS202: The Ultracode key machine, Courtesy of Steve Fish.

LSS202: The Kaba-Ilco Triax key machine, Courtesy of Steve Fish.

LSS202: Kaba-Ilco RW2 Transponder system, Courtesy of Steve Fish.

Keys can be copied through the use of clay molds. Courtesy of Hans Mejlshede.

Chapter Nine

Add text and photographs to section 9_5.3.1.4.1
Figure LSS+901 Shimming open a lock
Figure LSS+902 Rapping open a lock
Figure LSS+903 Examples of flat keys

Forensic implications of using a shim to open a lock prior to analysis. Courtesy of Hans Mejlshede.

Chapter Eleven

Add text to 11_8.3.7
Figure LSS+1101 Master key design
Figure LSS+1102 Master wafer too thin
Figure LSS+1103 Master wafer too thin, allows key jiggling to open the lock
Figure LSS+1104 Change key diagram

Chapter Twelve

Add section 12_2.7 Lock and Bolt Guards

Figure LSS+1204 Example of a mortised lock, and the mechanism for holding the cylinder.
Figure LSS+1205 Various HPC door guards produced to protect narrow aluminum doors.

Chapter Thirteen

Chapter Fourteen

Add Section 14_2.1.1 European Lever Locks

Chapter Fifteen

Chapter Sixteen

Add text to section 16_4.2.1

Figure LSS+1607 Re-pinning process with all pins loaded
Figure LSS+1608 Formation of a plug at Ikon factory
Figure LSS+1609 The broaching process
Figure LSS+1610 How a plug is broached
Figure LSS+1611 A plug that has been partially and fully broached
Figure LSS+1612 An Ikon profile created by a broach
Figure LSS+1613 The driver and lower pins in their three states.
Figure LSS+1614 Sectional view of the location and function of the mushroom tumblers.
Figure LSS+1615 The status of driver and bottom pins in the locked and plug rotating unlocked position.
Figure LSS+1615 The status of driver and bottom pins in the locked and plug rotating unlocked position.

The use of a pin tray or set-up tray is required for forensic disassembly of a lock. Courtesy of Hans Mejlshede.

Producing pins for cylinders. Courtesy of Hans Mejlshede.

Forensic issues regarding the bypass of security and mushroom tumblers. Courtesy of Hans Mejlshede.

LSS101: Ikon factory, Berlin, Germany: How locks are made.

Chapter Seventeen

Add section 17_6.1.3.5 Medeco BiLevel
Add section 17_2.5A IKON WSW System
Figure LSS+1701 The Evva 3KS sidebar lock showing the sidebar in an unlocked and locked position.
Figure LSS+1702 The Evva 3KS is a modular system. Shown is one cylinder in a locked position.
Figure LSS+1703 A BiLock key is distinctive in its dual bitting configuration.
Figure LSS+1704 Medeco BiLevel key and internal sidebar design.
Figure LSS+1705 The IKON WSW Lock system

Abloy master keying theory, Courtesy of Hans Mejlshede.

Forced entry of Abloy locks, and forensic indications, Courtesy of Hans Mejlshede.

The Peter Field (Medeco) patent for a security tumbler. Courtesy of Hans Mejlshede.

Forensic analysis of the Medeco cam lock. Courtesy of Hans Mejlshede.

Chapter Twenty-One

Add section 21_1.4 IKON CLIQ
Figure LSS+2101 The EVVA ELMO system
Figure LSS+2102 The IKON CLIQ System

Chapter Twenty-Three

Add text and photographs to section 23_2.1
Add text to section 23_2.3.1
Add section 23_2.3.1.1 S&G 8077 padlock series
Add section 23_2.3.1.2 S&G 8088 padlock series
Add section 23_2.3.1.3 S&G 8065 padlock series

Rename section 23_4.2 to 23_4.2A General Motors VATS
Add section 23_4.2 Vehicle Electronic Protection Systems
Add section 23_4.4.2 National Automobile Altered Numbers File
Add section 23_4.4.3 National Vehicle Identification Number Standard File
Add text to section 23_4.2A
Add text to section 23_4.3
Add text to section 23_7.1
Add section 23_7.1.1 History of Post Office Locks
Add section 23_7.1.2 Post Office locking systems
Add section 23_7.1.3 Post Office lock patents
Figure LSS+2301 **The English thumbscrews developed in the seventeenth century**
Figure LSS+2302 **Early Scandinavian padlock design.**
Figure LSS+2303 **Examples of Persian padlocks 17-18th century, and 1966 model of the same lock.**
Figure LSS+2304 **An early Chinese padlock.**
Figure LSS+2305 **Example of seventeenth century Spanish padlock and key.**
Figure LSS+2306 Puzzle locks
Figure LSS+2307 **A French padlock from the seventeenth century.**
Figure LSS+2308 Flemish padlock, sixteenth century
Figure LSS+2309 German padlock, seventeenth century
Figure LSS+2310 Screw action padlock
Figure LSS+2311 Italian screw design, seventeenth century
Figure LSS+2312 Screw design, nineteenth century
Figure LSS+2313 Various screw action padlock designs
Figure LSS+2314 Padlock and key, eighteenth century
Figure LSS+2315 Ball padlock
Figure LSS+2316 Eighteenth century padlock
Figure LSS+2317 Ne Plus padlock by George Price
Figure LSS+2318 Padlock diagram of simple locking dog
Figure LSS+2319 German Abus padlock, 1970
Figure LSS+2320 Chubb Hercules padlock, 1971
Figure LSS+2321 Chubb Conquest padlock
Figure LSS+2322 Diagram of the ratchet locking mechanism of the Club.
Figure LSS+2323. A modified Club that has been converted into a shotgun.

Figure LSS+2324. The Silca RW2 Transponder decoder and copier.
Figure LSS+2325 Railroad mail clerk badge and antique mail locks
Figure LSS+2326 Post office locks, including the famous Andrus lock that was patented in 1914
Figure LSS+2327 Arrow eight lever post office box lock
Figure LSS+2328 Rotary registered mail lock produced by the U.S. Postal Service

Discussion of transponder theft. Courtesy of Hans Mejlshede.

Bypass of push button locks. Courtesy of Don Shiles.

Chapter Twenty-Four

A forensic investigation involving the theft of a BMW automobile. Courtesy Hans Mejlshede.

Doing research on different bypass techniques is important for the forensic investigator. Courtesy of Don Shiles.

Analysis of a case involving forensics. Courtesy of Don Shiles.

Case example, burglary investigation. Courtesy of Don Shiles

Case example of hotel lock bypass. Courtesy of Don Shiles.

Case example, Courtesy of Hans Mejlshede.

Analysis of a case involving forensic locksmithing. Courtesy of Don Shiles.

Mail slot bypass device. Courtesy of Hans Mejlshede.

Keys can be copied by taking a 1:1 image using a copier machine. Courtesy of Hans Mejlshede.

Master key records. Courtesy of Hans Mejlshede.

Investigative clues that develop during a case. Courtesy Jim Bickers.

Pickability or ease with which a lock can be picked. Courtesy of Hans Mejlshede.

Chapter Twenty-Five

Add text to section 25_1.1.1

Add text to section 25_1.1.2
Add section 25_1.2.2 Queries During Analysis of Locks and Keys
Add text to section 25_1.3.1
Add section 25_3.0 Forensic Experts in Locks and Keys
Add section 25_3.1 I.A.I.L. Qualifications for Forensic Locksmiths
Add section 25_3.2 Crime Scene Processing
Add section 25_3.2.1 Securing and Examining the Crime Scene
Add section 25_3.2.2 Documentation
Add section 25_3.2.3 Collection and Preservation of Evidence
Add section 25_3.2.4 Presentation of Findings
Add section 25_3.2.5 U.S. Department of Justice Handbook of Forensic Science
Add section 25_3.3 Tool Marks
Add section 25_3.4 Forensic Photography
Add section 25_3.5 Admission of Evidence
Add section 25_3.5.1 Court Rulings and Federal Rules on Admissibility
Add section 25_3.6 Specialized Forensic Investigations
Add section 25_3.7 Forms and Reports
Add section 25_3.8 Bibliography for Forensic Locksmiths

Figure LSS+2501 Forensic investigation forms

Figure LSS+2502 Forensic evidence log-in report by Hans Mejlshede

Figure LSS+2503 Sample forensic analysis form by Hans Mejlshede

Art Paholke is the father of modern forensic locksmithing. Courtesy of Hans Mejlshede.

Many car thefts are simulated for insurance claims. Courtesy of Hans Mejlshede.

It is essential to save the pins from a lock that has been the subject of a burglary attack. Courtesy of Hans Mejlshede.

Pressure will often be applied to the forensic locksmith during the course of an investigation to change the results of a report. Courtesy of Hans Mejlshede.

A clean work area for the forensic locksmith is a necessity. Courtesy of Hans Mejlshede.

Care must be exercised in cleaning of components. Courtesy of Hans Mejlshede.

The Forensic locksmith is often called upon to investigative covert entry. Courtesy of Hans Mejlshede.

The forensic investigator must prepare detailed reports. Courtesy of Hans Mejlshede.

Evidence in car theft investigations. Courtesy of Don Shiles.

Analysis of vehicle locks. Courtesy of Hans Mejlshede.

Analysis of vehicle theft cases. Courtesy of Hans Mejlshede.

Simulation of vehicle theft. Comments on investigation. Courtesy of Hans Mejlshede.

Investigations involving vehicle fires. Courtesy of Hans Mejlshede.

Analysis of marks produced by a slimjim bypass tool. Courtesy of Hans Mejlshede.

Use of rubber or silicone-coated tweezers. Courtesy of Hans Mejlshede.

Discussion regarding microscopes for use in forensic analysis. Courtesy of Hans Mejlshede.

Issues regarding crime scene sketches. Courtesy of Don Shiles.

Evidence handling techniques. Courtesy of Don Shiles.

Methods of forensic analysis. Courtesy of Don Shiles.

The investigative locksmith as a witness. Courtesy of Don Shiles.

Required background of the forensic locksmith and investigator. Courtesy of Don Shiles.

Definition of a forensic locksmith.

Use of photograph. Courtesy of Don Shiles

What is an investigative locksmith? Courtesy of Don Shiles.

An introduction and summary of forensic locksmithing. Courtesy of Hans Mejlshede.

Forensic locksmithing history and the role of Art Paholke. Courtesy of Hans Mejlshede.

Was the lock picked? Courtesy of Don Shiles.

Macro lens, Courtesy of Hans Mejlshede.

Data back for documentation of images. Courtesy of Hans Mejlshede.

Photographic equipment requirements. Courtesy of Hans Mejlshede.

Ring strobe is a necessity for forensic photography. Courtesy of Hans Mejlshede.

Use of plastic tweezers. Courtesy of Hans Mejlshede.

Recovering stamped numbers from keys and locks. Courtesy of Hans Mejlshede.

Opinions of examiner, and certainty of their opinions. Courtesy of Hans Mejlshede.

Logging receipt of evidence. Courtesy of Hans Mejlshede.

Issues regarding investigative reports. Courtesy of Hans Mejlshede.

It is difficult to bypass laser track locks through the use of jiggle keys. Courtesy of Hans Mejlshede.

Definition of an Investigative locksmith. Courtesy of Don Shiles.

Forensic marks and their observation with proper lighting. Courtesy of Don Shiles.

The investigative locksmith gets involved in insurance fraud cases. Courtesy of Hans Mejlshede.

Marks on the back of the lock from bypass. Courtesy of Hans Mejlshede.

Use of WD-40 to clean and lubricate. Courtesy of Hans Mejlshede.

Oxidation and dating of marks in a forensic examination. Courtesy of Don Shiles.

Forensic implications of using a shim to open a lock prior to analysis. Courtesy of Hans Mejlshede.

An attempt may be made to mask pick marks so that the perpetrator is not identified. Courtesy of Hans Mejlshede.

Obtaining all keys that fit a particular cylinder. Courtesy of Hans Mejlshede.

Removal of cylinder and its analysis must be done correctly. Courtesy of Hans Mejlshede.

Changing or removal of top pins. Courtesy of Hans Mejlshede.

Preliminary issues in the examination of a lock. Courtesy of Don Shiles.

Examination of a lock and disassembly. Courtesy of Don Shiles.

Examination of a lock and marks that are visible. Courtesy of Don Shiles.

Information during a forensic investigation. Coutesy of Don Shiles.

Opening a lock using a blank key and a shim. Courtesy of Don Shiles.

LSS202: Forensic investigation and the locksmith, by Don Shiles

Chapter Twenty-Six

Add section 26_1.5.1.A, Method of Examination for Tool Marks
Add section 26_1.5.1.B, Results of Testing
Add section 25_1.5.5.A Markings on Wafers: General Issues
Add section 26_2.4.1 SEM Issues Regarding the Analysis of Pick Marks
Add section 26_2.4.2 Issues Regarding Metal Transfer

Figure LSS+2601 Cutaway view of plug, showing location of pick and tension wrench marks

Figure LSS+2602 A cylinder that has been picked and raked (left) and picked, then a forced entry tool was utilized.

Figure LSS+2603 An electric pick gun was utilized to open the lock on the left; impressioning and picking was utilized to open the lock on the left.

Figure LSS+2604 Impression, rake picking marks in plug

Figure LSS+2605 Normal use marks, and those from impressioning

Figure LSS+2606 Forensic marks from picking within lock body

Figure LSS+2607 Forensic marks on, normal pin from the factory

Figure LSS+2608 Forensic marks on pin from electric pick gun

Figure LSS+2609 Forensic marks on pin caused by impact tool such as pick gun

Figure LSS+2610 Forensic picking marks caused by a manual pick on surface of pin

Figure LSS+2611 Forensic marks on pin from pick gun and a rake pick

Figure LSS+2612 Forensic marks on pin caused by use of a key, a pick, and electric pick gun

Figure LSS+2613 Forensic marks on pin caused by conventional picking

Figure LSS+2614 Forensic marks on pin from a pick gun

LSS101: Scanning electron microscope Part I: Michael Platek

LSS101: Scanning electron microscope Part II: Michael Platek

LSS101: Scanning electron microscope Part III: Michael Platek

LSS203: The forensic investigation of locks and keys, by Hans Mejlshede.

Forensic indication of the use of a "999" or "bump key", Courtesy Hans Mejlshede

The age of picking marks can sometimes be determined through the analysis of corrosion within the lock. Courtesy of Hans Mejlshede.

Destructive analysis of locks is often required in an investigation. Courtesy of Hans Mejlshede.

Analysis of marks within the plug after it has been cut apart. Courtesy of Hans Mejlshede.

Marks left from a turning wrench. Courtesy of Don Shiles.

Use of a scanning electron microscope (SEM). Courtesy of Hans Mejlshede.

The use of pick guns with profile locks. Courtesy of Hans Mejlshede.

Forensic analysis of pick gun marks. Courtesy of Hans Mejlshede.

Pick gun marks and order of picking. Courtesy of Hans Mejlshede.

Dust motes, visible in forensic analysis. Courtesy of Don Shiles.

Marks on wafers from picking. Courtesy of Hans Mejlshede.

Pick marks may appear on surface of wafers. Courtesy of Hans Mejlshede.

Analysis of presence of grease on wafers in forensic investigation. Courtesy of Hans Mejlshede.

Marks produced from turning wrenches are identifiable. Courtesy of Don Shiles.

Forensic indications of the use of an electric pick gun. Courtesy of Hans Mejlshede.

Cylinders may be opened by rapping them. Courtesy of Hans Mejlshede.

A forensic examination takes five minutes or less. Courtesy of Hans Mejlshede.

Forensic investigations involving locks that have been impressioned. Courtesy of Hans Mejlshede.

Forensic analysis of gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

Marks on Ford wafer locks produced by gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

Wear information and tests on pins. Courtesy of Hans Mejlshede.

Wear marks on pins. Courtesy of Hans Mejlshede.

Markings on components by manufacturers. Courtesy of Don Shiles.

Milling marks on pins during manufacture. Courtesy of Don Shiles.

Forensic marks and their observation with proper lighting. Courtesy of Don Shiles.

Bypass techniques must be known to the forensic investigator. Courtesy of Hans Mejlshede.

An analysis of latches and bolts may be required. Courtesy of Hans Mejlshede.

Loids may be utilized to bypass latches and bolts. Courtesy

of Hans Mejlshede.

Virgin areas of the plug will provide an indication that the locks was picked. Courtesy of Hans Mejlshede.

Normal appearance of pins and what type of marks appear. Courtesy of Hans Mejlshede.

Forensic marks from the use of a lock pick. Courtesy of Hans Mejlshede.

Pickability or ease with which a lock can be picked. Courtesy of Hans Mejlshede.

Turning wrench or torque wrench will leave identifiable tool marks. Courtesy of Hans Mejlshede.

Tool mark comparison. Courtesy of Hans Mejlshede.

Picking marks on wafers from vehicle locks. Courtesy of Hans Mejlshede.

Marks produced by raking. Courtesy of Don Shiles.

Marks produced from keys making contact with pins. Courtesy of Don Shiles.

Different marks are created from various lock picks. Courtesy of Don Shiles.

Chapter Twenty-Seven

Figure LSS+2701 Schlage 922 wafer lock diagram and photograph

Figure LSS+2702 A milled blank is made to fit a restricted keyway

Bypass of a Schlage 922 series wafer lock. Courtesy of Don Shiles.

Metal filings at the scene of a safe burglary. Courtesy of Don Shiles.

Investigations may require a determination of whether a key has been copied. Courtesy of Hans Mejlshede.

Marks from key duplication. Courtesy of Don Shiles.

Chapter Twenty-Eight

Add text to section 28_3.2

Discussion of different bypass techniques. Courtesy of Don Shiles.

Bypass of an American Padlock Series 700. Courtesy of Don Shiles.

Forensic analysis of gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

Marks on Ford wafer locks produced by gang, jiggle, or tryout keys. Courtesy of Hans Mejlshede.

External bypass of a solenoid using a magnetic field. Courtesy of Don Shiles.

LSS303: Analysis of bypass techniques, by John Falle

Chapter Twenty-Nine

Change section name for 29_6.4 to 999 or Code 12 Rapping Keys
Add text to section 29_6.4
Add text to section 29_7.3.1.2
Add section 29_7.3.3 Safe Opening tools

Falle.
Figure LSS+2924 A variety of lever lock picking tools are produced by John Falle.
Figure LSS+2925, Diagram showing order of picking, and the misalignment of the five chambers.
Figure LSS+2926 Plug partially picked.
Figure LSS+2927 John Falle comb pick set
Figure LSS+2928 Safe opening tools for lever locks
Figure LSS+2929 The theory of lock picking
Figure LSS+2930 The use of a comb pick

The theory behind the use of the 999 key, Courtesy of Hans Mejlshede.

The proper technique for the use of the 999 or bump key, Courtesy of Hans Mejlshede.

Residue may be present when a dimple lock has been bypassed. Courtesy of Hans Mejlshede.

Order of picking. Courtesy of Hans Mejlshede.

The use of pick guns and forensic analysis of locks. Courtesy of Hans Mejlshede.

Use of a pick gun requires skill. It also leaves forensic indications. Courtesy of Hans Mejlshede.

LSS201: MSC Assortment of tension wrenches, courtesy of Mahmod Abu Shanab

LSS201: MSC "Sputnik" bypass tool, courtesy of MSC.

LSS202: The use of the "bump key" or "999" key, by Hans Mejlshede.

Chapter Thirty

Add text to section 30_4.5.1
Add text and exhibits to section 30_12.2.3.3
Add text to section 30_4.4.3
Figure LSS+3001 The impressioning light box allows viewing of keys during covert operations
Figure LSS+3002 Use of a pippin file for impressioning
Figure LSS+3003 John Falle self-impressioning system for lever locks
Figure LSS+3004 Falle foil impressioning system for specific dimple locks
Figure LSS+3005 Foil impressioning system for dimple locks by John Falle

Figure LSS+3006 Special dies for the Foil dimple impressioning system

A clever device for impressioning lever locks has been developed in Bulgaria. Courtesy of Hans Mejlshede.

The usefulness of the impressioning technique. Courtesy of Hans Mejlshede.

LSS301: Foil impressioning system, by John Falle

LSS304: DOM Dimple foil impressioning system, by John Falle

Chapter Thirty-One

Add section 31_4.4.1.8.1.A Fichet H series Lock
Add section 31_4.4.2.5 Evva 3KS Laser Track Lock
Add section 31_4.4.1.3.3 Chubb Battleship
Add section 31_4.6.3.1 Axira Radial Pin Decoder
Add section 31_4.4.2.6 Dom Diamond Decoder
Add section 31_4.4.2.7 Ford Galaxy Decoder
Add section 31_4.6.3.2 Picard Decoder
Add section 31_4.4.1.9A Key turn system
Add section 31_4.6.1.2.2 Pin and Cam Pin Lock Decoder system

Figure LSS+3101 John Falle pin and cam system principle
Figure LSS+3102 British lever locks that can be decoded by Pin and Cam system
Figure LSS+3103 European lever locks
Figure LSS+3104 CISA double locking cylinder system
Figure LSS+3105 MCM pin and cam key detail
Figure LSS+3106 Chubb/Lips lever lock
Figure LSS+3107 Ingersoll variable key system by John Falle
Figure LSS+3108 Fichet Monopole lock
Figure LSS+3109 Fichet H decoder system by John Falle
Figure LSS+3110 Fichet H version sidebar detail
Figure LSS+3111 Fichet H version sidebar detail
Figure LSS+3112 John Falle Fichet Pump 787 decoder system
Figure LSS+3113 Mottura key
Figure LSS+3114 Abloy DiscLock models
Figure LSS+3115 Chubb Ava padlock
Figure LSS+3116 John Falle for Chubb Ava, variable key generation system
Figure LSS+3117 John Falle Evva 3KS decoder system and lock
Figure LSS+3118 John Falle Dom Diamond decoder system
Figure LSS+3119 John Falle Dom diamond key bitting surface
Figure LSS+3120 John Falle Vehicle decoder system for laser track locks
Figure LSS+3121 John Falle Universal pin tumbler lock decoder
Figure LSS+3122 John Falle Needle assembly for pin tumbler lock decoder
Figure LSS+3123 Medeco ARX pins
Figure LSS+3124 Medeco key tips for John Falle decoder system

Discussion of endoscope and borescope. Courtesy of Hans Mejlshede.

The John Falle lever decoder system. Courtesy of Hans Mejlshede.

Bypass of laser track or sidewinder locks. Courtesy of Hans Mejlshede.

Master key records. Courtesy of Hans Mejlshede.

A discussion of reading the belly of a lever. Courtesy of Hans Mejlshede.

Forensic implications of the bypass of lever locks. Courtesy of Hans Mejlshede.

Forensic implications of picking or decoding the Abloy lock. Courtesy of Hans Mejlshede.

LSS301: Abus decoder, by John Falle

LSS301: European lever lock decoder, by John Falle

LSS301: Ford Galaxy decoding system, by John Falle

LSS302: Medeco lock decoding system, by John Falle

LSS302: Universal pin lock decoder, by John Falle

LSS302: European lever lock pick, by John Falle

LSS302: Axira lock decoding system, by John Falle

LSS302: BMW lock decoder system, by John Falle

LSS303: Pin and cam system for CISA and other European locks, by John Falle

LSS303: BiLock decoder system, by John Falle

LSS303: Abloy decoder system, by John Falle

LSS303: Universal pin and cam system, by John Falle

LSS304: Universal belly reader system, by John Falle

LSS304: Key turning system for lever locks, by John Falle

LSS304: DOM Diamond decoder and pick system, by John Falle.

LSS304: Chubb AVA pick and decoder system, by John Falle

LSS305: EVVA 3KS pick and decoder system, by John Falle

LSS305: Pin lock decoder system with pin and cam technology, by John Falle.

Chapter Thirty-Two

Add section 32_3.3 Pounding, Driving, Prying, Fracturing
Add section 32_3.10.1.1.1 Addition of Broco Operations Manual
Add text to section 32_4.4
Add text to section 32_4.4.1
Add text to section 32_3.5.3 Addition to text
Add section 32_3.5.4 Core Removal Tool,
Add text to section 32_4.4.3 Basic tool mark examinations
Add section 32_5.0 Forced Entry Tools for Motor Vehicles
Add section 32_6.0 Hybrid Entry Tools for Locks and Doors
Add section 32_7.0 Specific Entry Problems for Doors, Gates, and Windows

Figure LSS+3201 Sigma Baby ram
Figure LSS+3202 Explosive Wall Breaching System
Figure LSS+3203 Sigma Firecracker ram
Figure LSS+3204 Sigma Mitts
Figure LSS+3205 Sigma Ripper
Figure LSS+3206 Power actuated tool

Figure LSS+3207 External - Right hand inward opening timber door with standard Yale type lock; Internal - Left hand inward opening steel gate in confined area armed with single deadlock. Courtesy Ian Bauchop.

Figure LSS+3208 External - Left hand outward opening solid timber door with two locks; Internal - Left hand inward opening steel grille. Confined space with one deadlock and two sliding bolts

Figure LSS+3209 Internal concertina mild steel window grilles behind 6 mm float glass casement window

Figure LSS+3210 Right hand inward opening solid timber door with multipoint locking system

Figure LSS+3211 External - Right hand outward opening steel gate, slightly recessed with single lock and cover plate down lock side on two rising butt hinges; Internal - Right hand inward opening timber door

Figure LSS+3212 External - Steel cage protecting front door with right hand outward opening single lock with now cover plate. External steel grilles protection windows; Internal - Inward opening solid timber door

Figure LSS+3213 Right hand inward opening flush solid timber door with one visible lock

Figure LSS+3214 Internal view of LSS+3213 detailing timber braces and additional deadlock and night chain

Figure LSS+3215 Right hand inward opening solid timber door with four individual locks. Attack made with chain saw on hinge side

Figure LSS+3216 External - Right hand opening steel gate with single lock,

full cover plate and rising butt hinges; Internal - Right hand outward opening solid timber door, locks unseen

Figure LSS+3217 External - Right hand outward opening steel gate, single lock, no cover plate and standard butt hinges; Internal - Right hand inward opening solid timber door, one lock visible

Figure LSS+3218 External - Right hand outward opening timber and glass door with single lock; Internal - Right hand opening timber and glass paneled door with two locks

Figure LSS+3219 Recessed Left hand inward opening solid timber door with multipoint locking system, set in steel frame plus additional top lock

Figure LSS+3220 External - Flush with building right hand outward opening steel paneled gate with steel mesh and full cover plate; Internal - Standard timber door with glass panel

Figure LSS+3221 Left hand outward opening recessed solid timber fire door with steel panel

Figure LSS+3222 External - Heavy duty right hand outward opening steel gate proud of building line with single lock and no cover plate; Internal - Right hand inward opening timber door, locks unseen

Figure LSS+3223 External - Recessed right hand outward opening steel gate with three standard butt hinges and no cover strip; Internal - Right hand inward opening timber paneled door with two locks visible

Figure LSS+3224 A sigma forced entry team shows the technique for breaching a door.

Figure LSS+3225 MSC Lock Force tool is similar to that produced by SIGMA

Figure LSS+3226 There are various dies for the MSC LOCK FORCE tool to fit different profiles

Figure LSS+3227 The use of the MSC LOCK FORCE tool is straightforward

Figure LSS+3228 The BROCO thermic lance is a small self contained package

Figure LSS+3229 The BROCO control nozzle and chemical self starter for the thermic lance

Figure LSS+3230 The KIBB security lock and strike system makes

bypass difficult
Figure LSS+3231, an attack on a file cabinet safe with a variety of tools.

Figure LSS+3232 A hole saw can be used to ream out the entire plug.

Figure LSS+3233 A new shear line is created by drilling the plug.

Figure LSS+3234 The mounting for the cylinder is cast and can be fractured, allowing removal of the lock.

Figure LSS+3235 Knob locks should not be used as the sole protection on exterior doors.

Figure LSS+3236 Rim locks must be mounted properly to increase their resistance to attack.

Figure LSS+3237 Cylinders can be pried loose if not mounted properly.

Figure LSS+3238 The cylinder was pounded through the mounting.

Figure LSS+3239 A pipe wrench can be utilized to twist loose a key-in-knob or cylinder lock.

Figure LSS+3240 The ease by which a cylinder can be removed by shearing the set screw.

A wrench attack on cylinders can be very effective. Courtesy of Don Shiles.

Figure LSS+3241 A diagram showing the principle of jamb spreading.

Figure LSS+3242, examples of burglary tools found at the scene of a safe job.

Cylinders can be forcibly removed by applying torque and destroying internal set screws. The set screws can also be removed during business hours to allow the cylinder to be unscrewed at a later time. Courtesy of Don Shiles.

Figure LSS+3243, a special drill bit for removing plugs, called a rotary pick.
Figure LSS+3244 A lock can be drilled by raising all drivers above shear line.
Figure LSS+3245 A lock can be drilled to create a new shear line.
Figure LSS+3246 A lock can be drilled and then shimmed with a

fine wire.

Sigma analysis of the Kibb interlocking strike plate, with Ian Bauchop.

Demonstration of different forced entry techniques on doors utilizing the Kibb interlocking strike plate design.

A wrench attack on cylinders can be very effective. Courtesy of Don Shiles.

Forensic evidence of forced entry. Courtesy of Hans Mejlshede.

Opening a padlock by bouncing the locking dog. Courtesy of Don Shiles.

LSS201: MSC Lock Force tool, courtesy of MSC

LSS201: Forced entry tools produced by Sigma. Courtesy of Ian Bauchop.

LSS202: Broco Thermic lance description and use, by Tom Joos.

Figure LSS+3243, a special drill bit for removing plugs, called a rotary pick.

Chapter Thirty-Three

Figure LSS+3301 A seventeenth century German strongbox
Figure LSS+3302 German chest lock, seventeenth century and a French chest, sixteenth century
Figure LSS+3303 German chest locks, seventeenth century, and fifteenth century.

Figure LSS+3304 Record safe with internal component layout.

Figure LSS+3305 The money safe and internal view.

Figure LSS+3306 Examples of composite safe, claded safe, and combination safe.

Figure LSS+3307, an example of a floor safe and SMNA labels for fire and burglary rating.
Figure LSS+3308 Examples of fire protected file cabinets.

LSS101: Discussion of safe design by Bill Sherlock.

Chapter Thirty-Four

Add text to section 34_1.1
Add section 34_4.1.1.1 Other combination locks
Add section 34_7.2.1.1 Sargent & Greenleaf Model 6600 Series
Add section 34_7.2.1.2 Sargent & Greenleaf Model 8400 Series
Add section 34_7.2.1.3 Sargent & Greenleaf Model 8500 Series
Add section 34_7.2.1.4 Mosler Model 300-400 and 301-401 MR Series Locks
Add section 34_7.2.1.5 Mosler Model 302-402 MR and 302-402 MRK Series
Add section 34_7.2.1.6 LaGard Model 1980
Add section 34_7.2.1.7 Mas-Hamilton X-07
Add text to section 34_7.2.3
Add text to section 34_8.0 Changing Combinations, including new section
Add section 34_8.1 Procedures for Changing Combinations
Add text to section 34_9.0 Time Locks

W.B. Dodds
Hall's Double Dial Premier (mid-size) with Consolidated Time Lock
Hall's Premier (mid-size)
Hall's Crescent
Hall's Crescent
Hall's Safe Lock
Hall's Single Dial Premier (mid-size) with Consolidated Time Lock
Herring, Farrel, and Sherman Double Dial
Herring Grasshopper Key Lock
H.C. Jones Patent Combination Lock
"Hobnail" (Early American) Safe Key
Lillie (attributed) Click Lock with Key
Lillie (attributed) Dial Lock w/Knob
Lillie (Lewis) "Click Lock" Safe Key
Miller Combination Lock Patent Model
Rosengrens Safe Lock
Safe Deposit Lock-1
Sargent's Magnetic Lock #2 (early)
Sargent & Greenleaf #3 Fire Proof Lock
Sargent & Greenleaf #1 Vault Door Lock
T. J. Sullivan
Yale Double Dial Bank Lock Earliest pat. Date-July 14, 1857
Yale Double Dial Split-Bolt Vault Lock
Yale Pin Dial Time Lock (56 hour, 2 movement)
Yale 101-1/2 Double Dial
Yale Quadruplex Safe Key

LSS101: Discussion of the X-07 and X-08 with Joe Cortie

Chapter Thirty-Five

Add text to section 35_1.6.2.2 Tear gas
Add text to section 35_4.2.1
Add section 35_4.2.2A Prying and Wedging
Add section 35_4.2.2B Pulling
Add section 35_4.2.2C Pounding
Add section 35_4.2.2D Wedging
Add section 35_4.2.7.7 Definition of Conventional Explosives

Add text and graphics to section 35_10.1
Add text to section 35_10.2.3
Add audio segments to section 35_10.2.7

3563-15
3563-16
3563-17
3563-1819

Figure LSS+3501 Chemical composition of tear gars
Figure LSS+3502 Tear gas canister
Figure LSS+3503 Table of Explosives
Figure LSS+3504 Emergency dials
Figure LSS+3505 Fire and record safes
Figure LSS+3506 Money safes
Figure LSS+3507 Cash safes
Figure LSS+3505 Fire and record safes
Figure LSS+3506 Money safes
Figure LSS+3507 Cash safes

Figure LSS+3508. Punching involves the wheel pack being forced inward

Figure LSS+3509, diagram showing how a safe is peeled by gaining an access point to remove layers of metal.

Figure LSS+3510. In this figure, peeling was accomplished from the corner using a cold chisel.

Figure LSS+3511 This was a peel and punch attack to access the bolts (left). A classic peel attack is shown (right)

Figure LSS+3512, examples of peeling of the outer skin on the top of the container and the rivets popped.

Figure LSS+3513 Prying and wedging.

Figure LSS+3514 A safe that has had the door pulled loose by the application of extreme pressure.

Figure LSS+3515, (ISP 38-3563 left, and 39-3563 right). The result of pounding of components.

Figure LSS+3516, Bolts were sheared from shock waves through the use of the welded bar to the front of the door.

Figure LSS+3517. Example of punching. Pressure was applied to the hinge side.

Figure LSS+3518. This was a pound attack. The door was pounded with many hits.

Figure LSS+3519, An attack by the use of a wedge to pry apart and separate portions of the container.
Figure LSS+3520, The top of the safe was cut into to provide access to the bolt works.
Figure LSS+3521 Attacks by torch. In the middle picture, an inept attempt to open the safe by cutting through the side.
Figure LSS+3522. Attack using a torch where there was obviously no knowledge of where to cut.
Figure LSS+3523 Additional examples of the use of a torch. In the photographs, the lock box is burned out.
Figure LSS+3524 Lines scored by an oxy-acetylene torch in the outer shell of a Chubb safe.
Figure LSS+3525, examples of torch attack. Incorrect tools were utilized on the side of the safe.
Figure LSS+3526, attack by torch that did not result in an opening.
Figure LSS+3527, A torch attack where burglars cut a portion from the door for access.
Figure LSS+3528, Examples of attack by oxyacetylene.
Figure LSS+3529. The thermic lance develops high temperature and can be utilized virtually anywhere.
Figure LSS+3530 An example of a safe attacked with a thermic lance.
Figure LSS+3531 An example of arc welding with cutting rods.
Figure LSS+3532, A free-standing Chubb safe was attacked with explosives.
Figure LSS+3533 A safe was open with explosives, after being filled with water.
Figure LSS+3534 A fixed drill rig.
Figure LSS+3535 A burglary where it is suspected that a drill rig caused the fracture of the outer skin of the door.
Figure LSS+3536 Core drill can produce a large hole for access to the bolt works or lock box.
Figure LSS+3537 Critical drill points are shown. This is a rear view, with the lock case removed.
Figure LSS+3538 (ISP 23-2963) Deflector plates made of angle iron are added to deter drilling.
Figure LSS+3539 (ISP 104-3563) The bolt is punched out of

the way in order for the handle cam to be rotated.

Figure LSS+3540 Burglars drilled into the side of the safe to punch and drive the bolt out of the way.

Figure LSS+3541 A scope is inserted to obtain a view of the wheel pack.

Figure LSS+3542 The fence is a prime target for drilling, either the soldered link or the actual fence material.

Figure LSS+3543 Progression of movement of the fence into the gate of the wheel pack.

Figure LSS+3544 A 90 degree angle view with a borescope using a mirror on a Mosler MR 302.

Figure LSS+3545 Locating the fence for drilling.

Figure LSS+3546 A lever fence that has been drilled, and then removed.

Figure LSS+3547 Drilled relockers and zoom view.

Figure LSS+3548 Mosler MR-302 point of penetration.

Figure LSS+3549 Hole drilled through cover plate.

Figure LSS+3550 Side drilling and scoping the lock case.

Figure LSS+3551 Floor safe that has been angle drilled to view wheel pack.

Figure LSS+3552 Safe drilled from the top of safe to lock box to view the wheel pack.

Figure LSS+3553 Many burglaries are simulated.

Figure LSS+3554 The burglar uses a drill without much knowledge of the safe.

3563-15 Individual must have knowledge

3563-16 Tool knowledge of the burgar

3563-17 Time limit for burglary

3563-1819 Proficiency in burglarizing types of safes

LSS201: A primer on the burglary of safes, Courtesy of Bill Sherlock.

LSS201: Forensics and locks, Courtesy of Bill Sherlock.

LSS202: Steve Mattoon on the use of explosives to gain entry.

Chapter Thirty-Six

Add text to 36_3.1.2

Figure LSS+3601 Mas-Hamilton Soft Drill system

Figure LSS+3602 Soft Drill display screens during manipulation

Figure LSS+3603 Parallax error can cause problems during manipulation

2963-42 The use of robot dialers

Use of ultra violet to determine which keys have been depressed on a keypad. Courtesy of Don Shiles.

LSS201: Mark Bates on Manipulation

LSS201: Mark Bates on the Soft Drill

Chapter Thirty-Seven

Add text to section 37_12.0 from case citations.

Add text to §1716a Nonmailable locksmithing devices and motor vehicle master keys

Figure LSS+3701 UL Label

Figure LSS+3702 UL Label designations and nomenclature

Figure LSS+3703 SMNA Label designations

Chapter Thirty-Nine

Figure LSS+3901 Kwikset key-in-knob bypass tool

Hinges and forensic evidence. Courtesy Don Shiles.

Case example: removal of sliding glass door. Courtesy of Don Shiles.

Chapter Forty

Add section 40_1.1.1 Operational Requirements
Add section 40_2.1.1.1 Sensor Applications
Add section 40_2.1.1.2 Detection Factors
Add section 40_2.1.6 Power Supply
Add section 40_3.0.0 Performance Characteristics
Add section 40_3.0.2 Environmental Considerations

Add section 40_3.1.1 Balanced Magnetic Switch
Add section 40_3.1.8 Taut wire
Add section 40_3.2.3.A Fence Vibration
Add section 40_3.2.3.B Strain Sensitive Cable
Add section 40_3.2.3.C Fiber optic Fence
Add section 40_3.2.4 Wall Vibration
Add section 40_3.2.5 Fiber Optic Wall
Add section 40_3.2.6 In-ground fiber optic
Add section 40_3.2.7 Ported Coax Buried Line
Add section 40_3.2.8 Balance buried pressure
Add section 40_3.2.9 Buried Geophone
Add section 40_3.4.1 Electric Field
Add section 40_3.5.1.2 Radar
Add section 40_3.5.2.1 Passive Infrared
Add section 40_3.5.2.2 Active Ultrasonic
Add section 40_3.5.2.3 Audio Sensors
Add section 40_3.5.2.4 Acoustic Detection (Air Turbulence)
Add section 40_3.6.A Interior Active Infrared
Add section 40_3.6.B Exterior Active Infrared
Add section 40_3.7.1 Video Motion Detection

Add text to section 40_2.1.1 System Integration
Add text to section 40_3.0 Sensor Categories
Add text to section 40_2.1 Technology Solutions
Add text to section 40_2.1.2 Alarm Monitoring Systems
Add text to section 40_2.1.5 Alarm Assessment
Add text to section 40_2.1.1.2 Sensor Integration
Add text to section 40_2.1.4 Communications
Add text to section 40_1.1.1 Cost Considerations
Add text to section 40_3.1 Mechanical Switch
Add text to section 40_3.1.1 Magnetic Switch
Add text to section 40_3.2.2 Glass Break
Add text to section 40_3.3 Photo Electric Beam
Add text to section 40_3.5 Microwave
Add text to section 40_3.6 Passive Infrared
Add text to section 40_3.5.1.1 Dual Technology Passive IR/Microwave
Add text to section 40_3.4 Capacitance

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www.security.org is the Internet supplement to **Locks, Safes, and Security** (Second Edition). The site contains an extremely comprehensive database about locks and safes. Detailed information regarding bypass tools and techniques is accessible, together with patent data, manufacturer listing, and comprehensive drill-point diagrams for all of the major safe and lock manufacturers throughout the world.

Much of the information contained within the website requires a security clearance for access, due to the sensitive nature of the information. You can obtain a clearance by **registering** on line.

21 (Popup - LINKS TO OTHER INTERNET SITES)

Links to many forensic sites, as well as leading lock and safe manufacturers may be found at **www.security.org**.

22 (Popup - LSS+/x CD/ROM)

The **LSS+ GOVERNMENT version CD/ROM** will contain restricted information regarding the bypass of locks and safes. Extensive video presents detailed instructions and discussion regarding the techniques and tools that can be utilized to open many high security locks. Bypass tools produced by John Falle, Mark Bates, Martin Newton, HPC, and other vendors are described.

In order to purchase a copy of this CD/ROM, you must be employed by a government agency responsible for covert entry. Certain restrictions apply to the purchase and use of this material.

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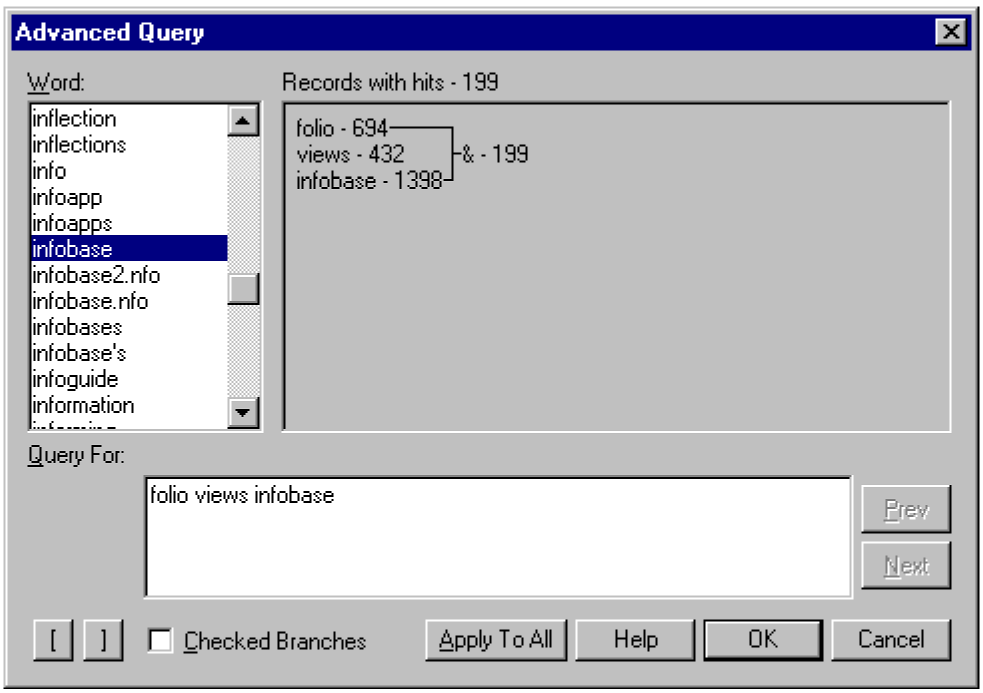
All **patents** appear as a series of integers without any comma separation. To search for a specific patent, enter the number

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To go directly to a particular section, enter the chapter_section. Thus, to go directly to the beginning of chapter 31, enter **31_1.1**.

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F3
F4 Next hig
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Bold	CTRL+B
Bookmark	CTRL+M
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Copy	CTRL+C
Cut	CTRL+X
Document Pane	CTRL+SHIFT+D
Exclusive Or Operator (Advanced Query Dialog)	CTRL+E
Expand All	CTRL+*
Expand Branch	*
Expand One Level	+
Explore Infobases	CTRL+E
Find Infobase	CTRL+F
Go Back	F6
Go Forward	SHIFT+F6
Go To	CTRL+G
Help	F1
Highlighter	CTRL+H
Hit List Pane	CTRL+SHIFT+H
Infobase Properties	CTRL+SHIFT+I
Italic	CTRL+I
Jump Destination	CTRL+D
Jump Link	CTRL+J
Next Hit	F4
Next Link	CTRL+DOWN ARROW
Next Pane	F8
Next Partition Hit	F5
Next Record	CTRL+DOWN ARROW
Next View	F7
Not Operator (Advanced Query Dialog)	CTRL+N
Note	CTRL+N
Object Pane	CTRL+SHIFT+O
Open	CTRL+O
Or Operator (Advanced Query Dialog)	CTRL+O

Action	Windows Keystroke
Query	F3
Query Template	CTRL+Number Key (1 - 9)
Page Break	CTRL+Q
Paste	CTRL+V
Picture Dialog	CTRL+SHIFT+P
Popup Menu	F10
Previous Hit	SHIFT+F4
Previous Link	CTRL+UP ARROW
Previous Pane	SHIFT+F8
Previous Partition Hit	SHIFT+F5
Previous Record	CTRL+UP ARROW
Previous View	SHIFT+F7
Print	CTRL+P
Remove Link	CTRL+SHIFT+J
Remove Note	CTRL+SHIFT+N
Save	CTRL+S
Strikeout	CTRL+K
Styles	CTRL+SHIFT+S
Tag Record	CTRL+T
Underline	CTRL+U

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Depending upon access rights, you are allowed to highlight entries and print the material. You may also utilize the "shadow files" function to enter your own comments or notes at any point in the Infobase, for later reference. And, don't forget, all comments are also indexed.

You may also customize the appearance of the Infobase to suit your individual requirements.

Finally, you will note that there are several views displayed at the bottom of the page. By pressing the appropriate button (All, Search, Browse, Document, Contents, HitList, and Object). Each of these provides a different level of display, that is explained in the help files.

Understanding the Default Views

A ***view*** is a way of looking at information. Depending on what you are doing in an infobase, you may need to look at the information in different ways. To facilitate this, Folio Views™ provides seven different views of an infobase.

Each view contains one or more panes. Each pane presents a type of infobase data. The ***Document*** pane displays the body of the infobase — the text, objects, links, highlighters, and other data stored in an infobase. The ***Contents*** pane displays a dynamic table of contents for the infobase. The ***Hit List*** pane displays search results after a query is performed. The ***Reference Window*** pane is always connected to the top of the Document pane — it displays the path to the current information (such as Volume 1-Biology, Chapter 12, The Life Cycle of Amphibians).

The default views are all listed on tabs at the bottom of the infobase window. To change the view of an infobase, click on a tab.



The seven views are:

All — Displays the Contents, Document, Reference Window, and Hit List panes. Use this view when searching the infobase or when you need to see all of the related information at once.

Search — Displays the Document, Reference Window, and Hit List panes. Use this view when you are searching to find the most relevant information. (The Hit List can help you identify the most relevant sections in the infobase to begin reading once your search is completed.)

Browse — Displays the Contents, Document, and Reference Window panes. Use this view when you are browsing the infobase for information: it gives you the best access to the table of contents while maximizing the space allocated for the infobase text.

Document — Displays Document and Reference Window panes. Use this view when you need as much of the body of the infobase on the screen as possible.

Contents — Displays only the Contents pane. Use this view when you are navigating or scanning the table of contents and need to see the full name of the headings in the table of contents. (Double-clicking on a heading in the Contents view takes you to the appropriate section in the Document view.)

Hit List — Displays only the Hit List pane. Use this view after performing a search to view as many references in the hit list as possible. (Double-clicking on a reference in the Hit List takes you to the appropriate section in the Document view.)

Object — Displays only the Object pane. The Object pane is activated whenever an object link is followed.

28 (Popup - MASTER EXHIBIT LISTING)

There is a **master exhibit summary** at the beginning of this text, as well as within each chapter. You may hyperlink to an exhibit directly from this listing.

Note that all new exhibits for the electronic edition are identified by "Figure LSS+" numbering to differentiate from the printed edition.

29 (Popup - PHOTOGRAPHS AND MAPPING)

There are three levels of photographs contained within the Infobase. The original exhibits that are contained within the printed edition of **Locks, Safes, and Security** appear as in the original text. Their captions are contained within pop-up notes, denoted by a yellow folder. The captions contain the original numbering associated with each chapter and sequential exhibit. All of these photographs are reproduced in black and white.

Additions to the Electronic Edition are in color and carry their own caption and distinct numbering system, in order to differentiate from the original illustrations. Note that the numbering may be out of sequence because of the way the Infobase has been edited.

Many of the complex or multisegment photographs are "mapped" for hypergraphic links. If the cursor is moved over a picture, especially one that contains one or more sub-parts, links may be indicated by the arrow changing to a hand. In such case, left-click to link to a more detailed photograph. In most cases, hypergraphic links are utilized to allow for the display of a larger image.

Hypergraphic links may also appear as highlighted text, usually in **dark blue**. Simply click on the text to view the associated photograph.

Where there is significant detail contained in a photograph, the resolution has been set so as to allow for use of the zoom function to magnify the image.

30 (Popup - HELP USING INFOBASE SOFTWARE)

On-line help files are available at security.org.

You may find detailed help files for using Open Market software by entering **F1** from anywhere within the Infobase. The Open Market Folio Views[tm] program is recognized as the most sophisticated search engine of its kind. It allow you to format searches utilizing complex limiting criteria.

All of the information contained within this work have been assigned to information groups to assist in performing precise queries. You will note that there are many preformatted search templates to assist you in locating the information you require.

31 (Popup - SEARCH TOOLS AND QUERY TEMPLATES)

There are many ways to search for information within this Infobase. A summary of search tools is provided below. You may also obtain detailed help by pressing [Function 1].

There are many terms in the lexicon of locksmithing that have not been standardized as to precisely how they appear. Thus, words may be separated by a space, hyphen, or joined together. For example, in various texts the term "strongroom" can be written as one word, two words, or hyphenated. Although uniformity was the goal throughout this text, it became impossible as we identified

some 2500 different terms that appear in trade journals and other books presented differently, with not standardization.

You are encouraged to search for terms keeping this in mind.

Search, Query

Purpose

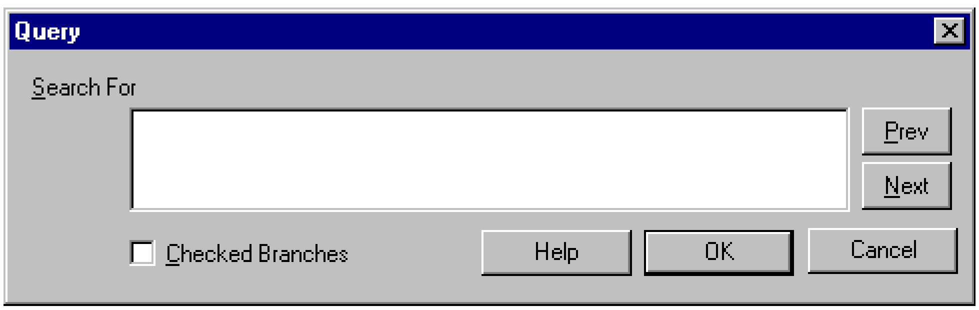
Use Query to perform basic relevancy ranked searches on the infobase. Query also allows you to perform ***smart searches*** or ***natural language searches*** (they do not require you use or understand the advanced Folio Views™ query syntax).

Steps

To perform a simple ranked search on an infobase:

1 Choose **Query** from the **Search** menu.

•The Query dialog appears.



2 Enter the terms you wish to search for.

•The more specific your search is, the better the search results will be. For example, searching for

cases about the death penalty

is allowable, but contains "noise words" that are not relevant to the topic. A better search (assuming you were searching in an infobase of legal cases) would be

death penalty

•Note that ranked queries may also include phrases.

3 If desired, choose **Checked Branches** at the bottom of the dialog to search only the checked branches of the table of contents.

•If you have not selected any branches in the Contents pane, do not select this option. Doing so will result in 0 hits (you will be searching an empty set).

•To select branches in the Contents, click in the Contents pane, choose **Show Check Boxes** from the **View** menu, and then click in the checkboxes next to the headings in the Contents pane.

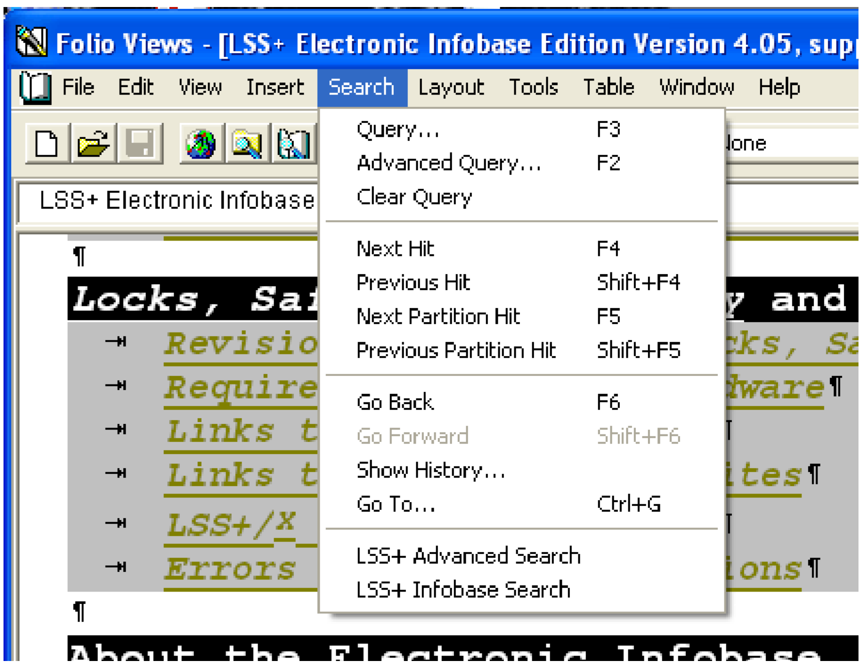
4 Choose **OK**.

•The most relevant records are listed first in the Hit List pane.

Search, Advanced Query

Purpose

Use Advanced Query to unleash the full power of the Folio Views query syntax. Advanced Query gives you complete access to the Folio Views Query Syntax. This syntax helps you focus and refine your searches through the use of Boolean operators, wildcards, proximity operators, and scope limitations. You may also use the custom query template by entering ctrl-F2.



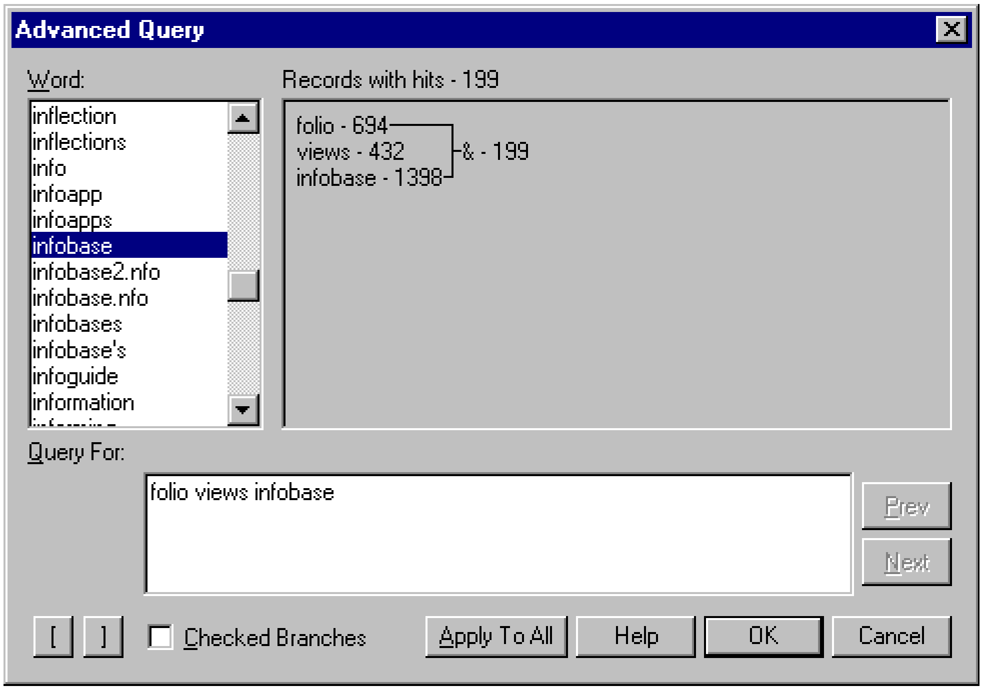
The advanced query templates are also available through the SEARCH menu.

Searching the Infobase

To search all text in the infobase, you may utilize the default advanced query, shown below, or you may search with the LSS+ Advanced Query template, by entering CTRL-F2, or do a direct search for chapter and section number by entering CTRL-F3.

1 Choose **Advanced Query** from the **Search** menu.

•The Advanced Query dialog appears.



2 Type the words you wish to search for, separated by a space or the appropriate operator.

•You may search by keyword (not using any specific operators). For example:

paragraph formatting options

•You may search for an exact phrase. Enclose the phrase in quotation marks. For example:

"searching the infobase"

•You may use Boolean operators (and, or, not, exclusive or). For example:

search and help
search or help
search not help
search xor help

•You may use wildcards (single character, multiple character, word form, synonym). For example:

run?
run*
run%
run$

•You may use proximity operators to specify how close terms must be. For example:

"phrase search"/5

•If you wish to modify a previous query, click the **Prev** button next to the **Query For** box to display the previous query.

•Note that as you type, the Query dialog attempts to complete the word you are typing with a word contained in the infobase. If the word is correct, press the ENTER key and type the next term.

•Queries may be up to 2048 characters in length.

3 If desired, choose **Checked Branches** at the bottom of the dialog to search only the checked branches of the table of contents.

•If you have not selected any branches in the Contents pane, do not select this option. Doing so will result in 0 hits (you will be searching an empty set).

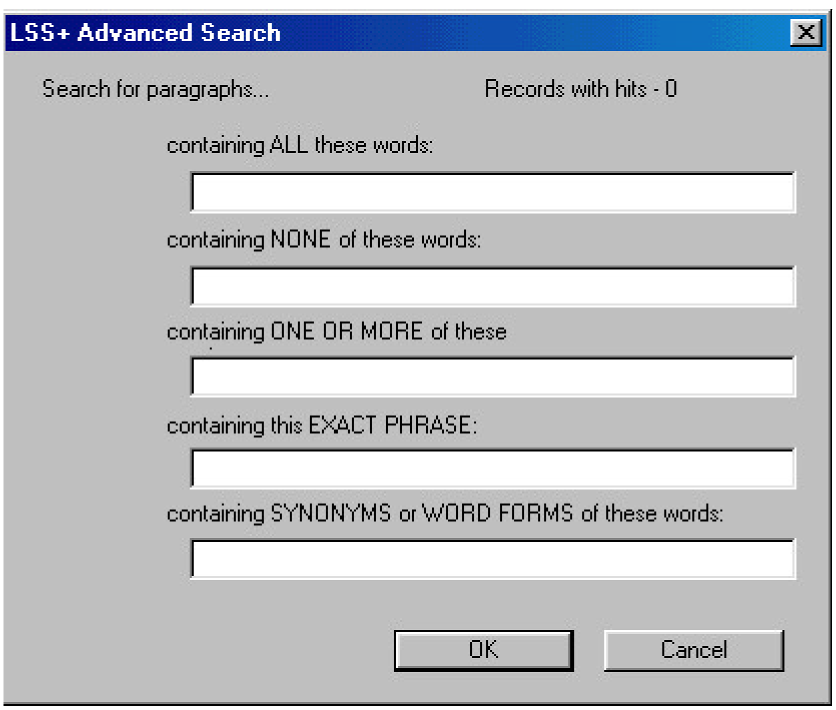
•To select branches in the Contents pane, click in the Contents pane, choose **Show Check Boxes** from the **View** menu, and then click in the checkboxes next to the headings in the Contents pane.

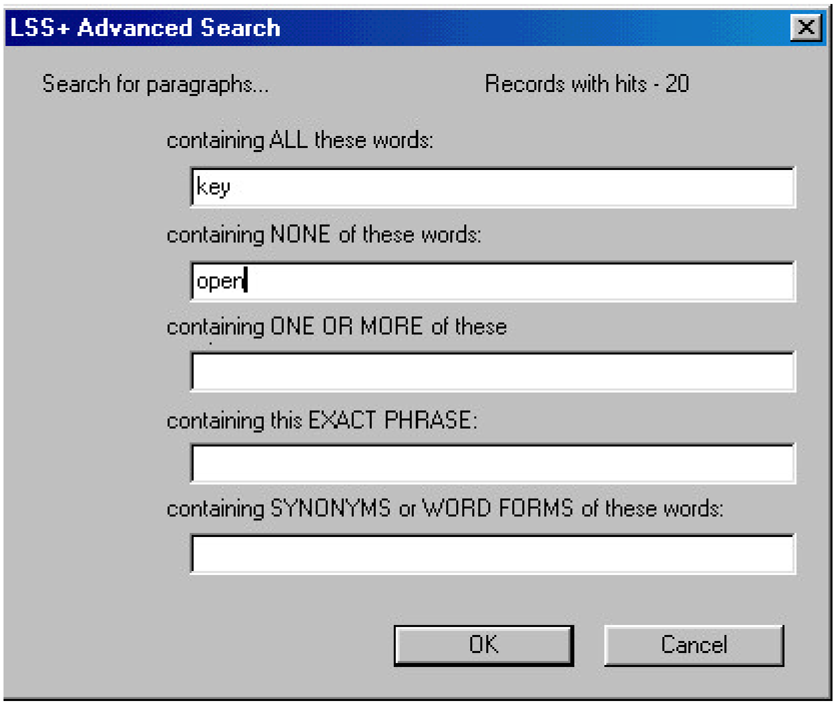
4 Choose **OK** to apply the search to the current infobase.

•Choose **Apply to All** to apply the search to all open infobases.

LSS+ Query for Advanced Search

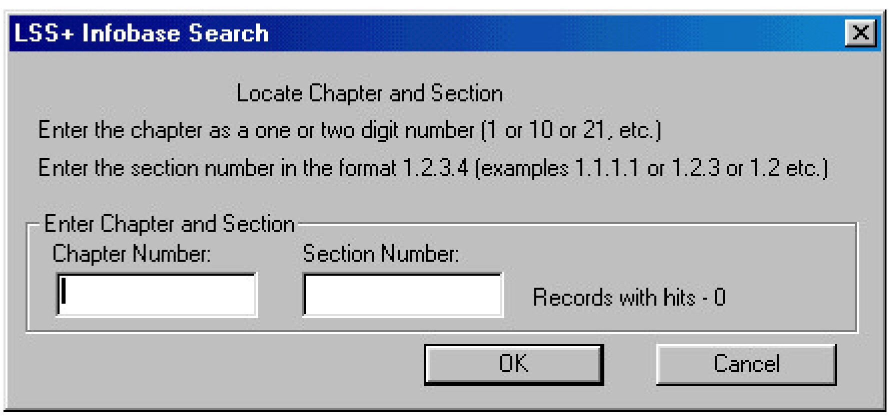
Enter CTRL-F2 to utilize this search tool. You may enter information in one or more search fields for a narrowed or limited query. Shown is the blank template, and a query that contains the word KEY, but not the word OPEN. This search returned a total of 20 hits. You may view each hit by first pressing ENTER, then F4 to view the next hit, or SHIFT-F4 for the previous hit. You may also switch to CONTENTS VIEW, BROWSE VIEW, OR ALL VIEW to see all of the hits.

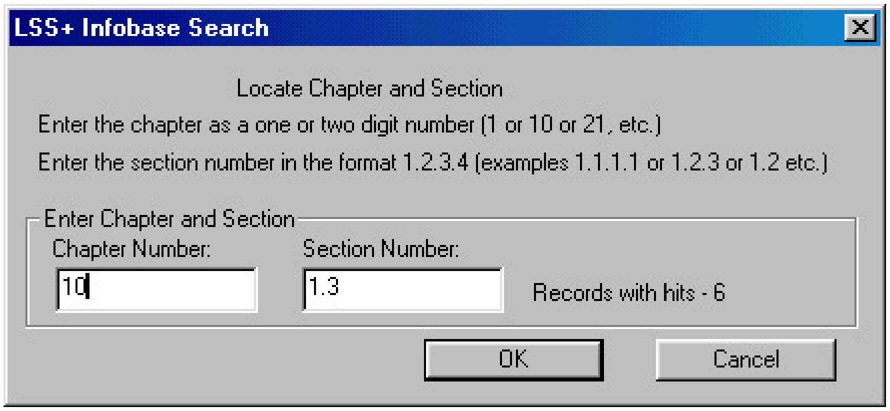




LSS+ Query to search for Chapter and Section directly.

Enter CTRL-F3 to utilize this search tool.





This example shows a blank template, and one that is running the search for Chapter 10, section 1.3.

32 (Popup - CREATING AND USING SHADOW FILES)

Creating a New Shadow File

To create a new shadow file:

1. Open the infobase to be shadowed.
2. Choose **New** from the **File** menu.
   •The New dialog appears.
3. Choose **File Type** and select **Folio Shadow File**.
4. Select **File Name** and enter a name for the shadow file.
   •The default extension is **.SDW**.
5. If necessary, choose **Drives** and/or **Directories** to specify where the new file should be created.
6. Choose **New** (**OK** on some platforms).

Note: Shadow files inherit the infobase password. If the infobase is password protected, then so is the shadow file.

Additional Information

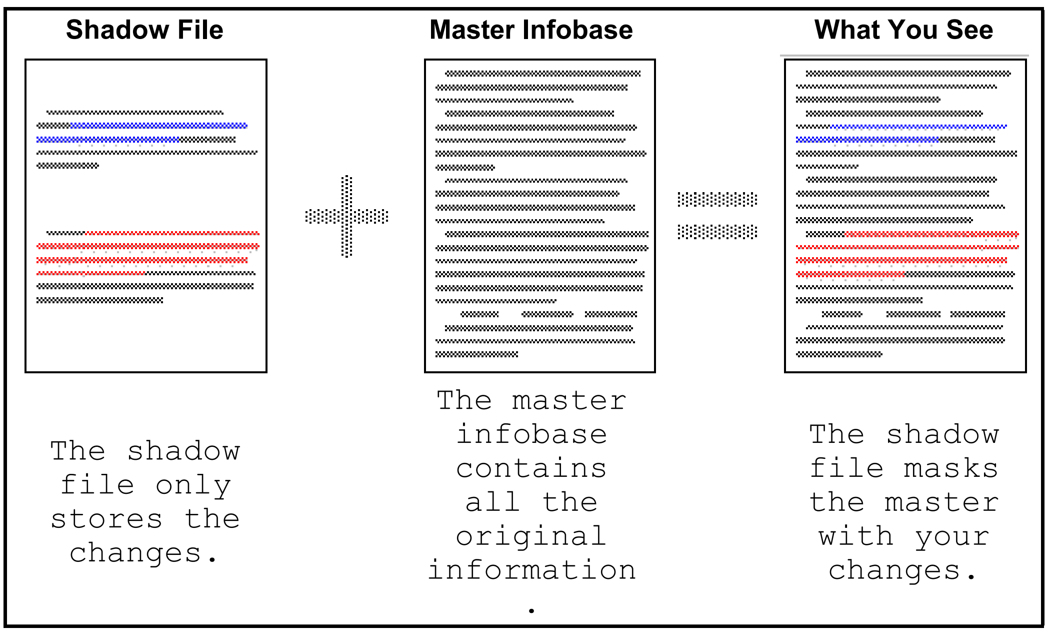
The following information is presented below:

- Understanding Shadow Files
- Uses for Shadow Files

Understanding Shadow Files

A shadow file stores personal changes you make to an infobase. Much like an overlay or transparency allows you to annotate information without changing the original, a shadow file allows you to change information in a personal view of an infobase without affecting the master infobase.

When you create a shadow file, you create an overlay for an infobase. When you add notes, highlighters, or bookmarks to the shadow file, they do not appear in the original infobase (the master). When you add or remove records from the shadow file, the changes do not appear in the master. Any change you make to the shadow file only appears in the shadow file. Changes that are made to the master infobase, however, ***are*** displayed in the shadow file. This allows you to view updated information while maintaining your personal annotations. The following illustration may clarify how shadow files work:



Working in a shadow file is just like working in an infobase. Anything you can do in an infobase you can do in a shadow file (with the exception of creating a shadow file — you cannot shadow a shadow).

Uses for Shadow Files

Shadow files provide a great deal of flexibility in their application. The way you choose to implement them may depend only on your imagination. Some of the more common uses for shadow files are

- annotating infobases on CD-ROM
- legal (and other) research
- sharing comments & edits
- prototyping changes to an infobase
- updating an infobase on CD-ROM.

Annotating Infobases on CD-ROM (or Other Read-Only Media)

Shadow files were originally designed to allow you to annotate infobases stored on CD-ROM. Research has shown that using information (rather than just viewing information) provides higher learning and retention rates. With an infobase stored on CD-ROM, you can only access information, not use it. Shadow files allow you to make annotations to an infobase on CD-ROM and assist you in learning and remembering the information you use. Through a shadow file, you can add notes, highlighters, links, bookmarks, and other information to an infobase stored on CD. The information you add is placed in the shadow file, which is usually stored on your hard drive or on a network drive.

Sharing Comments / Edits

Managers of documentation departments and others who create information for others to consume are often frustrated by the review process. For some organizations and for some market-sensitive information, five or more people may have to review and approve a document before it is distributed. Coordinating the suggested edits — particularly the conflicting edits — is always challenging when done on paper.
However, the review process becomes much simpler if you make a shadow file of the document on the network and allow the reviewers to annotate it at will. Request that each reviewer make two passes on two different days. This allows the reviewers to see the comments made by each of the other reviewers. The reviewers can argue for and against changes within notes and popups within the infobase. When they have reached a consensus, you can incorporate the necessary changes in the master infobase and post it for final review.

Quick Keys

Action	*Default Keystrokes*
Open	CTRL+O
Save	CTRL+S

You must have a copy of Microsoft Windows Media Player software Version 7 (or higher) installed on your computer to view the video files. Your computer must be capable of playing WAV and mp3 files for audio, and viewing TIF files for still images.

All video files are stored in .WMV format. All patents and still images are compressed .JPG or .TIF files. Note that many of the patent files contained within the **Security.Org** website are FXS files. This is a special compression algorithm that is utilized by Symantec in their WinFax program. Contact the author if you require the viewer program for these files.

In order to view multimedia linked files on security.org, you should have a current Internet Explorer browser (version 5.0 or later) that supports java applicationsw. You will also need Windows Media Player.

Certain of the multimedia files require a security clearance and entry of a password, both for the CD/ROM and website. Contact the site administrator if you experience difficulty in registering on the site.

Some of the photograph sequences relating to picking, keying, master keying, shimming have been provided by HPC. Full descriptions of these processes are contained on the HPC Interactive Learning Series in video clips. These are highly recommended for locksmiths who are seeking additional information in the form of a tutorial.

34 (Popup - ANNUAL UPDATES AND EXPIRATION OF INFORMATOIN)

There will be periodic updates to the Electronic edition of **Locks, Safes and Security**. It is contemplated that additional materials will be added to **LSS+** and to the accompanying CDs. Your access to the supplementary materials will require the appropriate security clearance.

The data within each CD will expire one year from initialization. You must request an updated password in order to continue using the LSS+ Infobase.

All of the video segments are contained within the companion CD ROMS. They are labelled in sequence (LSS+101, 102, etc. as issued). If material has been added to a CD subsequent to the time of purchase of your version of LSS+, then you must go directly to the supplement and click on the multimedia link on that CD. As later versions of LSS+ are issued, these links will be integrated into the body of the Infobase.

35 (Popup - SUBMISSION OF INFORMATION)
Submission of information for inclusion in later editions is welcome, as are all comments, corrections, or suggestions. Please contact the author by e-mail at mwtobias@security.org, or send written inquiries to:

Marc Weber Tobias
INVESTIGATIVE LAW OFFICES
Box 90043
Sioux Falls, South Dakota 57109 USA

You may also check **Security.org** for updated contact information.

36 (Popup - SECURITY AND FILE ACCESS)
Certain ares of this CD/ROM may contain security restrictions that require a password to access information. Likewise, many areas within the **security.org** website cannot be accessed without an appropriate clearance. Please contact the site administrator for a password. You must complete the **registration** form and comply with the terms and conditions that are detailed on security.org.

You will be required to obtain a password to open certain sections of **LSS+** and **LSS+/^{x} CD/ROM**. This password is machine-specific to your computer, and will not allow you to use the CD/ROM on another device. You can only receive a password through the security.org website. NOTE: You must obtain your password while the Infobase program is opened on your computer. You will supply a code that the system generates; you will then receive another code that you must input into your computer to make the program operational. You may call 1.877.2 BUY LSS (1.877.228.9577) to register your copy of LSS+.

You must contact Investigative Law Offices (605.334.1155) or by e-mail (mwtobias@security.org) for a multiuser license.

Some material may be encoded on a DVD CD/ROM, and must be played on a DVD player. Region codes will not be required.

37 (Popup - SECURITY LEVELS AND ACCESS TO INFORMATION)
ACCESS SECURITY LEVELS and INFORMATIONT

his Infobase and multimedia supplements makes information available to a wide range of users, including the public, law enforcement investigators, crime lab technicians, forensic investigators, private security, locksmiths, and government intelligence agencies. The author shall determine the appropriate access level for each user, and shall have the right to enforce

these requirements as to the access and dissemination of information.

All information on the **LSS+** series of CD ROMs is encrypted and password protected. You must register your copy of the software before it can be accessed. The cost of the material is based upon security level. There is a specific set of disks that is provided for each security level.

Certain information relating to bypass of high security locks, equipment and technology, will be restricted to government intelligence agencies and specific law enforcement organizations only. Likewise, the description of bypass tools used to covertly enter high security locks, will be provided only to authorized agencies.

The following security levels have been established for LSS+ Infobase, to access information.

Level 1 PUBLIC: General information regarding locks and safes; on-line video; patents. No security clearance is required.

Level 2 RESTRICTED: Certain high security bypass tools that are not available for general distribution. LOCKSMITHS and QUALIFIED PRIVATE SECURITY. Access to all information regarding locks and safes, on-line video

Proof of identification required, verification of law enforcement status, agency approval, for government agencies. Membership in one or more professional organization approved by Author. Proof of licensing, bonding, or other professional certification. Membership in the following organizations will be accepted: NLA, NSO, ALOA, SAVTA, ASIS, ELF, MLA, AFTE.

Level 3 SECRET: LAW ENFORCEMENT, CRIMINALIST, AND GOVERNMENT INVESTIGATORS WITH POLICE POWERS, GOVERNMENT INTELLIGENCE, and COVERT ENTRY. Access to all information regarding locks, safes, and vaults, and bypass. Proof of identification required. Agency approval. Membership in NSO, SAVTA, ALOA or equivalent organization required for non-government agents.

38 (Popup - ABOUT THE AUTHOR, INVESTIGATIVE LAW OFFICES, AND SECURITY LABORATORIES)

Marc Weber Tobias has authored five law enforcement textbooks for Charles C. Thomas Publishers, dealing with criminal law, police communications, and security.

Tobias received a Bachelors Degree in 1970 from the University of Nebraska-Omaha, and a Juris Doctor Degree from Creighton Law School, (Omaha, Nebraska) in 1973.

He is an attorney in Sioux Falls, South Dakota, with Investigative Law Offices, P.C. As part of his practice, he routinely conducts technical fraud investigations and consults with corporations and government agencies throughout the world regarding the bypass of locks, analysis of design defects, and security liability issues.

The author has been granted two United States Patents, and several foreign derivative patents for bypass tools relating to locks.

He is a member of the Associated Locksmiths of America (ALOA), Safe and Vault Technicians Association (SAVTA), American Society for Industrial Security (ASIS), American Academy of Forensic Sciences (AAFS), International Association for Identification (IAI), American Polygraph Association (APA), and American Association of Policy Polygraphers (AAPP). He is also a technical advisor to the Association of Firearms and Tool Marks Examiners (AFTE), and a member of the International Association of Investigative Locksmiths (IAIL).

Tobias has provided technical support and investigative services involving surveillance, covert entry, interrogation, polygraph, and crime scene documentation to many law enforcement agencies throughout the world.

ABOUT INVESTIGATIVE LAW OFFICES

INVESTIGATIVE LAW OFFICES has offices in Sioux Falls, South Dakota, United States of America. We are a technology law office, focusing on the investigation of technical fraud, and related issues, in the representation of our clients. Our office provides technical support for law enforcement agencies, and consults with lock manufacturers, crime laboratories, and vendors of specialized surveillance equipment and related technologies. We also represent locksmiths, in the development and sale of sophisticated bypass tools, and related issues.

We conduct high tech surveillance operations for law enforcement organizations, law firms, business, and insurance companies, to develop evidence for civil and criminal prosecutions for fraud and related crimes.We conducts background investigations, and

have access to the most comprehensive computerized databases in the United States.

We can provide technical support and training, in the areas of covert entry, communications, computers, lie detection, and internal security investigations.
We represent clients, in order to determine potential liabilities from defective security products, and will analyze high security locks for bypass capability. We can determine ways of correcting defects, and improving upon locks, safes, and security products, including the procurement of patents.

We have experienced polygraph examiners on staff, who have been conducting lie detector examinations in criminal, civil, and security investigations for over twenty-five years. We conduct examinations, and training in the United States, and in foreign countries, upon request. We utilize Stoelting conventional polygraph instrumentation, and Axciton computerized polygraph.

Our office maintains a library of thousands of hours of videotape interrogations, for training of law enforcement agencies. We can provide technical support and training in the areas of covert entry, communications, encryption, computers, lie detection, and internal security investigations.

We conduct legal research relating to security issues, and associated technology, including product location and acquisition. We have reports available regarding many security products, and will provide contract legal research into potential defects in products.

Marc Weber Tobias and independent contractors of Investigative Law Offices are members of the following professional organizations: American Bar Association; American Polygraph Association; American Association of Police Polygraphists; American Society for Industrial Security; Associated Locksmiths of America; Safe and Vault Technicians Association; International Association for Identification; American Academy of Forensic Scientists; and Association of Firearms and Toolmarks Examiners.

The principal Attorney for Investigative Law Offices, Marc Weber Tobias, has lectured throughout the world on covert entry and surveillance. He is a member of the South Dakota and Nebraska Bars, and admitted to practice in those states, and the Eighth Circuit Court of Appeals.

Members and associates of Investigative Law Offices are members of the following professional organizations: American Bar Association; American Polygraph Association; American Association of Police Polygraphists; American Society for Industrial Security; Associated of Locksmiths of America; Safe and Vault Technicians Association; International Association for Identification; American Academy of Forensic Scientists; and Association of Firearms and Toolmarks Examiners.

ABOUT SECURITY LABORATORIES

Security Laboratories was formed by Investigative Law Offices, to bring together a number of professionals in technical disciplines relating to locks, safes, and security. We have available specialists in lock picking and covert entry, combination lock manipulation, forensics, computers, law, manufacturing, training, design of special covert entry hardware and software, law enforcement, and related areas. Security Laboratories has representatives in the United States, England, and Jersey (Channel Islands).

Our clients, both in the United States and in foreign countries, generally have special requirements involving the training and deployment of technologies relating to lock picking, safe cracking, and security. We have the capability of designing and manufacturing special bypass tools for almost any lock or locking system, and specialize in opening high security lever and pin tumbler locks. If your agency has a requirement for a special bypass tool or technique, e-mail mwtobias@security.org.

Security Laboratories is an independent group of associates who advise and consult with Investigative Law Offices, regarding security issues. Associates are not lawyers, and are not employees of Investigative Law Offices.

Contacting the Author

The author welcomes feedback from readers. His e-mail address is mwtobias@security.org. He may be contacted toll free utilizing Internet telephony or video conferencing, through **http://www.security.org**, or by writing to Charles Thomas Publishers in Springfield, Illinois.

39 (Popup - CONTACTING THE AUTHOR)

You may contact the author via telephone, facsimile, mail, or

e-mail. Contact numbers are also available at **security.org.**

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Facsimile and voicemail: 1.612.677.3999

e-mail: mwtobias@security.org

40 (Popup - COPYRIGHT NOTICE)

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Limited Warranty and Disclaimer: For a period of 60 days from the date the Software is acquired by you, the Publisher warrants that the media upon which the Software resides will be free of defects that prevent you from loading the Software on your computer. The Publisher's sole obligation under this warranty is to replace any defective media, provided that you have given the Publisher notice of the defect within such 60-day period. Except for such limited warranty, the Software is licensed to you on an "AS IS" basis without any warranty of any nature. THE PUBLISHER AND ITS LICENSORS DISCLAIM ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Limitation of Liability: THE PUBLISHER AND ITS LICENSORS SHALL NOT BE LIABLE FOR ANY DAMAGE OR LOSS OF ANY KIND ARISING OUT OF OR RESULTING FROM YOUR POSSESSION OR USE OF THE SOFTWARE (INCLUDING DATA LOSS OR CORRUPTION), INCLUDING ANY INCIDENTAL, CONSEQUENTIAL, SPECIAL OR INDIRECT DAMAGES, REGARDLESS OF WHETHER SUCH LIABILITY IS BASED IN TORT, CONTRACT OR OTHERWISE. IF THE FOREGOING LIMITATION IS HELD TO BE UNENFORCEABLE, THE MAXIMUM LIABILITY TO YOU SHALL NOT EXCEED THE AMOUNT OF THE LICENSE FEES PAID BY YOU FOR THE SOFTWARE. THE REMEDIES AVAILABLE TO YOU AGAINST THE PUBLISHER UNDER THIS AGREEMENT ARE EXCLUSIVE. SOME STATES DO NOT ALLOW THE LIMITATION OR EXCLUSION OF IMPLIED WARRANTIES OR LIABILITY FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES, SO THE ABOVE LIMITATIONS OR EXCLUSIONS MAY NOT APPLY TO YOU.

41 (Popup - WAIVERS AND DISCLAIMERS)

WAIVERS, CONDITIONS, and DISCLAIMERS

Information within this Infobase describes certain locks and safes, and how they may be bypassed. Specific techniques are disclosed regarding lock picking, impressioning, decoding, and manipulation. As such, the reader is cautioned that the misuse of such information may constitute a crime in certain jurisdictions.

This work is intended for use primarily by law enforcement, intelligence, and other government agencies, as well as professional locksmiths and safe technicians. It is not intended, nor shall it knowingly be distributed, to individuals who do not have a legitimate need-to-know the information contained herein.

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If you do not agree to the specified WAIVERS, CONDITIONS, AND DISCLAIMERS, you should return this CD ROM set, for a full refund. Acceptance of all WAIVERS, CONDITIONS, AND DISCLAIMERS shall be acknowledged by your possession and use of this CD set. Your LICENSE is based upon such ACCEPTANCE.

The term AUTHOR shall include and refer to Marc Weber Tobias, as well as the Publisher, and any person or entity who has provided any information or materials to the author for the preparation of this book or CD/ROM.

The term INFORMATION, shall describe and apply to all data, graphics, illustrations, diagrams, and photographs contained within this text, referenced in any CD/ROM or web site, or to any direct or indirect information or conclusions which can be inferred or deduced from such material.

READER shall be defined as the purchaser, user, or other individual or entity who, through any means, obtains INFORMATION, in any form, from this CD ROM set.

The reader understands, acknowledges, and agrees to the following WAIVERS, CONDITIONS, and DISCLAIMERS for the use, in any form whatsoever, of the INFORMATAOIN contained within this CD ROM set.

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2. No product endorsement or rating is intended or implied, unless specifically noted;

3. The AUTHOR assumes no liability whatsoever for the reliance, by any READER, with respect to the security rating of any product, which causes any loss of any kind;

4. Technical information and advice is believed accurate at the time of publication. The AUTHOR does not warrant the accuracy or reliability of any technical information or advice, and disclaims any liability based upon the reliance by any READER of such information.

5. AUTHOR assumes no responsibility to inform its readers of any inaccuracy that may be discovered after publication;

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DISCLAIMERS

1. The AUTHOR is not affiliated with any manufacturer, company, or organization, nor has any economic or contractual relationship with any vendor or product described in this CD ROM set;

2. All statements or opinions expressed herein with respect to any product, technique, or generic classification are those of the AUTHOR alone, and should be construed as opinions only;

3. AUTHOR does not endorse, warrant, or guarantee any product in this CD ROM set. The mere appearance within this text should not be so considered;

4. Bypass information is lock specific. A manufacturer may make changes to frustrate bypass techniques detailed herein which are unknown to the AUTHOR, or which have occurred since publication, or in different models of the lock;

5. The use or misuse of any of the INFORMATION and techniques described within this CD ROM set may be illegal by certain individuals in one or more jurisdictions. The AUTHOR assumes no liability for the use or misuse of any INFORMATION or procedures described herein, and in no way encourages the use of such information in cases where such may be unlawful;

6. Any statements or opinions by the AUTHOR, with respect to

the compromise of security of any product, is based upon data developed by the author or others, or known within the security and locksmithing industry. Any tests shall have been based on sample products that have been purchased from the manufacturer by the AUTHOR, or supplied to the AUTHOR by the manufacturer.

7. AUTHOR makes no representation that he has tested every product of any specific manufacturer described herein. AUTHOR further makes no representation that any product so tested is representative of all other products of any manufacturer.

8. The bypass of any product described within this text may reflect manufacturing tolerance errors, which may or may not be common to all locks or other security devices. Because it is impossible to test all such devices, there is no way to determine if all such devices exhibit the same characteristics. The READER should therefore draw their own conclusions as to the security and integrity of any product.

42 (Popup - TRADENAMES AND TRADEMARKS)
MASTER TRADEMARK INDEX

The following tradenames and trademarks have been used throughout this Infobase. They are utilized or owned by the following manufacturers.

ACE II, Chicago Lock Corporation
ACE, Chicago Lock Corporation
ACETAL, DuPont
ALCHRONITE
ALOXITE, Chubb
APEX, Fort Lock
AUDITCON, Mas-Hamilton
AVA, Chubb
AVIONAL, Silca
BIAXIAL, Medeco
CELCON, DuPont, used by S&G
CENCON, Mas-Hamilton
CODEMAX, HPC, Inc.
COMBISEC, Abloy
CONQUEST, Chubb
DELRIN, DuPont
DIAMATIP, Magnum (Commercial Security)
DISKLOCK, Abloy
DISKUS, Abus
DYMAX, Mas-Hamilton (MPB Corporation)

ELECTRO, Union Works/Chubb
EVEREST (Ingersoll-Rand and Schlage)
EXTRUDE, Kerr
FOLIO, NextPage, Inc.
FOLIO VIEWS, NextPage, Inc.
GEM, Fort Lock Company
GEMATIC, Fort Lock Company
GRANIT, Abus
HY-MU, Carpenter Steel
INSITE, Medeco Security Electronics
INVINCEBBLE, Ingersoll
KESO, Sargent
KIMLOY, Kenametal
LASERPOINT, HPC
LOCKMASTERS, Lockmaster, Inc.
M3 (Medeco)
MAGNIFOCUSER, Endroy Products
MARLOK, Marlok Corporation
MAXALOY, Shwayder Safe
MAXI-MOGUL, Folger Adam
MEDECO, Medeco Lock
MOGUL, Folger Adam
NITROTEC, Fort Lock (Nitrotec Surface Engineering)
OMNILOCK, OSI Security
OPTIVISOR, Lockmasters
PLANET, Chubb Safe Company
PLUS, Abus
PRIME CUT, Broco
PRIMUS, Schlage
QUATTROCODE, Silca
READ-EZE, Lockmasters
RELSOM, Mosler
SAFELOK, Winfield
SAFE-SAVER, Lockmasters
SCHLAGE EVEREST (Ingersoll-Rand)
SPRAY-MENT, 3M
STRONG-ARM MINIRIG, Strong Arm (Commercial Security)
TENITE, Mosler
TUBAR, Chicago Lock
UGIMAG, Ikon, Germany
VING, TrioVing
VINGCARD, TrioVing
X-07, Mas Hamilton

MANUFCTURERS THAT WERE CITED OR REFERENCED IN THIS CD ROM

All companies are in the United States, unless otherwise indicated.

3M, Minnesota Mining and Manufacturing
ABA (Taiwan)
ABLOY (Finland)
ABUS (Germany)
AMERICAN LOCK
AMERICAN MAGNETICS
ANKERSLOT (Holland)
ASSA-RUKO (Sweden)
AZBE (Spain)
BILOCK (Australia)
BKS (Germany)
BKA (Germany)
BLUE GRASS
BOLLINI (Germany)
BORDOGNA (Italy)
BRIGGS & STRATTON
BROCO
B-SAFE COMPANY
BTV SAFE (Spain)
BURKEY (Germany)
CARD ACCESS
CARD KEY
CARPENTER STEEL
CAS (Italy)
CCL INDUSTRIES (Canada)
CES (Germany)
CHICAGO LOCK
CHINON
CHUBB (UK)
CHUBB UNION AND ELECTRO (UK)
CISA (Italy)
CLARK INSTRUMENTS
CODE LOCK
CODIC
COHU VIDEO
COMPUTERIZED SECURITY SYSTEMS
COOKSON SUPPLY (UK)
CORBIN
CORKEY (Hong Kong)
CURTIS
DEISTER (Germany)
DIEBOLD

DOM (Canada)
DOOR KING
DRUMM (Germany)
ELMO
ELSAFE (Norway)
EMI
ENDROY PRODUCTS
EURAND AMERICA
EVVA (Austria)
FALLE-SAFE SECURITY (Jersey)
FICHET (France)
FIMO (Germany)
FOLGER-ADAMS
FORD MOTOR COMPANY
FORT LOCK
GENERAL MOTORS
GESSWEIN
HANDY KEY
HIRSCH
HONDA
HPC, Inc.
HUFF (Germany)
HYPERTHERM
IDENTIX
IKON (Germany)
ILCO-UNICAN (Canada)
ILLINOIS LOCK
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INTER LOCK (Germany)
IOWA-AMERICAN CORPORATION
ISM (Israel)
ITO-KILIT (Turkey)
JIS (Spain)
KABA
KALE (Turkey)
KERR
KESO (Switzerland)
KEY CONTROL
KEY LEX
KNOX
KXL
LaGARD
LCA
LeFEBURE
LEXUS (Japan)
LINEAR

LITTON
LOCK DEFEAT TECHNOLOGY CORPORATION
LOCKMASTERS
LOCKNETICS
LORI
LUCAS ELECTRONICS, Inc.
MAGNUM
MARLOK
MAS-HAMILTON
MASTER LOCK COMPANY
MBA (MARK BATES ASSOCIATES)
MCM
MEDECO
MEDECO ELECTRONICS
MELSMETALL
MERCEDES-BENZ (Germany)
MITSUBISHI (Japan)
MIWA (Japan)
MOSLER
MOTTURA (Italy)
MULLER SAFE (Germany)
MUL-T-LOCK (Israel)
MUNCHENER RUCK RE-INSURANCE (Germany)
NAUTA (Holland)
OLYMPUS
OMEN SAFE (Israel)
OMNI-CONCEPTS
OPEX
OSI SECURITY
PALADIN PRESS
PANAVISE
PCSC PROPRIETARY CONTROLS
POLAROID
PRO-LOCK
R AND D TOOL CO.
RYTAN
S&G
SAFEMARK
SARGENT
SARGENT & GREENLEAF
SCHLAGE
SCHULTE-SCHLAGBAUM (Germany)
SEA (Switzerland)
SECURA-KEY
SECURITY 777
SENTRY

SHOWA (Japan)
SILCA (Italy)
SIMPLEX
SMART SAFE
SMART-TERM
STONE AND BERG
TESA (Spain)
TIMELOK AB (Sweden)
TOURI-SAFE
TRIOVING (Norway)
TUFLOC
UCON, Union Carbide
UNION (UK)
UNION CARBIDE
VACHETTE (France)
VAN LOCK
VIDEAOLARM
WALSALL
WATEC (Japan)
WEKA OXYLANCE
WENDT (Germany)
WINFIELD (MASCO CORPORATION)
WINKHAUS (Germany)
WINNER INTERNATIONAL CORPORATION
YALE
YARDENI (Israel)

43 (Popup - COVERT ENTRY TOOLS)
There are many vendors of covert entry tools throughout the world. However, only a very few have quality and selection for the professinal locksmith, safe technician, and government agency. The author specifically recommends the following vendors. This in no way minimizes the quality or value of products produced by other manufacturers.

FALLE-SAFE SECURITY
John Falle
Jersey, Channel Islands
+441534.280091
www.safeventures.com

SAFE VENTURES
Martin Newton, John Falle, Bennie Wells
United Kingdom
www.safeventures.com

MBA
Mark Bates
101 Edgewood Plaza Drive
Nicholasville, Kentucky 40356
1.888.MBA.5495
www.mbausa.com

HPC, INC.
3999 25th Avenue
Box 2093
Schiller Park, Illinois 60176
1.847.671.6280
www.hpcworld.com

LOCKMASTERS, INC.
5085 Danville Road
Nicholasville, Kentucky 40356
1.859.885.6041
www.lockmasters.com

44 (Popup - FORCED ENTRY TOOL VENDORS)

Several vendors for forced entry tools have been identified within this Infobase. The following manufacturers are recommended by the author, based upon the quality and diversity of their products.

MBA
Mark Bates
101 Edgewood Plaza Drive
Nicholasville, Kentucky 40356
1.888.MBA.5495
www.mbausa.com

HPC, INC.
3999 25th Avenue
Box 2093
Schiller Park, Illinois 60176
1.847.671.6280
www.hpcworld.com

SIGMA
David Nightingale
135 Snargate Street
Dover, Kent CT17 9DA
United Kingdom
+441304.205050

IOWA-AMERICAN
Industrial Park, Box 517
Osceola, Iowa 50213
1.515.342.6091

LOCKMASTERS, INC.
5085 Danville Road
Nicholasville, Kentucky 40356
1.859.885.6041
www.lockmasters.com

45 (Popup - SAFES AND VAULTS: REFERENCE WORKS)
A comprehensive bibliography appears within this Infobase. There are many other reference works that are available to the locksmith trade. These can be found at The **National Locksmith** Publishing Company, HPC, INC LEARNING CENTER, **LOCKMASTERS**, MBA, ALOA, and ASIS.

An extremely comprehensive set of drill-point diagrams for all major combination locks and safes is available from Ed Willis, through **MBA**.

46 (Popup - TRAINING AND SEMINARS)
Training and seminars in covert and forced entry are conducted for law enforcement, security, and intelligence agencies by the following organizations and individuals:

Marc Weber Tobias
INVESTIGATIVE LAW OFFICES and SECURITY LABORATORIES
300 S. Phillips, Suite 202
Sioux Falls, South Dakota 57104 United States
1.605.334.1155
mwtobias@security.org

John Falle
FALLE SAFE SECURITIES
Jersey, United Kingdom
+441534 280091

Mark Bates
MBA
101 Edgewood Plaza Drive
Nicholasville, Ky 40356

HPC LEARNING CENTER
3990 25th Avenue, Box 2093
Schiller Park, Illinois 60176

SIGMA
135 Snargate Street
Dover, Kent CT17 9DA
United Kingdom

LOCKMASTERS, INC.
5085 Danville Road
Nicholasville, Ky 40356

ALOA
3003 Live Oak Street
Dallas, Texas 75204

47 (Popup - SECURITY ANALYSIS OF PRODUCTS FOR BYPASS)

The author and associates routinely analyze locks, safes, and security systems for clients, manufacturers, and government agencies. If you have a need of such services, please contact the author at **Investigative Law Offices** at 1.605.334.1155, or by e-mail at mwtobias@security.org. Please view the detailed information about the author found at **www.security.org**, and within this Infobase.

48 (Popup - LEGAL SERVICES BY INVESTIGATIVE LAW OFFICES)

Legal services for locksmiths and manufacturers are provided by **Investigative Law Offices.** These relate to product analysis for defects and bypass techniques, product design, and security consultation. Please contact the author at mwtobias@security.org.

49 (Popup - HISTORICAL REFERENCE TO LOCKS)

There is an excellent treatment of the history of the first locks in the George Price book contained within this Infobase.

50 (Popup - WOLVERHAMPTON)



51 (Popup - ASSOCIATED LOCKSMITHS OF AMERICA)

Associated Locksmiths of America, Inc. (ALOA)
3003 Live Oak Street
Dallas, TX 75204

52 (Popup - CHANGE KEY SETS)

Change key sets are available from:

KEELER, INC.
12931 Shackelforfd Lane
Garden Grove, CA 92841
714 636 5657
www.safe@keelex.com

53 (Popup - HARDWARE SCHEDULE)

The information on the hardware schedule should include:

manufacturer
type of hardware
finish
size
location
keying schedule for each locking device

54 (Popup - LEVELS OF KEYING - STANDARD KEY CODING SYSTEM)
TWO LEVEL SYSTEM
Master key MK
Change key CK

THREE LEVEL SYSTEM
Grand master GMK
Master key MK
Change key CK

FOUR LEVEL SYSTEM
Great grand master key GGMK
Grand master key GMK
Master key MK
Change key CK

FIVE LEVEL SYSTEM
Great great grand master key GGGMK
Great grand master GGMK
Grand master GMK
Master key MK
Change key CK

SIX LEVEL SYSTEM
Great great grand master key GGGMK
Great grand master GGMK
Grand master GMK
Master key MK
Sub-master SMK
Change key CK

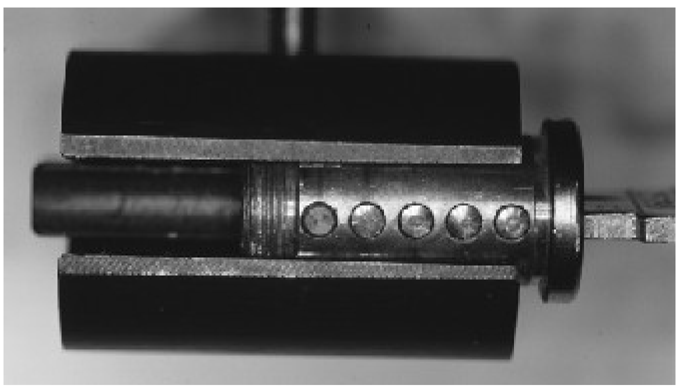
55 (Popup - US PATENT 2030837)
Page: 1,2,3,4

56 (Popup - FIGURE 4-3. HPC CODEMAX KEY MACHINE)
The HPC Codemax key machine is one of the most popular and versatile cutters on the market.



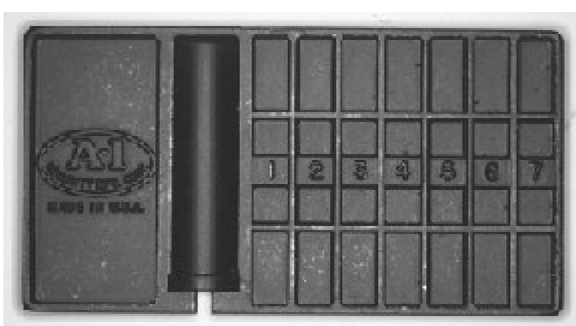
57 (Popup - FIGURE 4-5. PLUG HOLDER)

A plug holder retains the plug within a fixture during maintenance and pinning of the lock.



58 (Popup - FIGURE 4-6. SET-UP TRAY)

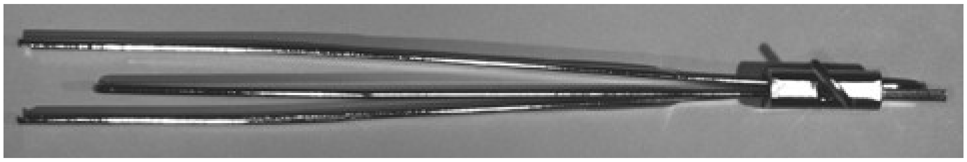
A setup tray is used to store all springs and pins during disassembly of a pin tumbler lock.



59 (Popup - FIGURE 4-7. TWEEZERS)

Special tweezers are utilized for the removal and insertion of pins within a cylinder. The type shown is produced by HPC, and

allows for the precise depression and control of an individual pin.



60 (Popup - US PATENT 1307379)
Page: 1,2,3,4
61 (Popup - US PATENT 6044672)
Page: 1,2,3,4,5
62 (Popup - US PATENT 5701773)
Page: 1,2,3,4,5,6,7
63 (Popup - US PATENT 4682398)
Page: 1,2,3,4,5
64 (Popup - US PATENT 4638567)
Page: 1,2,3,4,5,6
65 (Popup - US PATENT 4586233)
Page: 1,2,3,4,5
66 (Popup - US PATENT 5402661)
Page: 1,2,3,4
67 (Popup - US PATENT 5454245)
Page: 1,2,3,4,5,6
68 (Popup - US PATENT 4868409)
Page: 1,2,3,4,5,6,7,8
69 (Popup - BASIC OXYGEN FURNACE EXPLANATION)
In the basic oxygen process, the fuel is fed by a high-pressure stream of nearly pure oxygen blown into the furnace at supersonic speed. The oxygen combines with carbon and other unwanted elements and rapidly burns out impurities, converting the pig iron into steel.

70 (Popup - USE OF ELECTRIC ARC FURNACES)
In some furnaces, electricity instead of fire supplies the heat. Because refining conditions in such a furnace can be strictly regulated, electric furnaces are particularly valuable for producing steels that must be made to exacting specifications.

71 (Popup - DEFINITION OF ELEMENT)
element (èl´e-ment) noun

1. A fundamental, essential, or irreducible constituent of a composite entity.

2. elements. The basic assumptions or principles of a subject.

3. Chemistry & Physics. A substance composed of atoms having an identical number of protons in each nucleus. Elements cannot be reduced to simpler substances by normal chemical means.

4. One of four substances, earth, air, fire, or water, formerly regarded as a fundamental constituent of the universe.

[Middle English, from Old French, from Latin elementum.]

Synonyms: element, component, constituent, factor, ingredient. The central meaning shared by these nouns is "one of the individual parts of which a composite entity is made up."

72 (Popup - DEFINITION OF ATOM)

atomize

atomize (àt´e-mìz´) verb, transitive
atomized, atomizing, atomizes

1. To reduce to or separate into atoms.

2. To reduce to tiny particles or a fine spray.

3. To break into small fragments.

4. To subject to bombardment with atomic weapons.

- at´omiza´tion (-î-zâ´shen) noun

73 (Popup - DEFINITION OF COMPOUND)

compound (kòm-pound´, kem-, kòm´pound´) verb
compounded, compounding, compounds verb, transitive

1. To combine so as to form a whole; mix.

2. To produce or create by combining two or more ingredients or

parts: pharmacists compounding prescriptions.

verb, intransitive

1. To combine in or form a compound.

2. To come to terms; agree.

adjective (kòm´pound´, kòm-pound´, kem-)

1. Consisting of two or more substances, ingredients, elements, or parts.

2. Botany. Composed of more than one part.

noun (kòm´pound´)
Abbr. comp., cpd.

1. A combination of two or more elements or parts. See synonyms at mixture.

2. Chemistry. A pure, macroscopically homogeneous substance consisting of atoms or ions of two or more different elements in definite proportions that cannot be separated by physical means. A compound usually has properties unlike those of its constituent elements.

[Alteration of Middle English compounen, from Old French componre, compondre, to put together, from Latin componere. See component.]
- compound´able adjective
- compound´er noun

74 (Popup - DEFINITION OF MOLECULE)

molecule (mòl´î-ky¡l´) noun
Abbr. mol.

1. The smallest particle into which an element or a compound can be divided without changing its chemical and physical properties; a group of like or different atoms held together by chemical forces.

2. A small particle; a tiny bit.

[French molécule, from New Latin molêcula, diminutive of Latin molês, mass.]

75 (Popup - DEFINITION OF MIXTURE)

mixture (mîks´cher) noun

1. a. The act or process of mixing: an alloy made from the mixture of two metals. b. The condition of being mixed: the inevitable mixtures of urban neighborhoods.

2. Something produced by mixing.

3. Chemistry. A composition of two or more substances that are not chemically combined with each other and are capable of being separated.

[Middle English, from Old French, from Latin mixtúra, from mixtus, past participle of miscêre, to mix.]

Synonyms: mixture, blend, admixture, compound, composite, amalgam. These nouns refer to a combination produced by mixing. Mixture has the widest application: a mixture of tea and honey; yarn that is a mixture of nylon and cotton. "He showed a curious mixture of eagerness and terror" (Francis Parkman). Blend denotes an intimate, harmonious mixture in which the original components lose their distinctness: Admixture suggests that one of the components of the mixture is dissimilar to the others: The essential oil in the perfume contains a large admixture of alcohol.

A **compound** is a combination of elements or parts that together constitute a new and independent entity: The word houseboat is a compound. Creative genius is a compound made up of exceptional intellect and superior imagination. A **composite** usually lacks the unity of a compound since the components may not wholly lose their identities: The suite is a composite of themes for various parts of the opera. **Amalgam** implies an intimate union of diverse elements likened to an alloy of mercury and another metal.

76 (Popup - DEFINITION OF SOLUTE)

solute (sòl´y¡t, so´l¡t) noun

A substance dissolved in another substance, usually the component of a solution present in the lesser amount.

adjective
Being in solution; dissolved.

[From Middle English, loose, porous, from Latin solútus, past participle of solvere, to loosen.]

77 (Popup - DEFINITION OF SOLVENT)

solvent (sòl´vent, sôl´-) adjective

1. Capable of meeting financial obligations.

2. Chemistry. Capable of dissolving another substance.

noun

1. Chemistry. a. A substance in which another substance is dissolved, forming a solution. b. A substance, usually a liquid, capable of dissolving another substance.

2. Something that solves or explains.

[French, from Latin solvêns, solvent-, present participle of solvere, to loosen. See solve.]
- sol´vency noun

78 (Popup - DEFINITION OF SOLUTIONS)

Solutions, evenly distributed mixtures of two or more substances. The substance present in largest quantity is called the **solvent.** The substance in the smallest quantity is called the **solute.** Unlike colloids and suspensions, solutions appear the same throughout even under a microscope, and the solute cannot be separated by filtration. Salts, acids, and bases ionize when they are dissolved in water (see Ionization).

Certain metals are soluble in one another in the liquid state and solidify with the mixture of atoms preserved.

Some liquids can dissolve in each other in any proportion; others

have limits. If a solute added to a solution above a certain amount will not dissolve, the solution is called saturated. For most substances, solubility increases with increasing temperature of the solvent. In general, molecules that are structurally similar to the molecules of the solvent have the highest solubility.

When a solute is added to a solvent, several physical properties of the solvent change. Its boiling point rises and its freezing point lowers with increasing concentrations of solute.

79 (Popup - DEFINITION OF ALLOY)

alloy (àl´oi´, e-loi´) noun

1. A homogeneous mixture or solid solution of two or more metals, the atoms of one replacing or occupying interstitial positions between the atoms of the other: Brass is an alloy of copper and zinc.

2. A mixture; an amalgam: "Television news has . . . always been an alloy of journalism and show business" (Bill Moyers).

3.The relative degree of mixture with a base metal; fineness.
4.Something added that lowers value or purity.

verb, transitive
alloyed, alloying, alloys (e-loi´, àl´oi´)

1.To combine (metals) to form an alloy.

2.To combine; mix: idealism that was alloyed with political skill.

3.To debase by the addition of an inferior element.

[Alteration (influenced by French aloi), of obsolete allay, from Middle English alay, from Old North French allai, from allayer, to alloy, from Latin alligâre, to bind : ad-, ad- + ligâre, to bind.]

80 (Popup - DEFINITION OF CRYSTAL)

crystallize

crystallize also crystalize (krîs´te-lìz´) verb
crystallized also crystalized crystallizing crystalizing
crystallizes crystalizes verb, transitive

1. To cause to form crystals or assume a crystalline structure.

1. To assume a crystalline form.

2. To take on a definite, precise, and usually permanent form.
- crys´talliz´able adjective
- crys´talliza´tion (-lî-zâ´shen) noun
- crys´talliz´er noun

81 (Popup - DEFINITION OF ACICULAR)

acicular (e-sîk´ye-ler) adjective
Having the shape of a needle: acicular crystals.

82 (Popup - DEFINITION OF ALLOYING)

alloy (àl´oi´, e-loi´) noun

1.A homogeneous mixture or solid solution of two or more metals, the atoms of one replacing or occupying interstitial positions between the atoms of the other: Brass is an alloy of copper and zinc.

2. The relative degree of mixture with a base metal; fineness.

3. Something added that lowers value or purity.

verb, transitive
alloyed, alloying, alloys (e-loi´, àl´oi´)

1. To combine (metals) to form an alloy.

3. To debase by the addition of an inferior element.

[Alteration (influenced by French aloi), of obsolete allay, from Middle English alay, from Old North French allai, from allayer, to alloy, from Latin alligâre, to bind : ad-, ad- + ligâre, to bind.]

83 (Popup - TUNGSTEN)

Tungsten
element 74

84 (Popup - MOLYBDENUM)

Molybdenum
element 42

85 (Popup - COBALT)

Cobalt
element 27

86 (Popup - CARBON)

Carbon
element 6

87 (Popup - CHROMIUM)

Chromium
element 24

88 (Popup - VANADIUM)

Vanadium
element 23

89 (Popup - ELEMENTS USED TO ALTER THE CHARACTERISTICS OF METALS AND FOR THE PRODUCTION OF LOCKS AND SAFES)

Cobalt: used in superalloys for jet engines, chemicals (paint driers, catalysts, magnetic coatings), permanent magnets, and cemented carbides for cutting tools. More than 90% of the world's cobalt is produced in Canada, Finland, Norway, Russia, Zaire, and Zambia. The U.S. uses about one-third of total world consumption. Although its resources are relatively large, the U.S. has not produced cobalt since 1971; most U.S. cobalt resources are low grade, and production from these deposits is not economically feasible.

Columbium: used mostly as an additive in steelmaking and in superalloys. Brazil and Canada are the world's leading columbium raw materials (feedstock) producers. There is no U.S. columbium mining industry.

Copper: uses of copper in the U.S. are in building construction (42%), electrical and electronic products (24%), industrial machinery and equipment (13%), transportation (11%), and consumer and general products (10%). The leading producer is Chile, followed by the U.S., Canada, Russia, Australia, Zambia, Poland, and China. Principal mining states are Arizona, New Mexico, and Utah.

Gold: used in the U.S. in jewelry and the arts (70%), electronics and other industries (23%), and dentistry (7%). South Africa has about half the world's resources; significant quantities are also present in the U.S., Australia, Canada, the former Soviet Union, and Brazil. Gold is mined in nearly all the Western U.S. states and in Alaska.

Iron ore: the source of primary iron for the world's iron and steel industries. Major iron ore producers include Australia, Brazil, China, and the former Soviet Union.

Lead: the U.S., Australia, China, Peru, and Canada are the world's largest producers of lead. Transportation accounts for the major end use in the U.S., with 85% used in batteries, bearings, casting metals, and solders. Other uses include emergency power supply batteries, construction sheeting, sporting ammunition, and power cable coverings. The U.S. produces and consumes more than 20% of the world's lead metal.
Manganese: essential to iron and steel production. The U.S., Japan, and Western Europe have exhausted nearly all of their economically minable manganese. South Africa and the former Soviet Union have about 80% of the world's reserves.
Nickel: vital to the stainless steel industry; played a key role in the development of the chemical and aerospace industries. Leading producers include Russia, Canada, Australia, New Caledonia, and Indonesia.

Platinum-Group Metals: the platinum group consists of 6 closely related metals: platinum, palladium, rhodium, ruthenium, iridium, and osmium. They commonly occur together in nature and are among the scarcest of the metallic elements. They are consumed in the U.S. by the following industries: automotive, electrical and electronic, chemical, and dental and medical. The automotive, chemical, and petroleum-refining industries use platinum-group metals mainly as catalysts. The former Soviet Union and South Africa have nearly all the world's reserves.
Silver: used in the following U.S. industries: photography, electrical and electronic products, sterlingware, electroplated ware, and jewelry. Silver is mined in more than 60 countries. Nevada produces more than 50% of U.S. silver, Idaho 12%.
Tantalum: a refractory metal with unique electrical, chemical, and physical properties; used in the U.S. mostly to produce electronic components, mainly tantalum capacitors. Australia, Brazil, and Canada are the leading tantalum raw-material producers. There is no U.S. tantalum mining industry.
Titanium: as a metal, titanium is used mostly in commercial and

military aerospace applications. Titanium metal is produced primarily in China, Japan, Kazakstan, Russia, and the U.S.

Vanadium: used as an alloying element in steel and aerospace titanium alloys, as a catalyst in the production of maleic and phthalic anhydride, and in the production of sulfuric acid. China, South Africa, and Russia are the world's largest producers of vanadium-bearing ores and concentrates.

Zinc: used as a protective coating on steel, as diecastings, as an alloying metal with copper to make brass, and as a component of chemical compounds in rubber and paints. It is mined in more than 50 countries. Canada is the leading producer, followed by China, Australia, Peru, the U.S., and Mexico. In the U.S., mine production comes mostly from Alaska, Tennessee, New York, and Missouri.

90 (Popup - TENSILE STRENGTH)

tensile strength (noun)

strength: load-bearing capacity, tensile strength

91 (Popup - DEFINITION OF STRETCHING OR PULLING)

stretch (strèch) verb
stretched, stretching, stretches verb, transitive

1. To lengthen, widen, or distend: stretched the sweater out of shape.

2. To cause to extend from one place to another or across a given space: stretched the banner between two poles.

3. To make taut; tighten: stretched the tarpaulin until it ripped.

verb, intransitive

1. To become lengthened, widened, or distended.

2. To extend or reach over a distance or an area or in a given direction: "On both sides of us stretched the wet plain" (Ernest Hemingway).

noun

1. The act of stretching or the state of being stretched.

2. The extent or scope to which something can be stretched; elasticity.

[Middle English strecchen, from Old English streccan.]
- stretch´abil´ity noun
- stretch´able adjective

92 (Popup - DEFINITION OF COMPRESSION)

compress (kem-près´) verb, transitive
compressed, compressing, compresses

1. To press together: compressed her lips.

2. To make more compact by or as if by pressing. See synonyms at contract.

noun (kòm´près´)

1. A machine for compressing material.

[Middle English compressen, from Old French compresser, from Late Latin compressâre, frequentative of Latin comprimere : com-, com- + premere, to press.]

93 (Popup - DEFINITION OF SHEAR)

shear (shîr) verb
sheared, sheared or shorn (shôrn, shorn) shearing, shears verb, transitive

To cut with or as if with shears: shearing a hedge.

verb, intransitive
1. To use a cutting tool such as shears.

2. To move or proceed by or as if by cutting: shear through the wheat.

3. Physics. To become deformed by forces tending to produce a shearing strain.

noun

1. Physics. a. An applied force or system of forces that tends to produce a shearing strain. Also called shearing stress, shear stress. b. A shearing strain.

[Middle English scheren, from Old English sceran. N., from Middle English shere, from Old English scêar.]
- shear´er noun

94 (Popup - DEFINITION OF FATIGUE)

fatigue (fe-têg´) noun

1. Physical or mental weariness resulting from exertion.

2. The weakening or failure of a material, such as metal or wood, resulting from prolonged stress.

verb
fatigued, fatiguing, fatigues verb, transitive

1. To create fatigue in (a metal or other material).

[French, from Old French, from fatiguer, to fatigue, from Latin fatìgâre.]

95 (Popup - DEFINITION OF IMPACT)

impact (îm´pàkt´) noun

1. The striking of one body against another; collision.

2. The force or impetus transmitted by a collision.

3. The effect or impression of one thing on another: still gauging the impact of automation on the lives of factory workers.

verb
impacted, impacting, impacts (îm-pàkt´) verb, transitive

1. To pack firmly together.

2. To strike forcefully: meteorites impacting the lunar surface.

[From Latin impâctus, past participle of impingere, to push against. See impinge.]
- impac´tion noun

Synonyms: impact, repercussion. The central meaning shared by these nouns is "a strong effect exerted by one person or thing on another": the far-reaching impact of an oil embargo; a strike that had dire repercussions. See also synonyms at collision.

96 (Popup - DEFINITION OF FLEXURE OR BENDING)

flexure (flèk´sher) noun

1. A curve, turn, or fold, such as a bend in a tubular organ: a flexure of the colon.

2. The act or an instance of bending or flexing; flexion.
- flex´ural adjective

97 (Popup - DEFINITION OF TORSION OR TWISTING)

torsion (tôr´shen) noun

1.a. The act of twisting or turning. b. The condition of being twisted or turned.

2. The stress or deformation caused when one end of an object is twisted in one direction and the other end is held motionless or twisted in the opposite direction.

[Middle English torcion, wringing pain in the bowels, from Old French torsion, from Late Latin torsio, torsion-, a wringing pain, variant of Latin tortio, from tortus, past participle of torquêre, to twist. See torsade.]
- tor´sional adjective
- tor´sionally adverb

98 (Popup - DEFINITION OF DUCTILE)

ductile (dùk´tel, -tìl´) adjective

1. Easily drawn into wire or hammered thin: ductile metals.

2. Easily molded or shaped. See synonyms at malleable.

[Middle English ductil, from Old French, from Latin ductilis, from ductus, past participle of dúcere, to lead.]
- ductil´ity (-tîl´î-tê) or duc´tilibil´ity (-le-bîl´î-tê) noun

99 (Popup - DEFINITION OF BRITTLE)

brittle (brît´l) adjective
brittler, brittlest

1.a. Likely to break, snap, or crack, as when subjected to pressure: brittle bones. b. Easily disrupted: a brittle relationship between husband and wife. See synonyms at fragile.

[Middle English britel, probably from Old English *brytel, from bryttian, to shatter.]
- brit´tlely (brît´l-ê) adverb
- brit´tleness noun

100 (Popup - DEFINITION OF WEAR)

wear (wâr) verb
wore (wôr, wor) worn (wôrn, worn) wearing, wears verb, transitive

1. To damage, diminish, erode, or consume by long or hard use, attrition, or exposure. Often used with away, down, or off: rocks worn away by the sea; shoes worn down at the heels.

2. To produce by constant use, attrition, or exposure: eventually wore hollows in the stone steps.

3. To bring to a specified condition by long use or attrition: wore the clothes to rags; pebbles worn smooth.

verb, intransitive

1. To break down or diminish through use or attrition: The rear tires began to wear.

noun

1. Gradual impairment or diminution resulting from use or attrition.

2. The ability to withstand impairment from use or attrition: The engine has plenty of wear left.

- phrasal verb.
wear down

To break down or exhaust by relentless pressure or resistance.
wear off

To diminish gradually in effect: The drug wore off.
wear out

1. To make or become unusable through long or heavy use.

2. To use up or consume gradually.

3. To exhaust; tire.

[Middle English weren, from Old English werian.]
- wear´er noun

101 (Popup - DEFINITION OF CORROSION)

corrosive (ke-ro´sîv, -zîv) adjective

1. Having the capability or tendency to cause corrosion: a corrosive acid.

2. Gradually destructive; steadily harmful: corrosive anxiety; corrosive increases in prices; a corrosive narcotics trade.

noun

A substance having the capability or tendency to cause corrosion.
- corro´sively adverb

- corro´siveness noun

102 (Popup - DEFINITION OF VERDIGRIS)

verdigris (vûr´dî-grês´, -grîs´, -grê´) noun

1. A blue or green powder consisting of basic cupric acetate used as a paint pigment and fungicide.

2. A green patina or crust of copper sulfate or copper chloride formed on copper, brass, and bronze exposed to air or seawater for long periods of time.

[Middle English vertegrez, from Old French verte grez, alteration of vert-de-Grice : verd, green. See verdure + de, of (from Latin dê). See de- + Grice, Greece.]

103 (Popup - DEFINITION OF DEFORMATION)

deform (dî-fôrm´) verb
deformed, deforming, deforms verb, transitive

1. To spoil the natural form of; misshape: a body that had been deformed by disease.

2. Physics. To alter the shape of by pressure or stress.

verb, intransitive
To become deformed. See synonyms at distort.

[Middle English deformen, from Old French deformer, from Latin dêformâre : dê-, de- + forma, form.]
- deform´abil´ity noun
- deform´able adjective

104 (Popup - DEFINITION OF CLEAVAGE)

cleavage (klê´vîj) noun

1. The act of splitting or cleaving.

2. The state of being split or cleft; a fissure or division.

3. Mineralogy. The splitting or tendency to split of a crystallized substance along definite crystalline planes, yielding smooth surfaces.

105 (Popup - DEFINITION OF QUENCHING)

quench (kwènch) verb, transitive
quenched, quenching, quenches

1. To put out (a fire, for example); extinguish.

2. To cool (hot metal) by thrusting into water or other liquid.

[Middle English quenchen, from Old English âcwencan.]
- quench´able adjective
- quench´er noun
- quench´less adjective

106 (Popup - DEFINITION OF ANNEALING)

anneal (e-nêl´) verb
annealed, annealing, anneals verb, transitive

1. To subject (glass or metal) to a process of heating and slow cooling in order to toughen and reduce brittleness.

2. To strengthen or harden.

verb, intransitive

To become strengthened or hardened: "the time she needed for opinion to anneal around her policy" (Alexander M. Haig, Jr.).

[Middle English anelen, from Old English onælan, to set fire to : on, on. See on + ælan, to kindle.]

107 (Popup - DEFINITION OF NORMALIZING)

normal (nôr´mel) adjective

1. Abbr. n, N, n. Chemistry. a. Designating a solution having one gram equivalent weight of solute per liter of solution. b.

Designating an aliphatic hydrocarbon having a straight and unbranched chain of carbon atoms.

[Middle English, from Late Latin normâlis, from Latin, made according to the square, from norma, carpenter's square.]
- nor´mally adverb

108 (Popup - Popup)

temper (tèm´per) verb
tempered, tempering, tempers verb, transitive

2. To bring to a desired consistency, texture, hardness, or other physical condition by or as if by blending, admixing, or kneading: temper clay; paints that had been tempered with oil.

3. To harden or strengthen (metal or glass) by application of heat or by heating and cooling.

verb, intransitive
To be or become tempered.

noun

1. a. The condition of being tempered. b. The degree of hardness and elasticity of a metal, chiefly steel, achieved by tempering.

2. A modifying substance or agent added to something else.

[Middle English temperen, from Old English temprian, from Latin temperâre, probably from temper-, variant of tempor-, stem of tempus, time, season.]
- tem´perabil´ity noun
- tem´perable adjective
- tem´perer noun

109 (Popup - DEFINITION OF CARBURIZING)

carburize (kär´be-rìz´, -bye-) verb, transitive
carburized, carburizing, carburizes

1. To treat, combine, or impregnate with carbon, as when

casehardening steel.

2. To carburet.

[carbur(et) + -ize.]
- car´buriza´tion (-ber-î-zâ´shen, -byer-) noun

110 (Popup - DEFINITION OF CYANIDING)

cyanide (sì´e-nìd´) noun also cyanid (-nîd)

Any of various salts or esters of hydrogen cyanide containing a CN group, especially the extremely poisonous compounds potassium cyanide and sodium cyanide.

verb, transitive
cyanided, cyaniding, cyanides

1. To treat (a metal surface) with cyanide to produce a hard surface.

2. To treat (an ore) with cyanide to extract gold or silver.

111 (Popup - DEFINITION OF ANODIZING)

anodize (àn´e-dìz´) verb, transitive
anodized, anodizing, anodizes

To coat (a metallic surface) electrolytically with a protective or decorative oxide.

[anod(e) + -ize.]
- an´odiza´tion (-dî-zâ´shen) noun

112 (Popup - DEFINITION OF DIPPING)

dip (dîp) verb
dipped, dipping, dips verb, transitive

1. To plunge briefly into a liquid, as in order to wet, coat, or saturate.

2. To galvanize or plate (metal) by immersion.

verb, intransitive

1. To plunge into water or other liquid and come out quickly.

noun

1. A brief plunge or immersion, especially a quick swim.

2. A liquid into which something is dipped, as for dyeing or disinfecting.

[Middle English dippen, from Old English dyppan.]

113 (Popup - DEFINITION OF ELECTROPLATE)

electroplate (î-lèk´tre-plât´) verb, transitive
electroplated, electroplating, electroplates

To coat or cover with a thin layer of metal by electrodeposition.

114 (Popup - DEFINITION OF GALVANIZING)

galvanize (gàl´ve-nìz´) verb, transitive
galvanized, galvanizing, galvanizes

1. To stimulate or shock with an electric current.

2. To coat (iron or steel) with rust-resistant zinc.
- gal´vaniza´tion (-nî-zâ´shen) noun
- gal´vaniz´er noun

115 (Popup - DEFINITION OF BROACHING)

broach (broch) verb, transitive
broached, broaching, broaches

1. To pierce in order to draw off liquid: broach a keg of beer.

3. To draw off (a liquid) by piercing a hole in a cask or other container.

4. To shape or enlarge (a hole) with a tapered, serrated tool.

noun

1.a. A tapered, serrated tool used to shape or enlarge a hole. b. The hole made by such a tool.

[Middle English brochen, to pierce, probably from broche, pointed weapon or implement, from Old French, from Vulgar Latin *brocca, from Latin broccus, projecting.]
- broach´er noun

116 (Popup - DEFINITION OF EXTRUDING)

extrude (îk-str¡d´) verb
extruded, extruding, extrudes verb, transitive

1. To push or thrust out.

2. To shape (a plastic, for instance) by forcing it through a die.

verb, intransitive
To protrude or project.

[Latin extrúdere : ex-, ex- + trúdere, to thrust.]

117 (Popup - DEFINITION OF FORGING)

Forging, process of shaping iron and other metals by hammering or pressing them after softening them with heat. Forging techniques are useful because the metal can be given the desired form while the process improves the structure of the metal, particularly by refining the grain size. Forged metal is stronger and more ductile than cast metal, exhibiting greater resistance to fatigue and impact.

Hand Forging

Sometimes called smithing, or blacksmithing, hand forging is the simplest form of forging; it is one of the methods by which metal was first worked. The metal is heated to red heat in the fire and

then beaten into shape with hammers on a metal anvil. The forge consists of an open hearth, made of some durable, refractory substance such as firebrick and provided with a number of openings through which air is forced by a bellows or blower fan. Charcoal, coke, and coal are used as fuels.

Machine Forging

The chief difference between hand forging and machine forging is that in machine forging various types of machine-powered hammers or presses are used instead of hand hammers. These machines enable the operator to strike heavy blows with great rapidity and thus to produce forgings of large size and high quality as swiftly as required by modern production lines. Another advantage of machine forging is that the heavier the blows struck during forging, the greater the improvement in the quality of metallic structure.

118 (Popup - DEFINITION OF TURNING)

turning (tûr´nîng) noun

1. a. The shaping of metal or wood on a lathe. b. turnings. Shavings produced in shaping metal on a lathe.

119 (Popup - DEFINITION OF MILLING)

milling (mîl´îng) noun

1. The act or process of grinding, especially grinding grain into flour or meal.

2. The operation of cutting, shaping, finishing, or working products manufactured in a mill.

120 (Popup - DEFINITION OF DRILLING)

drill (drîl) noun

1.a. An implement with cutting edges or a pointed end for boring holes in hard materials, usually by a rotating abrasion or repeated blows; a bit. b. The hand-operated or hand-powered holder for this implement. c. A loud, harsh noise made by or as

if by a powered tool of this kind.

verb
drilled, drilling, drills verb, transitive

1.a. To make a hole in (a hard material) with a drill: a bit for drilling masonry. b. To make (a hole) with or as if with a drill: drills holes in trees with its chisellike bill.

verb, intransitive
1.To make a hole with or as if with a drill.

[Obsolete Dutch dril, from drillen, to bore, from Middle Dutch drillen.]
- drill´er noun

121 (Popup - US PATENT 4182947)
Page: 1,2,3,4,5,6,7,8,9

122 (Popup - US PATENT 4069407)
Page: 1,2,3,4,5

123 (Popup - US PATENT 6175638)
Page: 1,2,3,4,5,6,7

124 (Popup - US PATENT 1795318)
Page: 1,2,3,4,5

125 (Popup - US PATENT 709240)
Page: 1,2,3,4,5

126 (Popup - US PATENT 4638567)
Page: 1,2,3,4,5,6

127 (Popup - EASYENTRIE KEY MACHINE AVAILABILITY)
The Easy entrie is distributed in the United States by **Lockmasters** in Nicholasville, Kentucky.

128 (Popup - NEWTON'S LAWS OF MOTION)
Newton's Three Laws of Motion

Newton's first law of motion states that, if the vector sum of the forces acting on an object is zero, then the object will remain at rest or remain moving at constant velocity.

Newton's second law of motion states that a net force on an object will accelerate the object at a rate proportional to the strength of the force and in the same direction as the force.

Newton's third law of motion states that an object experiences a force because it is interacting with some other object, and that the force exerted by object 1 on object 2 must be equal to the force exerted by object 2 on object 1 but in the opposite direction.

Courtesy Encarta 1997.

129 (Popup - BEST LOCK CORP. V. ILCO UNICAN CORP.)
UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT
95-1528

BEST LOCK CORPORATION,

Plaintiff-Appellant,

v.

ILCO UNICAN CORPORATION,

Defendant-Appellee.

Appealed from: U.S. District Court for the Southern District of Indiana (Indianapolis)

Judge McKinney

United States Court of Appeals for the Federal Circuit
95-1528

BEST LOCK CORPORATION,

Plaintiff-Appellant,

v.

ILCO UNICAN CORPORATION,

Defendant-Appellee.

DECIDED: August 29, 1996

Before ARCHER, Chief Judge, NEWMAN and LOURIE, Circuit Judges.

Opinion for the court filed by Circuit Judge LOURIE. Dissenting

opinion filed by Circuit Judge NEWMAN.

LOURIE, Circuit Judge.

Best Lock Corporation appeals from the final decision of the United States District Court for the Southern District of Indiana in which the court held that Best Locks U.S. Design Patent 327,636 was invalid. Best Lock Corp. v. Ilco Unican Corp., 896 F. Supp. 836, 36 USPQ 2d 1527 (S.D. Ind. 1995). Because the court did not clearly err in finding that the claimed design was functional and hence not ornamental, we affirm.

BACKGROUND

This case involves a design patent for a key "blade." A typical key consists of a bow, which allows the user to turn the key in a corresponding lock, and a blade, which is the portion of the key inserted into the lock's keyway. When a key is manufactured, the key blade is "blank," i.e., the blade has not been cut or "bitted" with the combination required to operate the corresponding lock. Although a blank key blade will not operate the lock, the profile of the key blade is manufactured to fit into the corresponding lock's keyway. Subsequently, the blank key blade is cut to match the corresponding lock's combination.

In the replacement key market, a locksmith or a retail store with a key duplicating facility stocks blank key blades with various key profiles. The locksmith or retailer makes a replacement key by first selecting the appropriate blank key blade. This is done by matching the key blade profile with the corresponding lock keyway. Then, the locksmith or retailer cuts the blade of the key blank with the combination required to operate the lock.

Best Lock manufactures and sells locks and keys used to maintain security at industrial, commercial, and institutional facilities. At these facilities, it is often feared that the keys used in their locks may readily be duplicated. Consequently, key and lock manufacturers, including Best Lock, have attempted to restrict unauthorized access to duplicate key blanks by obtaining utility or design patent protection on the keys. By obtaining patent protection, a company hopes to control the market for duplicate key blanks during the life of the patent. 1

Best Lock is the assignee of the two patents that were at issue

before the district court, U.S. Patent 5,136,869 and U.S. Design Patent 327,636. The '869 patent, entitled "High Security Key and Cylinder Lock Assembly," claims an improved key blade and cylinder lock assembly that provides a wider key profile than standard keys and includes other features to deter lock picking. The '636 patent, entitled "Portion of a Key Blade Blank," claims the ornamental design for the operative portion of a key blade blank. In addition to the '636 design patent, Best Lock is the assignee of 33 other design patents on key blade designs. It also is the assignee of 34 design patents directed to keyways designed to mate with the key blades claimed in Best Lock's 34 key blade design patents. The '636 patent is the only design patent at issue on appeal. Figures 1-5 of the '636 design patent are shown below:

Ilco manufactures duplicate and replacement key blanks for existing locks. It sells its replacement key blanks to locksmiths and replacement key retailers. In 1993, Ilco copied the design of a Best Lock key, which had a key blade shaped like the design shown in the '636 patent. It subsequently distributed key blanks with that key blade shape at the annual convention of the Associated Locksmiths of America. In response, Best sued Ilco, alleging, inter alia, infringement of the '636 design patent and the '869 utility patent. Ilco counterclaimed, seeking a declaratory judgment of invalidity and noninfringement of both patents.

After a ten-day bench trial, the district court held that the '869 patent claims were invalid under 35 U.S.C. § 102 because the claims were anticipated by the prior art. Best Lock Corp. v. Ilco Unican Corp., 896 F. Supp. 836, 837, 36 USPQ2d 1527, 1528 (S.D. Ind. 1995). Best Lock has not appealed that holding. The court also held that the '636 design patent was invalid. In particular, the court found that Best Lock's key blades were not "a matter of ornamental concern to the purchaser or the user." Id. at 843, 36 USPQ2d at 1534. The court further found that the design patent was invalid because the shape of the blank key blade was dictated by its function. Id. Best Lock appeals, challenging the district court's decision regarding the '636 patent.

DISCUSSION

Under 35 U.S.C. § 171, a design patent may be granted for a "new, original and ornamental design for an article of manufacture." However, if the design claimed in a design patent is dictated

solely by the function of the article of manufacture, the patent is invalid because the design is not ornamental. See Bonito Boats, Inc. v. Thunder Craft Boats, Inc., 489 U.S. 141, 148, 9 USPQ2d 1847, 1851 (1989) ("To qualify for protection, a design must present an aesthetically pleasing appearance that is not dictated by function alone, and must satisfy the other criteria of patentability."); see also In re Carletti, 328 F.2d 1020, 1022, 140 USPQ 653, 654 (CCPA 1964) ("[I]t has long been settled that when a configuration is the result of functional considerations only, the resulting design is not patentable as an ornamental design for the simple reason that it is not 'ornamental'--was not created for the purpose of ornamenting."). A design is not dictated solely by its function when alternative designs for the article of manufacture are available. See L.A. Gear, Inc. v. Thom McAn Shoe Co., 988 F.2d 1117, 1123, 25 USPQ2d 1913, 1917 (Fed. Cir.), cert. denied, 114 S. Ct. 291 (1993). We review for clear error the district court's determination that the design claimed in the '636 patent is functional. See id. at 1124, 25 USPQ2d at 1917.

On appeal, Best Lock argues that the court erred in holding the '636 design patent invalid as being directed solely to a functional design. As support, it asserts that although a particular key and its corresponding lock must mate to operate the lock, an unlimited number of key blade and corresponding keyway designs are available. Choice of any particular design is arbitrary. Thus, Best Lock maintains that the key blade blank may have any number of different shapes and is therefore not dictated solely by functional concerns.

We disagree. The design shown in the claim of the '636 patent is limited to a blank key blade as shown in Figures 1-5 of the patent. Best Lock did not claim a design for the entire key. See 37 C.F.R. § 1.153 (1995) (The claim of a design patent "shall be in formal terms to the ornamental design for the article . . . as shown, or as shown and described.") (emphasis added). The parties do not dispute that the key blade must be designed as shown in order to perform its intended function--to fit into its corresponding lock's keyway. An attempt to create a key blade with a different design would necessarily fail because no alternative blank key blade would fit the corresponding lock. In fact, Best Lock admitted that no other shaped key blade would fit into the corresponding keyway, and it presented no evidence to the contrary. Therefore, we find no clear error in the court's finding that the claimed key blade design was dictated solely by the key blade's function. Any aesthetic appeal of the key blade

design shown in the '636 patent is the inevitable result of having a shape that is dictated solely by functional concerns.

Further, Best Lock's assertion that a variety of possible shapes of interfaces between keys and locks exists does not compel a different result. Clearly, different interfaces between key blades and corresponding lock keyways can be designed to permit the combination to function as a lock and key set. However, Best Lock's patent does not claim the combination of a lock and corresponding key. Instead, the claim in the '636 design patent is limited to a key blade, which must be designed as shown in the '636 patent in order to perform its intended function.

Moreover, the fact that Best Lock also has a design patent on the keyway that mates with the key blade shown in the '636 patent does not alter our analysis. The existence of a separate patent on the keyway is irrelevant to the construction of the '636 patent claim and to the ultimate determination that the claimed design is dictated solely by function. See Elmer v. ICC Fabricating, Inc., 67 F.3d 1571, 1577, 36 USPQ2d 1417, 1421 (Fed. Cir. 1995) (construing design patent as limited to the article of manufacture "as shown and described" in the patent). The validity of a patent must be evaluated based on what it claims rather than on the totality of the claims of multiple patents.

For the foregoing reasons, the district court's finding that the claimed design is solely governed by functional concerns is not clearly erroneous. Consequently, we affirm its resulting conclusion that the '636 patent is invalid under 35 U.S.C. § 171 for failure to satisfy the statute's ornamentality requirement.

AFFIRMED

NEWMAN, Circuit Judge, dissenting.

I respectfully dissent. The design of this key blade profile meets the statutory criteria of design patent subject matter. The design statute defines this subject matter as follows:

35 U.S.C. §171 Patents for designs

Whoever invents any new, original and ornamental design for an article of manufacture may obtain a patent therefore, subject to the conditions and requirements of this title.

The provisions of this title relating to patents for inventions shall apply to patents for designs, except as otherwise provided.

Whether the design of the D'636 patent is otherwise patentable, for example on the criteria of originality or non-obviousness, was not reached by the district court and is not before us. However, the panel majority has misapplied 35 U.S.C. §171 in holding that the arbitrary design of the key profile is "functional" because it mates with its matching keyway.

The design of the key profile is not removed from access to the design statute because the key fits a matching keyway. That two articles are designed in harmony does not deprive the design of access to the design patent law. The design of the key profile is not determined by the function of the key to fit the lock. In the case at bar there are said to be "thousands" of alternative key blade profiles.

The district court concluded that the design of the D'636 patent was not "a matter of ornamental concern to the purchaser or the user," and thus held that the design was functional. The statute requires that the subject of a design patent be an ornamental design of a useful object. However, "ornamental" does not always mean artistic or pleasing to the eye. The Court of Customs and Patent Appeals early recognized that "the beauty and ornamentation requisite in design patents is not confined to such as may be found in the `aesthetic or fine arts.'" In re Koehring, 37 F.2d 421, 422 (CCPA 1930).

Recognizing that ornamentation is in the eye of the beholder, the courts have sought a more objective standard in the general rule that a design is "ornamental" for purposes of 35 U.S.C. §171 when it is not primarily functional. See In re Carletti, 328 F.2d 1020, 140 USPQ 653 (CCPA 1964) ("To qualify for protection, a design must present an aesthetically pleasing appearance that is not dictated by function alone."). However, the article itself must have a utility in order for its design features to be patentable under 35 U.S.C. §171. See L.A. Gear, Inc. v. Thom McAn Shoe Co., 988 F.2d 1117, 1123, 25 USPQ2d 1913, 1917 (Fed. Cir.) ("A design patent is directed to the appearance of an article of manufacture. An article of manufacture necessarily serves a utilitarian purpose, and the design of a useful article is deemed to be functional when the appearance of the claimed design is `dictated by' the use or purpose of the article."), cert. denied, 510 U.S. 908 (1993).

If the design is dictated by the function performed by the article of manufacture, the design is not patentable. Power Controls Corp. v. Hybrinetics, Inc., 806 F.2d 234, 238, 231 USPQ 774, 777 (Fed. Cir. 1986). See Bonito Boats, Inc. v. Thunder Craft Boats, Inc., 489 U.S. 141, 148, 9 USPQ2d 1847, 1851 (1989) ("To qualify for protection, a design must present an aesthetically pleasing appearance that is not dictated by function alone, and must satisfy the other criteria of patentability."). A design is "not dictated by function alone" when there are alternative designs or configurations available for the article of manufacture, as in the case before us.

The legal principles governing design patents have their foundation in the important decision of Gorham Co. v. White, 81 U.S. (14 Wall.) 511 (1871), wherein the Supreme Court explained:

The appearance may be the result of peculiarity of configuration, or of ornament alone, or of both conjointly, but, in whatever way produced, it is the new thing, or product, which the patent law regards.

81 U.S. at 525. Courts have measured the term "ornamental" by the non-functionality that distinguishes the subject of a design patent from a utility patent, while recognizing that the design of a useful article is not insulated from the utility of the article. A review of patentable designs in general illustrates the mixture of functional and non-functional features embraced in the patented design. See, e.g., Winner Int'l Corp. v. Wolo Mfg. Corp., 905 F.2d 375, 15 USPQ2d 1076 (Fed. Cir. 1990) (design of steering wheel lock); Lee v. Dayton-Hudson Corp., 838 F.2d 1186, 5 USPQ2d 1625 (Fed. Cir. 1988) (design patent for massage device); FMC Corp. v. Hennessy Indus., Inc., 836 F.2d 521, 5 USPQ2d 1272 (Fed. Cir. 1987) (design patent for changer for tubeless tires); Unette Corp. v. Unit Pack Co., 785 F.2d 1026, 228 USPQ 933 (Fed. Cir. 1986) (container for dispensing liquids); In re Igarashi, 228 USPQ 463 (Bd. Pat. App. & Interf. 1985) (tire tread design); Trans-World Mfg. Corp. v. Al Nyman & Sons, Inc., 750 F.2d 1552, 224 USPQ 259 (Fed. Cir. 1984) (design for eyeglass display rack).

An effective design patent law must recognize the distinction between functionality of the article and of the particular design of the article or features thereof. See L.A. Gear, supra, (the sneaker tongue, moustache, delta wing, and side mesh, were useful parts of the sneaker, but the overall design of these features

and the shoe was not dictated by function alone). This interaction of form and function does not remove the design from the statutory scope of the design patent law, or defeat the statutory patentability of a primarily non-functional design - although it is not always easy to draw a bright line between the functionality of an article and its design, as discussed by J.H. Reichman, Design Protection and the New Technologies: The United States Experience in a Transnational Perspective, 19 Balt. L. Rev. 6 (1989), for design patents often appear on quite mundane articles of manufacture. See, e.g., Tone Bros., Inc. v. Sysco Corp., 28 F.3d 1192, 31 USPQ2d 1321 (Fed. Cir. 1994) (bottle for spices); In re Klein, 987 F.2d 1569, 26 USPQ2d 1133 (Fed. Cir. 1993) (roof or siding shingle); KeyStone Retaining Wall Sys., Inc. v. Westrock, Inc., 997 F.2d 1444, 27 USPQ2d 1297 (Fed. Cir. 1993) (concrete block for retaining wall); In re Webb, 916 F.2d 1553, 16 USPQ2d 1433 (Fed. Cir. 1990) (femoral hip stem prosthesis); In re Cho, 813 F.2d 378, 1 USPQ2d 1662 (Fed. Cir. 1987) (bottle cap); Pacific Furniture Mfg. Co. v. Preview Furniture Corp., 800 F.2d 1111, 231 USPQ 67 (Fed. Cir. 1986) (upholstered armchair); Litton Sys., Inc. v. Whirlpool Corp., 728 F.2d 1423, 221 USPQ 97 (Fed. Cir. 1984) (microwave oven); In re Koehring, 37 F.2d 421 (CCPA 1930) (concrete mixing truck).

The design of the key blade profile is primarily non-functional, as the Patent and Trademark Office recognized in granting the patent in suit. The Manual of Patent Examining Procedure defines "design" as follows for purposes of §171:

The design of an object consists of the visual characteristics or aspects displayed by the object. It is the appearance presented by the object which creates a visual impact upon the mind of the observer.

Since a design is manifested in appearance, the subject matter of a design patent application may relate to the configuration or shape of an object, to the surface ornamentation on an object, or both.

Design is inseparable from the object to which it is applied and cannot exist alone merely as a scheme of surface ornamentation. It must be a definite, preconceived thing, capable of reproduction and not merely the chance result of a method.

MPEP §1502 (6th ed. 1995). See also 1 D. Chisum, Patents §1.04[2][a] (1996) ("[A] design rests on appearance created by the configuration of the article, surface ornamentation, or a

combination of configuration and ornamentation.") (footnote omitted).

The parties to this litigation agree that there are myriad possible designs of key profiles. All keys require, of course, mating keyways. In holding that because the key must fit a keyway, the abstract design of the key profile is converted to one solely of function, the court creates an exception to design patent subject matter. An arbitrary design of a useful article is not statutorily excluded from §171 simply because in use it interacts with an article of complementary design. Although precedent is sparse, it is contrary to this holding. In Motorola Inc. v. Alexander Mfg. Co., 786 F. Supp. 808, 21 USPQ2d 1573 (N.D. Iowa 1991), the only United States case on this point of which we are aware, the court considered a design patent for a battery housing intended for use in a portable phone. Since the battery housing had to fit into the phone and a battery charger, the accused infringer argued that this function dictated the design. The court disagreed:

The design of the battery housing was not dictated by the design of the battery charger because the charger did not exist when the housing was designed. The design of the phone was done concurrently with the battery housing. Therefore, the design of the battery housing cannot fairly be said to have been "dictated" by the design of the phone.

Id. at 812, 21 USPQ2d at 1557. This reasoning is equally apt in this case. The design of the key profile was not dictated by the design of the keyway, and indeed the two share the same arbitrary design.

In sum, the fact that the key blade is the mate of a keyway does not convert the arbitrary key profile into a primarily functional design. It is not the design of the key profile that is functional, but the key itself. Thus I must, respectfully, dissent from the ruling of the panel majority that the design of the key blade profile is not patentable because the key blade requires a mating keyway.

Footnotes

1 Key and lock manufacturers also use other methods to restrict access to duplicate key blanks. For example, some manufacturers limit the sale of a particular type of lock and key to a single

customer or particular geographic region, thereby making consumer demand for replacement keys for that particular lock design so small that replacement key manufacturers have no incentive to manufacture duplicate key blanks.

2 As our predecessor court previously held, "a design for an article of manufacture may be embodied in less than all of an article of manufacture. . . ." In re Zahn, 617 F.2d 261, 267, 204 USPQ 988, 994 (CCPA 1980).

As our predecessor court previously held, "a design for an article of manufacture may be embodied in less than all of an article of manufacture. . . ." In re Zahn, 617 F.2d 261, 267, 204 USPQ 988, 994 (CCPA 1980).

130 (Popup - US PATENT 4,966,021)
Page: 1,2,3,4,5,6,7,8,9,10,11
131 (Popup - US PATENT 4409807)
Page: 1,2,3,4
132 (Popup - STANDARD KEY CODING SYSTEM)
A, AA, AA1, 1AA..: Symbols for different levels of keying
A1, B1: A change key under the grand master key only
A1A, A1B..: In a system with a large number of master keys, each group may be named following this sequence. A1A, A1B, A1C...A2A, A2B, A2C...This becomes relevant when there are more than 22 master keys in the system. Alternative numbering may then be implemented.

AA1/AA12: This identifier would indicate a double cylinder with each lock keyed differently. AA1 would indicate the outside lock; AA12 the inside cylinder

BM: Block master key
CK: Change key
CMK: Construction master key
EMK: Emergency master key
ENG: Engineer key
GGGMK: Great great great grand master key
GGM: Great grand master key
GGMK: Great grand master key
GGM1: A change key directly under a great grand master key
GM: Grand master key
GMK: Grand master key
HGM: Horizontal group master key

HKP: Housekeeping master key
I: Do not use in standard key coding system to document a keying system
k: Key
KA: Key alike
KA1, KA2...Keyed alike group. This coding indicates that all cylinders in this string are to be operated by the same key or keys.
KA/2, KA/3...Indicates that the quantity of locks is keyed alike in groups.
KBA: Key bitting array
KD: Keyed different
KR: Keyed random, or key retaining, depending upon context.
KWY: Keyway
MK: Master key
NCK: No change key
NKR: Non key retaining
NMK: Not master keyed but part of system. Example: 1AA(NMK). The combination for a NMK lock is part of the progression for the master key system, but is not keyed to any master key level. In contrast, the SKD is simply a lock with a single key combination, such as a pharmacy, weapons or explosives vault or evidence room. The single keyed lock combination is generated as part of a system progression but is not related to any lock within the system. The KBA is utilized to generate the bitting code to prevent key interchange.

O: Do not use in standard key coding system to document a keying system
Q: Do not use in standard key coding system to document a keying system

RM: Row master key
SKD: Single keyed
SMK: Sub master key
TMK: Top level master key
VGM: Vertical group master key
VKC: Visual key control
X: Symbol that designates cross-keyed condition for a particular lock. Do not ever use as a master key symbol

X1X: Symbol that denotes a cross-keyed cylinder with no dedicated change key of its own

133 (Popup - SKCS RULES)

The coding scheme of keys that enable the specification of keying levels adhere to certain rules. Note that the system defines keys and how they are related to each other, but not how many locks are in the system.

General Rules

- coding begins at the lowest keying level;
- key symbols identify the lowest level key that will operate the lock and which is associated with all locks above it. Thus, AB5 is a change key that is part of a keying level that includes AB, A, and the TMK.

· never use the letters I, O, Q for defining keys, because they can be confused with 1 and 0;

· levels of keying can be bypassed or eliminated. For example, a five level system may require that certain change keys be associated directly with a GGGMK, and that there are no master keys under the GGGMK.

Rules for master and change keys

Master Keys

- master key coding always uses pairs of two identical letters (AA, BB);
- grand master keys are always identified by a single letter (never X);
- numbering for master key levels are assigned in a defined sequence or progression: AB, where A = the grand master key and B = master key. The lettering for the master key runs from A, alphabetically;

· the top level master key is noted as TMK, regardless of how many levels there are in the system. Thus, the TMK can be a master key in a two level system, a grand master key in a three level system, etc.;

· the term "sub-master key" is not used until the sixth keying level;

Change Keys

· change key coding always uses letters and numbers such as AA1, BA17;

· change keys are derived from the master key designators to which they are associated. The first letter of all associated keys, from the grand master to the change key, is the same. The second letter of the master key definition remains with the associated change key;

· change keys that are not associated with a master key level directly above it, but with a higher level are coded to that level. For example, in a four level system, a change key directly associated with the GGM would be coded GGM1. Likewise, a change key associated only with the grand master would be coded A1;

· certain locks may be single keyed (SKD), meaning that they are not associated with any other level of keying. They would be identified as SKD-1, SKD-2...In other systems, a change keyed cylinder may be part of the overall keying scheme, but not master keyed. It will then be designated by (NMK) in parenthesis after the key sumbol. Thus, AB28(NMK) would indicate that the lock is set to AB45, but will not be operated by any level of master key.

Rules for levels of keying for change keys

- for two levels of coding, use numbers (first) then letters (1AA, 2AA...) Thus, the key that is identified as 53AA would indicate a two level system, master key AA, change key 53 that is associated with that master key;

- for three or more levels of keying, change key numbers follow letters, thus AA1, AA2...;

134 (Popup - DOOR AND HARDWARE INSTITUTE)

Door and Hardware Institute
14170 Newbrook Drive
Chantilly, Virginia 22021-2223
703-222-2010

DHI publishes three technical references that you should be familiar with:

Abbreviations and Symbols used in Architectural Door and Hardware Schedules and Specifications. An on-line glossary of terms is

available.

Sequence and Formats for the Hardware Schedule

Basic Architectural Hardware

135 (Popup - MACS FOR SPECIFIC LOCK MANUFACTURERS)

MACS VIOLATION TABLE						
MANUFACTURER	DEPTH INCREMENT	SHALLOW TO DEEP	FORBIDDEN ADJACENT CUTS	MACS OR MOCS	CUTTER ANGLE	OTHER INFORMATION
ASSA TWIN and 600	.6mm/.0236"	9-1	17,18,19,28,29,39	5	90	single step tip to bow
ASSA 500/700	.5mm/.01975"	8-1	not for MK system	4	104	tip to bow
ASSA 500/700	.7mm/.0276"	7-1	16,17,27	4	104	single step tip to bow
ARROW (non-IC)	.014"	0-9	08,09,19	7 (8 if needed)	96	two step
BEST A2	.0125"	0-9		9	90	two step
BEST A3	.018"	0-6		6	90	single step
BEST A4	.021"	0-5		5	90	single step ****This is an exception to minimum depth increment rules**
CORBIN SYSTEM 70	.028	1-6	16	4	90	single step
CORBIN PRE SYSTEM 70	.014	1-0	10	8	90	two step

DEXTER	.015	0-9	08,09,19	7	90	two step
FALCON WEISER	.018	0-9	07,08,09,1819,29, also avoid 717,828.939	6	90	two step
LORI 80	.018	1-9	18,19,29	6	90	two step
KABA GEMINI	.0138	4-1	none	3		
KABA PEAKS 150	.0125	0-9	none	9	90	two step
KABA PEAKS 140	.0125	0-9	09	8	90	two step
KWIKSET	.023	1-7	16,17,27	4	90	single step
MEDECO ORIGINAL	.030	1-6	16,515,626	4	86	single step
MEDECO ORIGINAL	.015	0-X	09,90,0X,X01X,X1	8	86	two step
MEDECO BIAXIAL	.025	1-6	2 if FORE follows AFT 3 if FORE TO FORE, or AFT TO AFT 4 if AFT follows FORE	VARIES	86	bow to tip single step
RUSSWIN SYSTEM 70	.028	1-6	16	4	90	single step

RUSSWIN D H K & N MULTIPLEXES	.015	0-9	09	8	90	two step
RUSSWIN 752, A MULTIPLEX	.020	0-6	06	5	90	single step
SARGENT	.020	1-0	19,10,20	7	78	two step
SCHLAGE	.015	0-9	08,09,19	7	100	two step
YALE	.019	0-9	MACS=5 06,07,08,09,17,18,1928,29,39 MACS=6 07,08,09,1819,29	5 or 6	95 FOR MACS 5 86 FOR MACS 6	two step
YALE	.025	0-7	MACS=4 05,06,07,1617,27 MARC=5 06,07,17	4 or 5	95 for MACS 4 86 for MACS 5	single step

136 (Popup - TMK REGISTER CONTENTS)
The TMK register should contain the following information to insure proper system security for all clients and to avoid potential liability upon the part of the locksmith.

- **Register number**
- **Location**
- **File number**
- **Manufacturer**
- **Key section**
- **TMK bitting**
- **Parity pattern or angles**
- **Details and notes, to include the following:**

- **who installed the system**
- **factory derived system**
- **system inherited from another locksmith**
- **inventory information regarding cut and blank keys**
- **system changes**
- **specific authorization instructions**
- **use of OEM blanks required**
- **refer to bitting list**

137 (Popup - MAXIMUM ADJACENT CUT SPECIFICATIONS)

MACS is different for each manufacturer, and specifies the maximum vertical distance between adjacent cuts. Schlage, for example, sets a MACS of 7, which signifies that the difference between cuts cannot exceed this number. Thus, a 9 and a 2 cut can be next to each other, but a 9 and a 1 cut would violate the rule because the difference is 8. MACS prevent steep ramp angles which can lead to erratic operation of keys and improper seating of tumblers within a root that is too narrow.

138 (Popup - CROSS-KEYING TABLE FOR A CYLINDER WITH FIVE MASTER PINS)

The following combinations will open this lock:

258307 258327 258107 258127
250307 250327 250107 250127
218307 218327 218107 218127
210307 210327 210107 210127
058307 058327 058107 058127
050307 050327 050107 050127
018307 018327 018107 018127
010307 010327 010107 010127

139 (Popup - US PATENT 414,720)

Page: 1,2,3,4

140 (Popup - US PATENT 3206958)

Page: 1,2,3

141 (Popup - US PATENT 3206959)

Page: 1,2,3

142 (Popup - US PATENT 3603123)

Page: 1,2,3

143 (Popup - US PATENT 4386510)

Page: 1,2,3

144 (Popup - US PATENT 4444034)

Page: 1,2,3,4,5,6

145 (Popup - US PATENT 3738136)

Page: 1,2,3,4,5,6
208 (Popup - GB PATENT 2214226A)
Page: 1,2,3,4
209 (Popup - US PATENT 3633393)
Page: 1,2,3,4,5,6
210 (Popup - US PATENT 5355701)
Page: 1,2,3,4,5,6,7,8,9,10,
11,12,13,14,15,16,17,18,19,20
211 (Popup - GB PATENT 2252356A)
Page: 1,2,3,4,5,6,7,8,9,
10,11,12,13,14,15,
16,17,18
212 (Popup - GB PATENT 2273128A)
Page: 1,2,3,4,5,6,7,8,9,
10,11,12,13,14,15,
16,17,18
213 (Popup - WO PATENT 88/03594)
Page: 1,2,3,4,5,6,7,8,9,
10,11,12,13,14,15,
16,17,18,19,20,
214 (Popup - US PATENT 4549176)
Page: 1,2,3,4,5,6,7,8,9,
10
215 (Popup - US PATENT 4602253)
Page: 1,2,3,4,5,6,7,8,9
216 (Popup - US PATENT 5003801)
Page: 1,2,3,4,5
217 (Popup - GB PATENT 2174452A)
Page: 1,2,3,4,5,6,7,8
218 (Popup - US PATENT 4,149,394)
Page: 1,2,3,4,5,6,7
219 (Popup - US PATENT 5355701)
Page: 1,2,3,4,5,6,7,8,9,10,
11,12,13,14,15,16,17,18,19,20
220 (Popup - US PATENT 4,069,694)
Page: 1,2,3,4,5,6,7,8,9,10
221 (Popup - US PATENT 4,966,021)
Page: 1,2,3,4,5,6,7,8,9,10,11
222 (Popup - US PATENT 4,376,382)
Page: 1,2,3,4,5,6,7,8
223 (Popup - BEST REMOVABLE CORE SPECIFICATIONS FOR A2, A3, AND A4 LOCKS)
The **A2** series is the most popular, and has been copied by a number of other manufacturers. There are ten depths (0-9) with a

spacing of .0125", and a MACS of 9. A two-step progression is utilized for master keying, with a cutting angle of 90 degrees. There are no forbidden adjacent bittings.

The **A3** series allows seven depths (0-6), with a spacing of .018", and a MACS of 6. This lock utilizes a single step progression even though the .023" rule is violated, and a 90 degree cutting angle. There are no forbidden adjacent bitting patterns.

The **A4** series allows for six depths (0-5) with a spacing of of .021", and a MACS of 5. Single step progression is utilized for master keying, although it violates the .023" rule. A 90 degree cutting angle is utilized. There are no forbidden adjacent bittings.

224 (Popup - US PATENT 4462230)

Page: 1,2,3,4,5,6,7,8

225 (Popup - INSTAKEY MEASUREMENT)

SMALL FORMAT INTERCHANGEABLE CORE

FALCON, BEST, and ARROW measure from tip to bow. See the Instakey website for full specifications. The measurement for IC is from tip to leading the center of each cut.

226 (Popup - US PATENT 5109684)

Page: 1,2,3,4,5,6

227 (Popup - US PATENT 3983724)

Page: 1,2,3,4,5

228 (Popup - US PATENT2852928)

Page: 1,2,3,4,5

229 (Popup - US PATENT 3533253)

Page: 1,2,3,4,5,6,7,8,9

230 (Popup - US PATENT 2814940)

Page: 1,2,3,4,5,6,7,8,9

231 (Popup - US PATENT 2830447)

Page: 1,2,3,4,5,6

232 (Popup - US PATENT 4404823)

Page: 1,2,3,4,5,6,7,8

233 (Popup - US PATENT 5083122)

Page: 1,2,3,4,5,6,7,8,9,
10,11,12,13

234 (Popup - US PATENT 3868838)

Page: 1,2,3,4,5,6

235 (Popup - US PATENT 3330141)

Page: 1,2,3,4,5

236 (Popup - US PATENT 1899739)

Page: 1,2,3,4,5,6,7

237 (Popup - US PATENT 1863525)

Page: 1,2,3,4,5,6,7

238 (Popup - US PATENT 4375159)

Page: 1,2,3,4,5,6,7,8,9,10,11

239 (Popup - INTERNATIONAL ASSOCIATION OF INVESTIGATIVE LOCKSMITHS)

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Contact: Don Shiles
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240 (Popup - BIBLIOGRAPHY)

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241 (Popup - International Association of Investigative Locksmiths, Inc.)
The I.A.I.L. has adopted the following code of ethics for its members.

CODE OF ETHICS

Each member by their acceptance of membership in the International Association of Investigative Locksmiths, Inc. shall subscribe to the following Code of Ethics.

1. To pursue their professional work in the spirit of fairness to their clients, with fidelity to security in conformance with appropriateness, and with high ideals of personal honor.

2. To properly and impartially analyze examine examine material which is entrusted to their custody. To conduct themselves in a dignified manner at all times; to avoid using any improper or questionable methods of soliciting professional work.

4. To refrain from associating themselves with or allowing the use of their name by any enterprise of questionable character, or in any manner countenancing misrepresentation.

5. To cooperate with other investigative locksmiths through the

interchange of general information and experience.

6. To cooperate with local law enforcement officials and insurance investigators in all matters relating to the cases that they are working on, and to diligently pursue the education of the consumer in relation to their security.

7. To encourage and promote loyalty for the investigative locksmith profession and interest themselves in public welfare, always ready to apply their special knowledge, skill and training to enhance the security of the public.

8. To consistently abide by all applicable licensing and business regulations.

Adopted: October 7, 1999 by Board Resolution, International Association of Investigative Locksmiths, Inc.

242 (Popup - NOTES TO RULE 702)
HISTORY: (Jan. 2, 1975, P.L. 93-595, § 1, 88 Stat. 1937.)

Notes of Advisory Committee on Rules.

An intelligent evaluation of facts is often difficult or impossible without the application of some scientific, technical, or other specialized knowledge. The most common source of this knowledge is the expert witness, although there are other techniques for supplying it.

Most of the literature assumes that experts testify only in the form of opinions. The assumption is logically unfounded. The rule accordingly recognizes that an expert on the stand may give a dissertation or exposition of scientific or other principles relevant to the case, leaving the trier of fact to apply them to the facts. Since much of the criticism of expert testimony has centered upon the hypothetical question, it seems wise to recognize that opinions are not indispensable and to encourage the use of expert testimony in non-opinion form when counsel believes the trier can itself draw the requisite inference. The use of opinions is not abolished by the rule, however. It will continue to be permissible for the experts to take the further step of suggesting the inference which should be drawn from applying the specialized knowledge to the facts. See Rules 703 to 705 .

Whether the situation is a proper one for the use of expert

testimony is to be determined on the basis of assisting the trier. "There is no more certain test for determining when experts may be used than the common sense inquiry whether the untrained layman would be qualified to determine intelligently and to the best possible degree the particular issue without enlightenment from those having a specialized understanding of the subject involved in the dispute." Ladd, Expert Testimony, 5 Vand.L.Rev. 414, 418 (1952). When opinions are excluded, it is because they are unhelpful and therefore superfluous and a waste of time. 7 Wigmore § 1918.

The rule is broadly phrased. The fields of knowledge which may be drawn upon are not limited merely to the "scientific" and "technical" but extend to all "specialized" knowledge. Similarly, the expert is viewed, not in a narrow sense, but as a person qualified by "knowledge, skill, experience, training or education." Thus within the scope of the rule are not only experts in the strictest sense of the word, e.g., physicians, physicists, and architects, but also the large group sometimes called "skilled" witnesses, such as bankers or landowners testifying to land values.

Preliminary draft of proposed amendments.

The Committee on Rules of Practice and Procedure of the Judicial Conference of the United States proposed the following amendment of Rule 702, dated August 15, 1991:

Testimony providing scientific, technical, or other specialized information, in the form of an opinion or otherwise, may be permitted only if (1) the information is reasonably reliable and will substantially assist the trier of fact to understand the evidence or to determine a fact in issue and (2) the witness is qualified as an expert by knowledge, skill, experience, training, or education to provide such testimony. Except with leave of court for good cause shown, the witness shall not testify on direct examination in any civil action to any opinion or inference, or reason or basis therefore, that has not been seasonably disclosed as required by Rules 26(a)(2) and 26(e)(1) of the Federal Rules of Civil Procedure.

Committee notes.

This revision is intended to limit the use, but increase the utility and reliability, of party-initiated opinion testimony bearing on scientific and technical issues.

The use of such testimony has greatly increased since enactment of the Federal Rules of Evidence. This result was intended by the drafters of the rule, who were responding to concerns that the restraints previously imposed on expert testimony were artificial and an impediment to the illumination of technical issues in dispute. See, e.g., McCormick on Evidence , § 203(3d ed., 1984). While much expert testimony now presented is illuminating and useful, much is not. Virtually all is expensive, if not to the proponent then to adversaries. Particularly in civil litigation with high financial stakes, large expenditures for marginally useful expert testimony has become commonplace. Procurement of expert testimony is occasionally used as a trial technique to wear down adversaries. In short, while testimony from experts may be desirable if not crucial in many cases, excesses cannot be doubted and should be curtailed.

While concern for the quality and even integrity of hired testimony is not new, Winans v. New York & Erie R.R., 62 U.S. 88, 101 (1858); Hand, Historical and Practical Considerations Regarding Expert Testimony, 15 Harv. L. Rev. 40 (1901), the hazards to the judicial process have increased as more technical evidence is presented:

When the evidence relates to highly technical matters and each side has shopped for experts favorable to its position, it is naive to expect the jury to be capable of assessing the validity of dramatically opposed testimony.

3J. WEINSTEIN & M. BERGER, WEINSTEIN'S EVIDENCE, § 706[01] at 706-07(1985).

While the admissibility of such evidence is, and remains, subject to the general principles of Rule 403 , the revision requires that expert testimony be "reasonably reliable" and "substantially assist" the fact-finder. The rule does not mandate a return to the strictures of Frye v. United States, 293 F.2d 1013 (D.C. Cir., 1923) (requiring general acceptance of the scientific premises on which the testimony is based). However, the court is called upon to reject testimony that is based upon premises lacking any significant support and acceptance within the scientific community, or that otherwise would be only marginally helpful to the fact-finder. In civil cases the court is authorized and expected under revised Rule 26(c)(4) of the Federal Rules of Civil Procedure to impose in advance of trial appropriate restrictions on the use of expert testimony. In

exercising this responsibility, the court should not only consider the potential admissibility of the testimony under Rule 702 but also weigh the need and utility of the testimony against the time and expense involved.

In deciding whether the opinion evidence is reasonably reliable and will substantially assist the trier of fact, as well as in deciding whether the proposed witness has sufficient expertise to express such opinions, the court, as under present Rule 702, is governed by Rule 104(a) .

The rule is also revised to complement changes in the Federal Rules of Civil Procedure requiring pretrial disclosure of the expert testimony to be presented at trial. The rule precludes the offering on direct examination in civil actions of expert opinions, or the reasons or bases for opinions, that have not been adequately and timely disclosed in advance of trial. It has not been unusual for the testimony given at trial by an expert to vary substantially from that provided under former Fed. R. Civ. P. 26(b)(4)(A)(i) or at a deposition of the expert. At a minimum, any significant changes in an expert's expected testimony should be disclosed before trial, and this revision of Rule 702 provides an appropriate incentive for such disclosure in addition to those contained in the Rules of Civil Procedure.

Additions or other changes to an expert's opinions must, under Fed. R. Civ. P. 26(e)(1), be disclosed no later than the time the proponent is required to disclose its witnesses and exhibits that are to be used at trial. Unless the court has specified another time, these revisions must be disclosed at least 30 days before trial.

Of course, a witness should not be required to testify contrary to the person's oath or affirmation. If the witness is unable, consistent with the oath or affirmation, to testify in a manner consistent with the earlier disclosure, then--unless the court grants leave to deviate from the earlier testimony--the witness should not testify.

By its terms the new sentence applies only in civil cases. The consequences of the failure to make disclosures of expert testimony which may be required under new Fed. R. Crim. P. 16(a)(1)(E) and 16(b)(1)(C) will be determined in accordance with the principles that govern enforcement of the requirements of Fed. R. Crim. P. 16.

243 (Popup - NOTES ON FEDERAL RULE 703)
HISTORY: (Jan. 2, 1975, P.L. 93-595, § 1, 88 Stat. 1937; Mar. 2, 1987, eff. Oct. 1, 1987.)

Notes of Advisory Committee on Rules.

Facts or data upon which expert opinions are based may, under the rule, be derived from three possible sources. The first is the firsthand observation of the witness, with opinions based thereon traditionally allowed. A treating physician affords an example. Rheingold, The Basis of Medical Testimony, 15 Vand.L.Rev. 473, 489 (1962). Whether he must first relate his observations is treated in Rule 705 . The second source, presentation at the trial, also reflects existing practice. The technique may be the familiar hypothetical question or having the expert attend the trial and hear the testimony establishing the facts. Problems of determining what testimony the expert relied upon, when the latter technique is employed and the testimony is in conflict, may be resolved by resort to Rule 705 . The third source contemplated by the rule consists of presentation of data to the expert outside of court and other than by his own perception. In this respect the rule is designed to broaden the basis for expert opinions beyond that current in many jurisdictions and to bring the judicial practice into line with the practice of the experts themselves when not in court. Thus a physician in his own practice bases his diagnosis on information from numerous sources and of considerable variety, including statements by patients and relatives, reports and opinions from nurses, technicians and other doctors, hospital records, and X rays. Most of them are admissible in evidence, but only with the expenditure of substantial time in producing and examining various authenticating witnesses. The physician makes life-and-death decisions in reliance upon them. His validation, expertly performed and subject to cross-examination, ought to suffice for judicial purposes. Rheingold, supra, at 531; McCormick § 15. A similar provision is California Evidence Code § 801(b).

The rule also offers a more satisfactory basis for ruling upon the admissibility of public opinion poll evidence. Attention is directed to the validity of the techniques employed rather than to relatively fruitless inquiries whether hearsay is involved. See Judge Feinberg's careful analysis in Zippo Mfg. Co. v. Rogers Imports, Inc., 216 F.Supp. 670 (S.D.N.Y. 1963) See also Blum et al, The Art of Opinion Research: A Lawyer's Appraisal of an Emerging Service, 24 U.Chi.L.Rev. 1 (1956); Bonynge, Trademark Surveys and Techniques and Their Use in Litigation, 48 A.B.A.J.

329 (1962); Zeisel, The Uniqueness of Survey Evidence, 45 Cornell L.Q. 322 (1960); Annot., 76 A.L.R.2d 919.

If it be feared that enlargement of permissible data may tend to break down the rules of exclusion unduly, notice should be taken that the rule requires that the facts or data "be of a type reasonably relied upon by experts in the particular field." The language would not warrant admitting in evidence the opinion of an "accidentologist" as to the point of impact in an automobile collision based on statements of bystanders, since this requirement is not satisfied. See Comment, Cal.Law Rev.Comm'n, Recommendation Proposing an Evidence Code 148-150 (1965).

Notes of Advisory Committee on 1987 amendments to Rules.

The amendment is technical. No substantive change is intended.

244 (Popup - NOTES ON RULE 704)
HISTORY: (Jan. 2, 1975, P.L. 93-595, § 1, 88 Stat. 1937; Oct. 12, 1984, P.L. 98-473, Title II, Ch IV, § 406, 98 Stat. 2067.)

AMENDMENTS:

1984. Act Oct. 12, 1984 substituted this rule for one which read: "Testimony in the form of an opinion or inference otherwise admissible is not objectionable because it embraces an ultimate issue to be decided by the trier of fact."

Notes of Advisory Committee on Rules.

The basic approach to opinions, lay and expert, in these rules is to admit them when helpful to the trier of fact. In order to render this approach fully effective and to allay any doubt on the subject, the so-called "ultimate issue" rule is specifically abolished by the instant rule.

The older cases often contained strictures against allowing witnesses to express opinions upon ultimate issues, as a particular aspect of the rule against opinions. The rule was unduly restrictive, difficult of application, and generally served only to deprive the trier of fact of useful information. 7 Wigmore §§ 1920, 1921; McCormick § 12. The basis usually assigned for the rule, to prevent the witness from "usurping the province of the jury," is aptly characterized as "empty rhetoric." 7 Wigmore § 1920, p. 17. Efforts to meet the felt needs of particular situations led to odd verbal circumlocutions which

were said not to violate the rule. Thus a witness could express his estimate of the criminal responsibility of an accused in terms of sanity or insanity, but not in terms of ability to tell right from wrong or other more modern standard. And in cases of medical causation, witnesses were sometimes required to couch their opinions in cautious phrases of "might or could," rather than "did," though the result was to deprive many opinions of the positiveness to which they were entitled, accompanied by the hazard of a ruling of insufficiency to support a verdict. In other instances the rule was simply disregarded, and, as concessions to need, opinions were allowed upon such matters as intoxication, speed, handwriting, and value, although more precise coincidence with an ultimate issue would scarcely be possible.

Many modern decisions illustrate the trend to abandon the rule completely. People v. Wilson, 25 Cal.2d 341, 153 P.2d 720 (1944), whether abortion necessary to save life of patient; Clifford-Jacobs Forging Co. v. Industrial Comm., 19 Ill.2d 236, 166 N.E.2d 582 (1960), medical causation; Dowling v. L. H. Shattuck, Inc., 91 N.H. 234, 17 A.2d 529 (1941), proper method of shoring ditch; Schweiger v. Solbeck, 191 Or. 454, 230 P.2d 195 (1951), cause of landslide. In each instance the opinion was allowed.

The abolition of the ultimate issue rule does not lower the bars so as to admit all opinions. Under Rules 701 and 702 , opinions must be helpful to the trier of fact, and Rule 403 provides for exclusion of evidence which wastes time. These provisions afford ample assurances against the admission of opinions which would merely tell the jury what result to reach, somewhat in the manner of the oath-helpers of an earlier day. They also stand ready to exclude opinions phrased in terms of inadequately explored legal criteria. Thus the question, "Did T have capacity to make a will?" would be excluded, while the question, "Did T have sufficient mental capacity to know the nature and extent of his property and the natural objects of his bounty and to formulate a rational scheme of distribution?" would be allowed. McCormick § 12.

For similar provisions see Uniform Rule 56(4); California Evidence Code § 805; Kansas Code of Civil Procedures § 60-456(d); New Jersey Evidence Rule 56(3).

245 (Popup - NOTES ON RULE 705)
HISTORY: (Jan. 2, 1975, P.L. 93-595, § 1, 88 Stat. 1938; Mar. 2,

1987, eff. Oct. 1, 1987.) (Amended Dec. 1, 1993.)

Notes of Advisory Committee on Rules.

The hypothetical question has been the target of a great deal of criticism as encouraging partisan bias, affording an opportunity for summing up in the middle of the case, and as complex and time consuming. Ladd, Expert Testimony, 5 Vand.L.Rev. 414, 426-427 (1952). While the rule allows counsel to make disclosure of the underlying facts or data as a preliminary to the giving of an expert opinion, if he chooses, the instances in which he is required to do so are reduced. This is true whether the expert bases his opinion on data furnished him at secondhand or observed by him at firsthand.

The elimination of the requirement of preliminary disclosure at the trial of underlying facts or data has a long background of support. In 1937 the Commissioners on Uniform State Laws incorporated a provision to this effect in the Model Expert Testimony Act, which furnished the basis for Uniform Rules 57 and 58. Rule 4515, N.Y. CPLR (McKinney 1963), provides: "

Unless the court orders otherwise, questions calling for the opinion of an expert witness need not be hypothetical in form, and the witness may state his opinion and reasons without first specifying the data upon which it is based. Upon cross-examination, he may be required to specify the data . . .,".

See also California Evidence Code § 802; Kansas Code of Civil Procedure §§ 60-456, 60-457; New Jersey Evidence Rules 57, 58.

If the objection is made that leaving it to the cross-examiner to bring out the supporting data is essentially unfair, the answer is that he is under no compulsion to bring out any facts or data except those unfavorable to the opinion. The answer assumes that the cross-examiner has the advance knowledge which is essential for effective cross-examination. This advance knowledge has been afforded, though imperfectly, by the traditional foundation requirement. Rule 26(b)(4) of the Rules of Civil Procedure, as revised, provides for substantial discovery in this area, obviating in large measure the obstacles which have been raised in some instances to discovery of findings, underlying data, and even the identity of the experts. Friedenthal, Discovery and Use of an Adverse Party's Expert Information, 14 Stan.L.Rev. 455 (1962).

These safeguards are reinforced by the discretionary power of the judge to require preliminary disclosure in any event.

Notes of Advisory Committee on 1987 amendments to Rules.

The amendment is technical. No substantive change is intended.

Notes of Advisory Committee on 1993 amendments to Rules.

This rule, which relates to the manner of presenting testimony at trial, is revised to avoid an arguable conflict with revised Rules 26(a)(2)(B) and 26(a)(1) of the Federal Rules of Civil Procedure or with revised Rule 16 of the Federal Rules of Criminal Procedure, which require disclosure in advance of trial of the basis and reasons for an expert's opinions.

If a serious question is raised under Rule 702 or 703 as to the admissibility of expert testimony, disclosure of the underlying facts or data on which opinions are based may, of course, be needed by the court before deciding whether, and to what extent, the person should be allowed to testify. This rule does not preclude such an inquiry.

246 (Popup - HANS MEJLSHEDE REPORT)

On May 23, 1998, our locksmith Ole Mejlshede collected a cylinder for a door lock at above mentioned address. The cylinder and the key are shown on photo 454.01. In a larger scale the key is shown on photo 454 two and the face of the cylinder on photo 454 three. The cylinder is a Ruko type 5201 as is used for Ruko's program of rim locks. It is an older type, the age is estimated to 15-20 years. The key profile is Ruko's universal keyway, where there is no key control. The key is not one of the originals. It is a copy made on an aluminum blank.

Most locksmiths consider this type of cylinder as easy to pick, but all picking tools, when used, leave marks on the inner part of the cylinder, marks that are easy to trace in a microscope. In this cylinder there is an enormous amount of marks. In photo 454.04, the two first pins are shown from the tip, and on 454.05 from the side. These marks have NOT been made with a picking tool, but most likely with a smaller screwdriver. If the marks have been made in an attempt to open the lock, then the individual who made them hasn't got the slightest idea of lock

picking.

However, this doesn't conclude the finding. Photo 454.06 shows the two last pins of the cylinder. On these pins, there are clear marks from a pick gun, but the marks are not new. They are more likely 1-2 years old. This is seen on the oxidation of the marks, and of the wear that the key has produced over the marks.

In this case, we haven't dismounted the cylinder ourselves. For that reason, we can't be certain that the lock has functioned correctly, at the time of entry. Upon collection of the cylinder, we noticed a letter slot in the door. Coupled with the fact that the lock has a thumb turn on the inside makes it possible to use a "jimmy" to open the lock through the letter slot. This method of opening the door is virtually unknown to burglars in Denmark, so the probability it has been used is very little. However, we can't exclude it, and it is often not possible to trace.

Summary: The cylinder has some bruises, but it is very unlikely that it has been opened with any picking tool within the last year. The cylinder has been picked prior to this. The lock could have been opened with a "jimmy", but since the method is almost unknown, the probability for this is little.

Note by Author: this case suggests the probability that a simulated burglary may have been the cause of the marks on the first two pins. This is a common practice with lay persons who are not familar with lock picking procedures, and attempt to create the impressin of a burglary.

247 (Popup - ASSOCIATED LOCKSMITHS OF AMERICA)

ALOA
3003 Live Oak Street
Dallas, TX 75204.

248 (Popup - ARTICLE BY: ARTHUR R. PAHOLKE)

Page: 1,2,3

249 (Popup - ARTICLE BY: ARTHUR R. PAHOLKE AND WILLIAM SHERLOCK)

Page: 1,2,3,4

250 (Popup - ARTICLE BY: JAMES H. GLAZIER)

Page: 1,2,3,4,5,6

251 (Popup - ARTICLE BY: JAMES H. GLAZIER)

Page: 1,2,3,4

252 (Popup - ARTICLE BY: JAMES H. GLAZIER)

Page: 1,2,3,4,5,6,7

253 (Popup - ARTICLE BY: JAMES H. GLAZIER)

Page: 1,2,3,4

254 (Popup - ARTICLE BY: JAMES H. GLAZIER)

Page: 1,2,3,4,5

255 (Popup - STUDY BY W.G. PLUMTREE REGARDING THE ANALYSIS OF PIN TUMBLER LOCKS)

In 1975, **Plumtree** published the results of extensive **tests** that he performed on disc and pin tumbler cylinders in an effort to identify pick marks. He tested 300 pin tumbler cylinders, 225 disc tumbler cylindrs, 20 pin tumbler plugs, and 15 disc tumbler plugs. The lock components were all examined with a variable power microscope (X8 to X30). The following results were reported by Plumtree:

"Marks produced by a key (wear mark(s) on the tumblers of a cylinder appear as a single large wear area on the face of each tumbler. The wear marks are more pronounced on the pins near the front of the lock cylinder and become less pronounced toward the rear."

"There are no obvious striated or impression marks on the tumblers of cylinders that have only been operated by the proper key. Tumblers from a cylinder that have been manipulated with a hook or rake pick have striated marks on each tumbler. Tumblers that have been manipulated with a bounce pick have impression marks."

Source: **"The Examination of Disc and Pin Tumbler Locks for Tool Marks Made by Lock Picks,"** W.G. Plumtree, M.S. published in Forensic Sciences, American Acadmey of Forensic Sciences, Vol. 20, No.4, 10/1975, pp. 656-667.

256 (Popup - NOTE REGARDING SPRINGS)

Spring condition was varried to determine if erroneous readings would be obtained due to the position of each disc within its chamber.

257 (Popup - American Academy of Forensic Sciences references)

"The Examination of Disc and Pin Tumbler Locks for Tool Marks made by Lock Picks," W.G. Plumtree, M.S. published in Forensic Sciences, Vol 20, No.4, 10/1975, pp. 656-667.

258 (Popup - General References for Forensic Examination)

Locks, Safes, and Security (First Edition), M.W.Tobias, Thomas, Springfield, 1971, pp. 130-158.

Methods of Obtaining Locked Evidence, A.G. Bausch and M.L. Singer, Ninth Naval Intelligence Office, U.S. Navy, Washington, D.C. pp. 2-15.

"An Introduction to Tool Marks, Firearms and the Striagraph,", John E. Davis, Criminalist in Charge, Oakland Polie Department, Oakland, CA. Member, IAI, Copyright 1958, Library of Congress 57-12543.

"All Too Often Things Are Not What They Appear To Be,", A.R. Paholke, Newsletter of AFTE No. 10, October 1970, p.50.

"Are You Sure It Happened This Way," Keynotes (ALOA), June, 1991, pp. 24-25, 30, 38, 39.

259 (Popup - US PATENT 1667223)
Page: 1,2,3
260 (Popup - US PATENT 1639919)
Page: 1,2,3,4
261 (Popup - US PATENT 1450435)
Page: 1,2,3,4
262 (Popup - US PATENT 1403753)
Page: 1,2,3,4
263 (Popup - US PATENT 1944006)
Page: 1,2,3,4
264 (Popup - US PATENT 2309677)
Page: 1,2,3,4
265 (Popup - US PATENT 2565254)
Page: 1,2,3,4
266 (Popup - US PATENT 1977362)
Page: 1,2,3
267 (Popup - US PATENT 1944006)
Page: 1,2,3,4
268 (Popup - US PATENT 2565254)
Page: 1,2,3,4
269 (Popup - US PATENT 2309677)
Page: 1,2,3,4
270 (Popup - US PATENT 3264908)
Page: 1,2,3
271 (Popup - US PATENT 4156375)
Page: 1,2,3,4,5,6
272 (Popup - US PATENT 2064818)
Page: 1,2,3
273 (Popup - US PATENT 4186577)
Page: 1,2,3,4,5
274 (Popup - US PATENT 4006613)
Page: 1,2,3,4,5,6,7
275 (Popup - US PATENT 6082159)

Page: 1,2,3,4,5,6,7,8,9

334 (Popup - US PATENT 3985010)

Page: 1,2,3,4,5,6,7

335 (Popup - US PATENT 3987654)

Page: 1,2,3,4,5,6,7,8,9,10,11

336 (Popup - US PATENT 3985010)

Page: 1,2,3,4,5,6,7

337 (Popup - US PATENT 3987654)

Page: 1,2,3,4,5,6,7,8,9,10,11

338 (Popup - POTENTIAL SECURITY ISSUE WITH MEDECO BIAXIAL LOCK)

There is a potential problem with the design of the Biaxial regarding the actual numbers of differs that may be available, and the ability to impression the lock. It appears from preliminary tests that a key having a specific combination may very well open the lock with a different keying combination, much like cross-keying. In fact, a key with a depth code and fore or aft pin location may also open a different depth and fore or aft code. This results from the design of the lock and the lifting of pins at different points on their bitting ramps. The result is the reduction in security of the lock. Medeco should be consulted for the actual number of differs available within the Biaxial system, because it is believed that the published number is far greater than the actual number of useable combinations.

339 (Popup - US PATENT 2070342)

Page: 1,2,3

340 (Popup - US PATENT 2655808)

Page: 1,2,3,4

341 (Popup - US PATENT 3251206)

Page: 1,2,3

342 (Popup - US PATENT 4094176)

Page: 1,2,3,4,5,6,7,8,9

343 (Popup - US PATENT 4617813)

Page: 1,2,3,4,5,6,7,8,9,
10

344 (Popup - EXTRAPOLATION OF THE TOP LEVEL MASTER KEY)

The author has chosen to define the derivation of the bitting values of the TMK with the term **"extrapolation."** This denotes a process of decoding the individual pin stacks for master pins by using the change key as the standard for comparison.

345 (Popup - LOWER PINS)

The author uses the term "lower pin" to denote all pins in the pin stack, including bottom pin and master pin.

346 (Popup - VISUAL KEY CONTROL DEFINITION)

Visual key control is a specification that all keys and the visible front portion of any cylinder be identified with standard keying symbols.

347 (Popup - TPP SYSTEM)

Strictly speaking, all positions must be progressed in a total position progression system. That is why the distinction is drawn between TPP and PPP systems in this text.

348 (Popup - MEDECO CAM LOCK)

Medeco utilizes what can be called virtual master pins in the cam lock, but they still can be decoded.

349 (Popup - ASSA SIDEBAR CODING NOMENCLATURE)

Assa indicates left and right contact points with finger pins by writing the depth values as two digit numbers for each position.

350 (Popup - ASSA NOMENCLATURE FOR V10 SIDEBAR CODING)

The author utilizes the _underscore to indicate the inactive side milling for each position. Thus, _5_5 would denote that a Right contact finger pin with a depth of 5 was used in the first and second position.

351 (Popup - LEGALLY PROTECTED BLANKS)

The reader is cautioned that the use of profile milling machines for the duplication of legally protected blanks may constitute a federal offense. The reader should make their own determination as to their authority to replicate such blanks or secondary protective mechanisms. The infringement of patented keyways is not recommended, encouraged, or suggested by the author. Each agency must make their own assessment of the necessity and approval for such action.

352 (Popup - US PATENT 5355701)

Page: 1,2,3,4,5,6,7,8,9,10,
11,12,13,14,15,16,17,18,19,20

353 (Popup - US PATENT 4229959)

Page: 1,2,3,4,5,6,7,8,9

354 (Popup - US PATENT 3087050)

Page: 1,2,3,4

355 (Popup - US PATENT 5987946)

Page: 1,2,3,4,5,6,7,8,9

356 (Popup - US PATENT 6151936)

Page: 1,2,3,4,5,6,7,8,9,
10,11

357 (Popup - US PATENT 2713225)

Page: 1,2,3,4,5,6,7

358 (Popup - PETERSON MANUFACTURING COMPANY)

Box 744
East Rochester, NY 14445

359 (Popup - US PATENT 7918)
Page: 1,2
360 (Popup - BROCO, INC.)
BROCO, INC.
8690 Red Oak Street
Rancho Cucamonga, California 91730-4819
Tel: 909.483.3222 or 800.845.7259
Facsimile: 909.483.3233
E-mail: broco@worldnet.att.net
See **www.brocoinc.com**
361 (Popup - US PATENT 4069407)
Page: 1,2,3,4,5
362 (Popup - US PATENT 4182947)
Page: 1,2,3,4,5,6,7,8,9
363 (Popup - US PATENT 6044672)
Page: 1,2,3,4,5
364 (Popup - US PATENT 5701773)
Page: 1,2,3,4,5,6,7
365 (Popup - US PATENT 5402661)
Page: 1,2,3,4
366 (Popup - US PATENT 4586233)
Page: 1,2,3,4,5
367 (Popup - US PATENT 4682398)
Page: 1,2,3,4,5
368 (Popup - US PATENT 5540121)
Page: 1,2,3,4,5,6
369 (Popup - US PATENT 5237613)
Page: 1,2,3,4,5,6,7,8
370 (Popup - US PATENT 4266488)
Page: 1,2,3,4,5,6,7
371 (Popup - US PATENT 4470275)
Page: 1,2,3,4
372 (Popup - UK PATENT 2172931A)
Page: 1
373 (Popup - GB PATENT 2241983A)
Page: 1
374 (Popup - GB PATENT 2119011A)
Page: 1,2
375 (Popup - GB PATENT 2069589A)
Page: 1
376 (Popup - FIRE PROOF SAFES)
For an excellent discussion regarding the early development of fireproof safes, see Price, **Chapter 6**.

403 (Popup - 18 USC 2332a WEAPONS OF MASS DESTRUCTION and DESTRUCTIVE DEVICES)

The term "weapon of mass destruction" as extracted from 18 USC § 2332a and § 921 means

Any destructive device as defined (§ 921) below:

a. The term "destructive device" which means:

(1) any explosive, incendiary, or poison gas;

(2) bomb;

(3) grenade;

(4) rocket having a propellant charge of more than four ounces;

(5) missile having an explosive or incendiary charge of more than one-quarter

ounce;

(6) mine; or

(7) similar devices as described in section 921.

(8) The term "destructive device" shall not include:

(a) Any device which is neither designed or redesigned for use as a weapon;

(b) Any device, although originally designed for use as a weapon, which is redesigned for use as a signaling, pyrotechnic, line throwing, safety or similar device;

(c) Surplus ordnance sold, loaned, or given by the Secretary of

the Army pursuant to the provisions of section 4684 (2), 4685, or 4686 of title 10; or

(d) Any other device which Secretary of the Treasury finds not likely to be used as a weapon is an antique, or is rifle which the owner intends to use solely for sporting, recreational or cultural purposes.

b. Any type of weapon (other than a shotgun or a shotgun shell which the Secretary [Secretary of Treasury or his delegate] finds is generally recog-nized as particularly suitable for sporting purposes) by whatever name known which will, or which may be readily converted to, expel a projectile by the action of an explosive or other propellant, and which has any barrel with a bore of more than one-half inch in diameter; and

c. Any combination of parts either designed or intended for use in converting any device into any destructive device described in paragraphs a and b, above from which a destructive device may be readily assembled.

d. Any weapon that is designed or intended to cause death or serious bodily injury through the release, dissemination or impact of toxic or poisonous chemicals or their precursors;

e. Any weapon involving a disease or organism or;

f. Any weapon that is designed to release radiation or radioactivity at a level dangerous to human life.

404 (Popup - 18 USC 831 EXPLOSIVES AND OTHER DANGEROUS ARTICLES)
§ 831. Prohibited transactions involving nuclear materials

(a) Whoever, if one of the circumstances described in subsection (c) of this

section occurs—

(1) without lawful authority, intentionally receives, possesses, uses, transfers, alters, disposes of, or disperses any nuclear material or nuclear byproduct material and—

(A) thereby knowingly causes the death of or serious bodily

injury to any person or substantial damage to property or to the environ-ment; or

(B) circumstances exist, or have been represented to the defendant to exist, that are likely to cause the death or serious bodily injury to any person, or substantial damage to property or to the envi-ronment;

(2) with intent to deprive another of nuclear material or nuclear byproduct material knowingly—

(A) takes and carries away nuclear material or nuclear byproduct material of another without authority;

(B) makes an unauthorized use, disposition, or transfer, of nuclear material or nuclear byproduct material belonging to another; or

(C) uses fraud and thereby obtains nuclear material or nuclear byproduct material belonging to another;

(3) knowingly—

(A) uses force; or

(B) threatens or places another in fear that any person other than the actor will imminently be subject to bodily injury; and thereby takes nuclear material or nuclear byproduct material belonging to another from the person or presence of any other;

(4) intentionally intimidates any person and thereby obtains nuclear material or nuclear byproduct material belonging to another;

(5) with intent to compel any person, international organization, or gov-ernmental entity to do or refrain from doing any act knowingly threat-ens to engage in conduct described in paragraph (2) (A) or (3) of this subsection;

(6) knowingly threatens to use nuclear material or nuclear byproduct material to cause death or serious bodily injury to an person or sub-stantial damage to property or to the environment under circum-stances in which the threat may reasonably be understood as an expression of serious purposes:

(7) attempts to commit an offense under paragraph (1), (2), (3),

or (4) of this subsection; or

(8) is a party to a conspiracy of two or more persons to commit an offense under paragraph (1), (2), (3), or (4) of this subsection, if any of the parties intentionally engages in any conduct in furtherance of such offense;

Sub paragraphs (b) and (c) omitted.
(d) The Attorney General may request assistance from the Secretary of Defense under chapter 18 of title 10 in the enforcement of this section and the Secretary of Defense may provide such assistance in accordance with chapter 18 of title 10, except that the Secretary of Defense may pro-vide such assistance through any Department of Defense personnel.

(e)

(1) The attorney General may also request assistance from the Secretary of Defense under this subsection in the enforcement of this section. Notwithstanding section 1385 of this title, the Secretary of Defense may, in accordance with other applicable law, provide such assistance to the Attorney General if—

(A) an emergency situation exists (as jointly determined by the Attor-ney General and the Secretary of Defense in their discretion); and

(B) the provision of such assistance will not adversely affect the mili-tary preparedness of the United States (as determined by the Secretary of Defense in such Secretary's discretion).

(2) As used in this subsection, the term "emergency situation" means a circumstance—

(A) that poses a serious threat to the interests of the United States; and

(B) in which—

(i) enforcement of the law would be seriously impaired if the assistance were not provided; and

(ii) civilian law enforcement personnel are not capable of enforc-ing law.

(3) Assistance under this section may include—

(A) use of personnel of the Department of Defense to arrest persons and conduct searches and seizures with respect to violations of this section; and

(B) such other activity as is incidental to the enforcement of this sec-tion, or to the protection of persons or property from conduct that violates this section.

(4) The Secretary of Defense may require reimbursement as a condition of assistance under this section.

(5) The Attorney General may delegate the Attorney General’s function under this subsection only to a Deputy, Associate, or Assistant Attor-ney General.

(f) As used in this section—

(1) the term “nuclear material” means material containing any—

(A) plutonium;

(B) uranium not in the form of ore or ore residue that contains the mixture of isotopes as occurring in nature;

(C) enriched uranium, defined as uranium that contains the isotope 233 or 235 or both in such amount that the abundance ratio of the sum of those isotopes to the isotope 238 is greater than the ratio of the isotope 235 to the isotope 238 occurring in nature; or

(D) uranium 233;

(2) the term “nuclear byproduct material” means any material containing any radioactive isotope created through an irradiation process in the operation of a nuclear reactor or accelerator;

(3) the term “international organization” means a public international organization designated as such pursuant to section 1 of the International Organizations Immunities Act (22 U.S.C. 288) or a public orga-nization created pursuant to treaty or other agreement under international law as an instrument through or by which two or moreforeign governments engage in some aspect of their conduct of international affairs;

(4) the term “serious bodily injury” means bodily injury which

involves-

(A) a substantial risk of death;

(B) extreme physical pain:

(C) protracted and obvious disfigurement; or

(D) protracted loss or impairment of the function of a bodily member, organ, or mental faculty;

(5) the term “bodily injury” means

(A) a cut, abrasion, bruise, burn, or disfigurement;

(B) physical pain;

(C) illness;

(D) impairment of a function of a bodily member, organ, or mental faculty, or

(E) any other injury to the body, no matter how temporary;

(6) the term “national of the United States” has the same meaning as in section 101(a)(22) of the Immigration and Nationality Act (8 U.S.C. 1101(a)(22)); and

(7) the term “United States corporation or other legal entity” means any corporation or other entity organized under the laws of the United States or any State or Commonwealth, territory, possession, or district of the United States.

405 (Popup - US PATENT 4662201)
Page: 1,2,3,4,5,6,7,8,9,10,11,12
406 (Popup - GB PATENT 2153406A)
Page: 1,2,3,4,5,6,7,8
407 (Popup - GB PATENT 2197362A)
Page: 1,2,3,4,5,6
408 (Popup - US PATENT 3024640)
Page: 1,2,3,4,5
409 (Popup - US PATENT 4433563)
Page: 1,2,3,4,5,6,7,8
410 (Popup - US PATENT 4056956)
Page: 1,2,3,4,5

Page: 1,2,3,4
430 (Popup - US PATENT 4433563)
Page: 1,2,3,4,5,6,7,8
431 (Popup - US PATENT 4803860)
Page: 1,2,3,4,5,6,7,8,9,
10,11,12,13,14,15
432 (Popup - US PATENT 4905490)
Page: 1,2,3,4,5,6,7,8,9,
10
433 (Popup - REVIEW OF SOFT DRILL)
Don’t Call Me an AutoDialer!!

I’ve seen a lot of clever safe opening tools in my time, but must say none have grabbed my attention as much as the new SoftDrill lock profiler. The SoftDrill is capable of opening the most common combination safe locks with no damage...often in under 30 minutes! This is a pretty big claim--and before I was convinced I had to test it myself to believe it.

First a little background on the SoftDrill profiler. This clever device was developed by the Mas-Hamilton Group (the same folks who make the X-07 and Auditcon safe locks), starting from scratch about a year and a half ago. A team of engineers was dedicated solely to this project with the goal of developing a machine that could quickly and reliably "manipulate" common mechanical locks. They studied locks and the methods used by safe technicians to open them. The engineering team then took this information and strove to build a device that could open locks with little or no skill on the operator’s part.

The coined term "SoftDrill" is a play on words of sort. The device is "software" driven, and performs a task normally reserved for a drill. In addition the words imply a "soft" safe opening. Although the SoftDrill performs a function very similar to classic manipulation, the manufacturer refers to it as a lock "profiler". The implication is that even manipulation resistant locks are still capable of being profiled--that is, of revealing their secrets through careful analysis!

SoftDrill comes neatly fit into a briefcase-size carrying case, and tips the scales at 23 pounds. It consists of a control unit, magnetic base, stepper motor, various-size pulleys, connecting cables, and other support hardware. A user supplied laptop computer (loaded with the provided software) is also needed to run SoftDrill. When setup it is similar in appearance to an autodialer. Looks can be very deceiving!

LAPTOP REQUIREMENTS: You will need your own laptop to run SoftDrill. Many of us are already equipped with laptops to run code and business programs. If you don't have one yet this is one more reason to go shopping. Virtually any new laptop has what it takes to run SoftDrill. To check out your old clunker for compatibility, here are the minimum requirements:

Computer: IBM-compatible laptop
Processor: Pentium
Drives: CD-ROM
Hard Drive: 5MB free space
PCMCIA Card Slot: One-Type II
RAM: 16 MB
Monitor: VGA
O/S: Microsoft Windows 95 or 98 (no, you can't skate by with 3.1!)
To prepare your laptop to operate SoftDrill you will need to do two basic things: Load the SoftDrill program onto your hard drive, and install the DAC card into your laptop's PCMCIA slot. (These items and installation instructions are included with SoftDrill.) Installation is straightforward, and after the setup is done you don't have to fuss with it anymore.

SOFTDRILL SETUP: Once your laptop is prepared you are ready to setup the SoftDrill hardware on your safe. Remember that this device does not open safes--it opens safe locks. The assumed circumstance for using SoftDrill is when there is a lock in working order--but with a lost combination. Currently two common locks are supported: The S&G 6730 and the LaGard 3330 (both are extremely common worldwide). Use the appearance of the dial and ring, as well as contact points and wheel counting to determine if you are dealing with one of the supported locks. Future software upgrades will be made available to open a wider range of locks.

Next, examine the surface of the safe immediately surrounding the dial and ring. Note the presence or absence of any escutcheon, handle, hinge, or other object that disrupts the surface. Check to see if the surface itself will attract a magnet (the SoftDrill hardware is mounted by magnets). The geography of the safe in the area of the dial dictates where to attach the magnetic base and how to configure it. A base extension (included) helps you position the magnets outside most non-magnetic escutcheons. The base itself is asymmetrical and reversible--permitting a wide range of possible mounting configurations.

Once the configuration and position of the base is determined you can mount the stepper motor to the base in advance of mounting the base on the safe. The stepper motor slides onto a pivot stud that extends outwards from the mounting base, and is held in place by a series of large, knurled locking nuts. The belt tension spring that extends from the stepper motor assembly is connected to a separate stud on the mounting base. You are now ready to mount the base!

The two "locator studs" on the base are butted against the dial ring to assure the proper relation between the base and dial. Now carefully bring the base near the safe and let the strong magnets do their work. Once in place the base will be difficult (if not impossible) to reposition without entirely removing it and starting over. That's how powerful the three mounting magnets are! Learning this step may cause a few pinched fingers, but in no time you'll be positioning the base quickly and painlessly.

The next step is to determine which of the SoftDrill's six aluminum dial pulleys fits your safe's dial. This selection covers just about every dial you are likely to encounter with the supported locks. Push the correct size pulley onto the dial and secure it with the provided set screws. Next, loop the timing belt over the pulley at the end of the stepper motor, then over the dial pulley. (The motor can be easily pushed towards the dial to help you accomplish this, courtesy of the belt tension spring.) Now adjust the knurled locking nuts so that the dial pulley and motor pulley are well-aligned. This adjustment will keep the timing belt "on track".

We are now ready to make the various cable connections. These are surprisingly straightforward--there is virtually no chance of plugging something into "the wrong place". Great for those of us with "computer connection phobia"!

Make sure the rocker switch in the briefcase is in the "off" position, then plug the power cord into a 110V AC outlet.
Plug the serial port cable into the back of your laptop, and one end of the PCMCIA cable into the DAC card you installed. Boot the laptop.
Plug the other end of your serial port cable into the appropriate connector in the briefcase.
Plug the other end of the PCMCIA cable into the briefcase.
Connect the cable that comes from the stepper motor to the stepper motor/encoder connector in the briefcase.

Mount the magnet-base accelerometer (think of it as a microphone) near the safe dial, and plug its cable into the BNC connector in the briefcase.
Set the safe dial with "0" under the opening index.
Turn the rocker switch in the briefcase "ON" to power the SoftDrill.
NOTE: Believe me folks--this entire setup procedure flies by once you've done it a few times. It now takes me absolutely less than five minutes to mount the base and make all the connections.

THE PROGRAM: The big moment has arrived! The SoftDrill is mounted and ready to run. Double click on the SoftDrill icon on your desk top to open the profiler's program. Here you are presented with a few options. You tell the program which lock you are dealing with and whether you want the program to make its own setup decisions, or whether you want to adjust the setup yourself. (Automatic setup is easiest of course--but I found adjusting the setup myself can improve opening time). After making these few choices, the stepper motor jumps to life, the dial starts turning, and your lock is on its way to being opened.

The SoftDrill begins by parking the wheels in a series of predetermined locations and checking the contact points. After finding a favorable wheel position it begins to look in earnest at one particular wheel--all the time informing the user of what it's doing. You don't have much control at this point over what's happening, but somehow it's reassuring to have the program inform you of its progress! As each wheel's secrets are uncovered, the user is informed of the top five candidates for that wheel's combination.

Perhaps it's the technician in me, but I found it absolutely fascinating to watch SoftDrill do its thing. The more I watched it the more I admired the folks who developed it. When checking contact points the device--like its human counterparts--oscillates the dial and takes several readings for accuracy. Also, SoftDrill seems to be exceedingly thorough. The dial turns in one number increments only--a step that adds a little time to the process but pays back with a very high "successful openings" rate. Lastly, SoftDrill doesn't give up without a fight. If the correct numbers do not turn up after SoftDrill's initial testing, it executes a well-planned attack that very thoroughly examines the lock until it yields--as most inevitably will. SoftDrill not only gives you the precise combination, but actually opens the lock as well!

MY TEST RESULTS: I have experimented with SoftDrill on over 100 attempted safe openings. This involved about 10 different locks (all S&G 6730s), on a variety of safes (including fairly thick-door fire safes). All of this was done either at my offices, or at a number of recent trade shows. Some of the trial combinations used were of my own making, but most were offered up by other folks.

An early version of the software I played with (several months ago) opened virtually every 6730 that met the following criteria:

1. The lock did not have the third wheel set in the forbidden zone.

2. The lock was "handed" correctly.

3. The lock’s third wheel "read" first, followed by wheels two and one.

The first two conditions are not so bad. Both conditions can be compensated for with a little cunning. The third condition was unacceptable though. Most 6730s do indeed read "wheel 3 first", but the goal is to open the really tricky ones as well! I phoned my concerns to the engineer who was writing the code for SoftDrill. After some discussion it was agreed that the device should be able to open locks regardless of which order the wheels read. I was delighted (but knowing the company--not surprised) to learn that the program had been rewritten to cover all possibilities.

To save time, the new program assumes a "3-2-1" lock, but if the opening fails the "wildcard" program is automatically executed. I thought the early version of the software was cool--but this "wildcard" feature is opening locks that had failed to previously yield.

SUCCESS AND THE TIME FACTOR: Most of my successful test openings were completed in 19 to 24 minutes. Several opened in 15 or 16 minutes. Two or three took about 45 minutes. Several took 60 to 69 minutes. I had several locks fail to open. In all fairness I must add that the failed openings all happened when I was using the early software. One of these failings had the last number set in the forbidden zone. Most all of the others did open--once I learned to manually adjust the setup. Of the no-excuse failures (once I had adjusted the setup and tried again), every single one revealed at least two correct numbers on the correct wheels! I

have yet to experience a failed opening using the new software.

"PROBLEM" LOCKS: All of the locks I worked with were in acceptable mechanical order. If your lock has a sticky or poorly aligned dial you should try the usual remedies (tap dial back into alignment and lubricate) before setting up SoftDrill. Although I didn't experience it myself, I am informed by Howard Dame of Mas-Hamilton that he had two locks with mechanical problems opened under his watch. The first was a lock he was using for demonstration purposes at a trade show. The lock had been opened on different combinations by SoftDrill perhaps 200 times. (Although SoftDrill causes a heck of a lot less wear to the lock than a common autodialer, 200 openings would cause severe strain).

After all these openings in the usual 20 minute time frame, the lock suddenly took 45 and 50 minutes to open--but nevertheless opened. Curious, Howard took the lock apart and discovered that the spine keyway had widened causing "loose spline key" syndrome. Experienced safe technicians know that to open such a lock, they need to add numbers when dialing left and subtract numbers when dialing right. SoftDrill had successfully opened this problem lock!

An even trickier problem was solved by SoftDrill. One lock that had been subjected to numerous SoftDrill openings eventually developed a "stuck fly". This problem can be diagnosed and opened by a good safe technician--but I have heard of numerous cases where the safe was drilled. I am informed that SoftDrill successfully opened this problem lock in about 20 minutes. This opening was repeated to make sure it wasn't a fluke. Again the lock opened in a similar time.

SUMMARY: In my experience, which has been limited to about 100 trials using S&G locks in good working order, my opening times have ranged from just under 15 minutes to nearly 69 minutes. The great majority yielded in 19 to 24 minutes. Six locks failed to open even after I manually adjusted the setup. All of the failed tests were conducted using an early version of the software.

THE BOTTOM LINE: This stunning technology does not come cheap. SoftDrill sells to security professionals for $6,995. However, if you are turning away safe openings or don't feel comfortable leaving your autodialer unattended for a day or more, this could be the ticket. Just two safe openings a month at $300 each pays for SoftDrill in one year.

FUTURE DEVELOPMENTS: Even now, software updates are being developed that will support an ever-growing variety of locks. The word from Mas-Hamilton is "Why should we stop with these two locks?". When I asked the obvious question about whether they would go after manipulation-resistant locks, I didn't get a "yes" or a "no"--just a sly smile.

434 (Popup - US PATENT 3024640)
Page: 1,2,3,4,5
435 (Popup - MOSLER MR-302 and MRK-302)
The MR-302 is the most popular form of this design. The MRK-302 is a key changeable model.

The original lock was constructed of brass and delrin or brass and zamak, and contained three wheels. The critical feature that made the lock manipulation-resistant was the design of the shutter. Its manipulation resistance resulted from the drive wheel mechanical design that caused it to "snap" while passing through the drop-in area. and a spring-loaded detent located on the lock body which rested against the drive wheel.

The drive wheel was of a split design: half would be fixed during rotation by a detent. This portion of the wheel would return to its original position upon reaching a certain position. The split drive wheel was held together by a "C" clip and post configuration. The wheel centers are made of zamak, and all are identical with the exception of the #1 wheel, which contains no drive pin on the bottom side. The outer portion of the wheels are constructed of delrin, and have teeth that mesh with the zamak inner wheel.

The cover of this lock is unique, for it holds the wheel pack as well as the detent that depresses the relocker when the cover is properly seated. The fence screw rests and moves within an interior slot, and the cover can only be removed if the bolt is fully extended. Thus, in order to change the combination, the door must be locked open with the bolt protruding.

The MR-302 series lock has the same mounting footprint as the S&G 6730, however the spindle is a smaller diameter and not interchangeable.

436 (Popup - CHICAGO LOCK COMPANY V. FANBERG)
CHICAGO LOCK CO. v. FANBERG, 676 F.2d 400 (9th Cir. 1982)

CHICAGO LOCK CO., A CORPORATION,

PLAINTIFF-APPELLEE,

v.

MORRIS v. FANBERG AND VICTOR FANBERG, CO-PARTNERS, D/B/A A-ADVANCED LOCKSMITH,

DEFENDANTS-APPELLANTS.

No. 80-5000.

United States Court of Appeals, Ninth Circuit.

Argued and Submitted August 3, 1981.

Decided May 6, 1982.

Rehearing Denied July 14, 1982.

Neil F. Martin, San Diego, Cal., for Chicago Lock.

Bruno J. Verbeck, San Diego, Cal., for defendants-appellants.

H. Chester Horn, Jr., Los Angeles, Cal., for intervenor.

Appeal from the United States District Court for the Southern District of California.

Before ELY and NORRIS, Circuit Judges, and PECKHAM,[fn*] District Judge.

[fn*] The Honorable Robert F. Peckham, Chief Judge, Northern District of California, sitting by designation.

ELY, Circuit Judge:

The Chicago Lock Company ("the Company"), a manufacturer of "tubular" locks, brought suit against Morris and Victor Fanberg, locksmiths and publishers of specialized trade books, to enjoin the unauthorized dissemination of key codes for the Company's "Ace" line of tubular locks. The District Court granted summary judgment in favor of the Fanbergs as to the Company's federal

claims of trademark infringement and unfair competition, but held trial on the common law claim of unfair competition under former Cal.Civ. Code § 3369.[fn1]

The court concluded that the key codes for the Company's tubular locks were improperly acquired trade secrets and enjoined distribution of the Fanbergs' compilation of those codes. For the reasons set forth in this opinion, we reverse the District Court and order that judgment be entered in favor of the Fanbergs.

THE FACTS

Since 1933 the Chicago Lock Company, a manufacturer of various types of locks, has sold a tubular lock, marketed under the registered trademark "Ace," which provides greater security than other lock designs. Tubular Ace locks, millions of which have been sold, are frequently used on vending and bill changing machines and in other maximum security uses, such as burglar alarms. The distinctive feature of Ace locks (and the feature that apparently makes the locks attractive to institutional and large-scale commercial purchasers) is the secrecy and difficulty of reproduction associated with their keys.

The District Court found that the company "has a fixed policy that it will only sell a duplicate key for the registered series `Ace' lock to the owner of record of the lock and on request of a bona fide purchase order, letterhead or some other identifying means of the actual recorded lock owner." Finding of Fact No. 14, Excerpt of Record at 89. In addition, the serial number-key code correlations are maintained by the Company indefinitely and in secrecy, the Company does not sell tubular key "blanks" to locksmiths or others, and keys to Ace locks are stamped." Do Not Duplicate." See Excerpt at 86-91.

If the owner of and Ace lock loses his key, he may obtain a duplicate from the Company. Alternatively, he may have a proficient locksmith "pick" the lock, decipher the tumbler configuration, and grind a duplicate tubular key. The latter procedure is quicker than the former, though more costly. The

locksmith will, to avoid the need to "pick" the lock each time a
key is lost, record the key code (i.e., the tumbler configuration) along with the serial number of the customer's lock. See Excerpt at 92. Enough duplicate keys have been made by locksmiths that substantial key code data have been compiled,
albeit noncommercially and on an ad hoc basis.

Appellant Victor Fanberg, the son of locksmith Morris Fanberg and a locksmith in his own right, has published a number of locksmith manuals for conventional locks. Realizing that no compilation had been made of tubular lock key codes, in 1975 Fanberg advertised in a locksmith journal, Locksmith Ledger, requesting that individual locksmiths transmit to him serial number-key code correlations in their possession in exchange for
a copy of a complete compilation when finished. A number of locksmiths complied, and in late 1976 Fanberg and his father began to sell a two-volume publication of tubular lock codes, including those of Ace locks, entitled "A-Advanced Locksmith's Tubular Lock Codes." In 1976 and 1977 Fanberg advertised in the manuals in the Locksmith Ledger for $49.95 and indicated that it would be supplemented as new correlations became known. See Excerpt at 95-98. About 350 manuals had been sold at the time of
trial. The District Court found that Fanberg "had lost or surrendered control over persons who could purchase the books," id. at 98, meaning that nonlocksmiths could acquire the code manuals.

The books contain correlations which would allow a person equipped with a tubular key grinding machine to make duplicate keys for any listed Ace lock if the serial number of the lock was
known. On some models, the serial numbers appear on the exterior
of the lock face. Thus, Fanberg's manuals would make it considerably easier (and less expensive) for a person to obtain (legitimately or illegitimately) duplicate keys to Ace locks without going through the Company's screening process. This is what caused consternation to the Company and some of its customers. At no time did Fanberg seek, or the Company grant, permission to compile and sell the key codes. Nor did the individual locksmiths seek authorization from the Company or their customers before transmitting their key code data to

Fanberg.

The Company filed a three-count complaint against the Fanbergs, alleging federal question jurisdiction and diversity of citizenship, on December 2, 1976. The complaint, see Excerpt at 1-12, was predicated on theories of trademark infringement under 15 U.S.C. §§ 1051 et seq., federal unfair competition under 15 U.S.C. §§ 1125(a), and California common law unfair competition under former Cal.Civ. Code § 3369. On November 17, 1977, Judge Enright granted summary judgment for the Fanbergs on the federal claims, but left intact the state law claim. See Excerpt at 32-34. The complaint was amended, see Excerpt at 38-46, and a four-day bench trial was held before Judge Kerr on January 23-26, 1979. On November 28, 1979, Judge Kerr entered judgment in favor of the Company and filed findings of fact and conclusions of law. See Excerpt at 75-121.

The court found that the Company's high security policy for its Ace tubular locks, of which the confidential key code data were a part, was a "valuable business or trade secret-type asset" of the Company, and that the Fanbergs' publication of their compilation of these codes so undermined the Company's policy as to constitute "common law unfair competition in the form of an unfair business practice within the meaning of Section 3369 of the Civil Code of the State of California," as broadly interpreted in Barquis v. Merchants Collection Association, 7 Cal.3d 94, 496 P.2d 817, 101 Cal.Rptr. 745 (1972). Excerpt at 118-120. The court enjoined the Fanbergs from publishing or distributing any lists of key code correlations for the Company's registered series Ace tubular locks. See Excerpt at 121.

On this appeal the Fanbergs argue that the District Court erred on three grounds: (1) that the injunction against publication of their book constitutes a prior restraint prohibited by the First Amendment to the United States Constitution; (2) that the

statute
under which the injunction issued, former Cal.Civ. Code § 3369, is
unconstitutionally vague; and (3) that the District Court applied
erroneously the common law doctrine of trade secrets in
concluding that the Fanbergs had committed an "unfair business
practice" under Section 3369.

THE TRADE SECRETS CLAIM

Appellants argue that the District Court erroneously concluded
that they are liable under Section 3369 for acquiring appellee's
trade secret through improper means. We agree, and on this basis
we reverse the District Court.

Although the District Court's Findings of Fact and Conclusions
of Law are lengthy, the thrust of its holding may be fairly
summarized as follows: appellants' acquisition of appellee's
serial number-key code correlations through improper means, and
the subsequent publication thereof, constituted an "unfair
business practice" within the meaning of Section 3369. See
Excerpt at 119-20. Even though the court did not make an explicit
finding that appellee's serial number-key code correlations were
protectable trade secrets, both appellants and appellee premise
their appeal on such an "implicit" finding. See Brief of
Appellee at 13-14. We think it clear that the District Court
based its decision on a theory of improper acquisition of trade
secrets, and in the following discussion we assume arguendo
that appellee's listing of serial number-key code correlations
constituted a trade secret.[fn2]

California courts have adopted the theory of trade secret
protection set out in the Restatement (First) of Torts, § 757,
and the comments thereto, in resolving disputes involving trade
secrets. See Sinclair v. Aquarius Electronics, Inc., 42
Cal.App.3d 216, 116 Cal.Rptr. 654 (1974); Uribe v. Howie, 19
Cal.App.3d 194, 96 Cal.Rptr. 493 (1971); Cal Francisco
Investment Corp. v. Vrionis, 14 Cal.App.3d 318, 92 Cal.Rptr. 201
(1971). Commission of this common law tort is enjoinable under
the purview of "unfair competition" and "unlawful" or "unfair

business practice" under Section 3369. See Barquis v. Merchants Collection Association, 7 Cal.3d 94, 496 P.2d 817, 101 Cal.Rptr. 745 (1972); Hesse v. Grossman, 152 Cal. App.2d 536, 313 P.2d 625, 627 (1957).

The pertinent portion of Section 757 of the Restatement provides:

> One who discloses or uses another's trade secret, without a privilege to do so, is liable to the other if
>
> (a) he discovered the secret by improper means, or
>
> . . . .
>
> (c) he learned the secret from a third person with notice of the facts that it was a secret and that the third person discovered it by improper means . . .
>
> . . . .

Trade secrets are protected, therefore, in a manner akin to private property, but only when they are disclosed or used through improper means. Trade secrets do not enjoy the absolute monopoly protection afforded patented processes, for example, and trade secrets will lose their character as private property when the owner divulges them or when they are discovered through proper means. "It is well recognized that a trade secret does not offer protection against discovery by fair and honest means such as by independent invention, accidental disclosure or by so-called reverse engineering, that is, starting with the known product and working backward to divine the process." Sinclair, 42 Cal.App.3d at 226, 116 Cal.Rptr. at 661.

Thus, it is the employment of improper means to procure the trade secret, rather than mere copying or use, which is the basis of liability. Restatement (First) of Torts, § 757, comment a (1939). The Company concedes, as it must, that had the Fanbergs

bought and examined a number of locks on their own, their reverse
engineering (or deciphering) of the key codes and publication
thereof would not have been use of "improper means." Similarly,
the Fanbergs' claimed use of computer programs in generating a
portion of the key code-serial number correlations here at issue
must also be characterized as proper reverse engineering. Excerpt
at 96, 100-01; Brief of Appellee at 29-30. The trial court found
that appellants obtained the serial number-key code correlations
from a "comparatively small" number of locksmiths, who
themselves had reverse-engineered the locks of their customers.
See Excerpt at 96-97. The narrow legal issue presented here,
therefore, is whether the Fanbergs' procurement of these
individual locksmiths' reverse engineering data is an "improper
means" with respect to appellee Chicago Lock Company.

The concept of "improper means," as embodied in the
Restatement, and as expressed by the Supreme Court, connotes the
existence of a duty to the trade secret owner not to disclose the
secret to others. See Restatement (First) of Torts, § 757,
comment h (1939). "The protection accorded the trade secret
holder [i.e., in this case the Company] is against the
disclosure or unauthorized use of the trade secret by those to
whom the secret has been confided under the express or implied
restriction of disclosure or nonuse." Kewanee Oil Co. v. Bicron
Corp., 416 U.S. 470, 475, 94 S.Ct. 1879, 1883, 40 L.Ed.2d 315
(1974) (emphasis added).

Thus, under Restatement § 757(c), appellants may be held liable
if they intentionally procured the locksmiths to disclose the
trade secrets in breach of the locksmiths' duty to the Company
of nondisclosure. See Restatement (First) of Torts, § 757,
comment h (1939). Critical to the District Court's holding,
therefore, was its conclusion that the individual locksmiths,
from whom the Fanbergs acquired the serial number-key code
correlations, owed an implied duty to the Company not to make the
disclosures. See Excerpt at 116.

We find untenable the basis upon which the District Court

concluded that the individual locksmiths owe a duty of nondisclosure to the Company. The court predicated this implied duty upon a "chain" of duties: first, that the locksmiths are in such a fiduciary relationship with their customers as to give rise to a duty not to disclose their customers' key codes without permission, see Excerpt at 116; and second, that the lock owners are in turn under an "implied obligation [to the Company] to maintain inviolate" the serial number-key code correlations for their own locks, see id.

The court's former conclusion is sound enough: in their fiduciary relationship with lock owners, individual locksmiths are reposed with a confidence and trust by their customers, of which disclosure of the customers' key codes would certainly be a breach. This duty, however, could give rise only to an action by "injured" lock owners against the individual locksmiths, not by the Company against the locksmiths or against the Fanbergs.[fn3]

The court's latter conclusion, that lock owners owe a duty to the Company, is contrary to law and to the Company's own admissions. A lock purchaser's own reverse-engineering of his own lock, and subsequent publication of the serial number-key code correlation, is an example of the independent invention and reverse engineering expressly allowed by trade secret doctrine. See Sinclair, 42 Cal.App.3d at 226, 116 Cal.Rptr. at 661.[fn4] Imposing an obligation of nondisclosure on lock owners here would frustrate the intent of California courts to disallow protection to trade secrets discovered through "fair and honest means." See id. Further, such an implied obligation upon the lock owners in this case would, in effect, convert the Company's trade secret into a state-conferred monopoly akin to the absolute protection that a federal patent affords. Such an extension of California trade secrets law would certainly be preempted by the federal scheme of patent regulation. See Kewanee Oil Co. v. Bicron Corp., 416 U.S. 470, 94 S.Ct. 1879, 40 L.Ed.2d 315 (1974); Compco Corp. v. Day-Brite Lighting, Inc., 376 U.S. 234, 84

S.Ct. 779, 11 L.Ed.2d 669 (1964); Sears, Roebuck & Co. v. Stiffel Co., 376 U.S. 225, 84 S.Ct. 784, 11 L.Ed.2d 661 (1964).

Appellants, therefore, cannot be said to have procured the individual locksmiths to breach a duty of nondisclosure they owed to the Company, for the locksmiths owed no such duty. The Company's serial number-key code correlations are not subject to protection under Restatement § 757, as adopted by the California courts, because the Company has not shown a breach of any confidence reposed by it in the Fanbergs, the locksmiths, or the lock purchasers - i.e., it has failed to show the use of "improper means" by the Fanbergs required by the Restatement.

The District Court's conclusion that the Fanbergs committed an "unfair business practice" under Section 3369, therefore, must be reversed, and judgment should be entered in favor of appellants.
In view of the foregoing we find it unnecessary to reach appellants' First Amendment and vagueness claims.

REVERSED AND REMANDED with instructions that judgment be entered in favor of defendants-appellants.

[fn1] Former Section 3369 was recodified virtually verbatim in 1977 as Cal.Bus. & Prof. Code §§ 17200-17203 (West). For simplicity this opinion will refer to the statute throughout as "Section 3369."

[fn2] Both parties devote much of their argument to whether the Company's key code data properly constitutes a "trade secret" within the meaning of Restatement (First) of Torts § 757, comment b (1939). See Brief of Appellants at 30-33; Brief of Appellees at 13-20. Although for purposes of our holding we may assume arguendo that the correlations do constitute a trade secret, we think it clear that because the correlations are an unpatented compilation of information, they constitute a "trade secret" within the meaning of the Restatement as adopted by California courts. See Sinclair v. Aquarius Electronics, Inc., 42 Cal.App.3d

216, 222, 116 Cal.Rptr. 654, 658 (1974); Restatement (First) of Torts § 757, comment b (1939).

[fn3] The Company premised its complaint on a violation of its own rights under trade secret law; the Company did not allege violations of the lock owners' rights. Cf. Barquis v. Merchants Collection Ass'n, 7 Cal.3d 94, 110, 101 Cal.Rptr. 745, 756 (1972) (Section 3369 permits members of the public to sue on behalf of the public generally); Hernandez v. Atlantic Finance Co. of Los Angeles, 105 Cal.App.3d 65, 72-73, 164 Cal.Rptr. 279, 284 (1980) (statute authorizes suits for injunction by individuals on behalf of the general public).

[fn4] If a group of lock owners, for their own convenience, together published a listing of their own key codes for use by locksmiths, the owners would not have breached any duty owed to the Company. Indeed, the Company concedes that a lock owner's reverse engineering of his own lock is not "improper means." See Brief of Appellee at 24.

437 (Popup - RUBIN V. COORS)
SUPREME COURT OF THE UNITED STATES

Syllabus

RUBIN, SECRETARY OF THE TREASURY v. COORS BREWING CO.

certiorari to the united states court of appeals for the tenth circuit

No. 93-1631. Argued November 30, 1994 -- Decided April 19, 1995

Because §5(e)(2) of the Federal Alcohol Administration Act (FAAA or Act) prohibits beer labels from displaying alcohol content, the federal Bureau of Alcohol, Tobacco and Firearms (BATF) rejected respondent brewer's application for approval of proposed labels that disclosed such content. Respondent filed suit for relief on the ground that the relevant provisions of the Act violated the First Amendment's protection of commercial speech. The Government argued that the labeling ban was necessary to suppress the threat of "strength wars" among brewers, who, without the regulation, would seek to compete in the marketplace

based on the potency of their beer. The District Court invalidated the labeling ban, and the Court of Appeals affirmed. Although the latter court found that the Government's interest in suppressing "strength wars" was "substantial" under the test set out in Central Hudson Gas & Electric Corp. v. Public Serv. Comm'n of N. Y., 447 U.S. 557, the court held that the ban violates the First Amendment because it fails to advance that interest in a direct and material way.

Held: Section 5(e)(2) violates the First Amendment's protection of commercial speech. Pp. 3-15.

(a) In scrutinizing a regulation of commercial speech that concerns lawful activity and is not misleading, a court must consider whether the governmental interest asserted to support the regulation is "substantial." If that is the case, the court must also determine whether the regulation directly advances the asserted interest and is no more extensive than is necessary to serve that interest. Central Hudson, supra, at 566. Here, respondent seeks to disclose only truthful, verifiable, and nonmisleading factual information concerning alcohol content. Pp. 3-6.

(b) The interest in curbing "strength wars" is sufficiently "substantial" to satisfy Central Hudson. The Government has a significant interest in protecting the health, safety, and welfare of its citizens by preventing brewers from competing on the basis of alcohol strength, which could lead to greater alcoholism and its attendant social costs. Cf. Posadas de Puerto Rico Associates v. Tourism Co. of Puerto Rico, 478 U.S. 328, 341. There is no reason to think that strength wars, if they were to occur, would not produce the type of social harm that the Government hopes to prevent. However, the additional asserted interest in "facilitat[ing]" state efforts to regulate alcohol under the Twenty first Amendment is not sufficiently substantial to meet Central Hudson's requirement. Even if the Government possessed the authority to facilitate state powers, the Government has offered nothing to suggest that States are in need of federal assistance in this regard. United States v. Edge Broadcasting Co., ___ U. S. ___, ___, distinguished. Pp. 7-9.

(c) Section 205(e)(2) fails Central Hudson's requirement that the measure directly advance the asserted government interest. The labeling ban cannot be said to advance the governmental interest in suppressing strength wars because other provisions of the FAAA and implementing regulations prevent §205(e)(2) from

furthering that interest in a direct and material fashion. Although beer advertising would seem to constitute a more influential weapon in any strength war than labels, the BATF regulations governing such advertising prohibit statements of alcohol content only in States that affirmatively ban such advertisements. Government regulations also permit the identification of certain beers with high alcohol content as "malt liquors," and they require disclosure of content on the labels of wines and spirits. There is little chance that §205(e)(2) can directly and materially advance its aim, while other provisions of the same Act directly undermine and counteract its effects. Pp. 9-13.

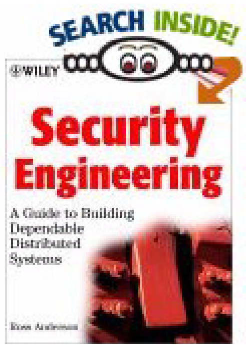
(d) Section 205(e)(2) is more extensive than necessary, since available alternatives to the labeling ban--including directly limiting the alcohol content of beers, prohibiting marketing efforts emphasizing high alcohol strength, and limiting the ban to malt liquors, the segment of the beer market that allegedly is threatened with a strength war--would prove less intrusive to the First Amendment's protections for commercial speech. Pp. 14-15.

2 F. 3d 355, affirmed.

Thomas, J., delivered the opinion of the Court, in which Rehnquist, C. J., and O'Connor, Scalia, Kennedy, Souter, Ginsburg, and Breyer, JJ., joined. Stevens, J., filed an opinion concurring in the judgment.

438 (Popup - SECURITY ENGINEERING)

Security Engineering: A Guide to Building Dependable Distributed Systems, by Ross J. Anderson.



[Amazon.com link for more information]

439 (Popup - Alphonse Bertillion Identification of Criminals)

The following description of the Bertillion identification method has been provided as an excerpt from the Central Missouri State University criminal justice system.

Alphonse Bertillion

In 1877, Alphonse Bertillion was appointed to the Prefecture of Police as a records clerk. He shortly became disgusted with the way in which records were maintained. Within a year he presented a new scheme for identifying criminals, based on body and head measurements. Using this technique (anthropometric or "man measurement"), he identified his first recidivist in 1883. In 1884, Bertillion identified 241 and was recognized for developing the first scientific method of identifying a criminal to be used by a police force.

This system was soon incorporated by the British and American police. Although it would be replaced by fingerprinting in the early twentieth century, the Bertillion system was responsible for bringing precision into a haphazard process. Prior to this development, criminal identification depended on the memories of witnesses. Criminals were able to commit their crimes and disappear into the streets with the knowledge that the police were unlikely to capture them. Bertillion made identification possible without requiring the witness to be present at the arrest. More than just a system of measurements, Bertillion also created the portrait parle (speaking likeness) system which was a precise method of describing a person's facial and physical characteristics. This portion of Bertillion's system is still used by the majority of the world's police departments, although it has lost much of its exactness due to the evolution of shortcuts in the process.

The difficulty that finally led to the discrediting of Bertillion's anthropometric system was the inability to ensure uniformity in measurement. The problem was two-fold. First, different officers frequently obtained different measurements from the same individual. This was caused by a lack of agreement on how tightly the calipers should fit in order to obtain the measurement. The second problem was caused by the aging process. As people age, so do many of the bodily characteristics, especially if the original measurements were obtained when the person was not yet an adult.

The system was ultimately discredited as a result of the Will West case in 1903. Will West was mistakenly identified in Leavenworth, Kansas as a previous convict, William West. The use of fingerprints allowed the police to identify the real William West, who was serving time in another prison. This case marked the end of anthropometric measurements and the beginning of fingerprinting as the principle means of criminal identification.

Bertillion received great criticism as a result of this, which sometimes obscures his other achievements. It was those other contributions, however, that make this man one of the great pioneers in criminalistics. He was instrumental in introducing the use of photography to police investigations, especially at crime scenes. He introduced handwriting and forgery analysis, ballistics, galvanoplastic preservation of footprints, the dynamometer, which was employed in determining the degree of force used in housebreaking, and the "Bertillion Kit", the case containing instruments of evidence collection taken by detectives to a crime scene.

440 (Popup - FALSE ACCEPT RATE IN BIOMETRICS)
A false acceptance allows a person to access a system with biometric features that have not been registered on the system.
441 (Popup - FALSE REJECT RATE IN BIOMETRICS)
A false rejection rate prevents the legitimate user from accessing a system for which he or she has access authority.
442 (Popup - DEPARTMENT OF ENERGY)
Video and images from DOE were provided by the Office of Security and Safety Performance Assurance, in German Town, Maryland.

Certain materials were excerpted from the **NRC Inspection Manual** and the **Physical Security Systems Inspections Guide**, because of their application to all intrusion detection system design and evaluation.
443 (Popup - CASING AN ESTABLISHMENT)

This term designates casing or surveillance of a location by a burglar.

444 (Popup - PUNCHING)

This technique is known as "punching." See **Chapter 35**.

445 (Popup - ALFRED C. HOBBS AND THE BRAMAH LOCK)

See the information in **Chapter One** regarding the Bramah lock and the Great Exhibition, and how Alfred C. Hobbs bypassed a mechanism that had never been compromised..

446 (Popup - FIREPROOF WORD DERIVATION)

The term "fireproof" also appears as "fire proof" and "fire-proof" in this text, due to the differing use of English, especially in early works. You may wish to search for all three derivations.

447 (Popup - PROPERTIES OF ALUMINOUS EARTH)

"Aluminous earth is also employed in different combinations by the dyer and the calico printer, as a mordant for fixing various colours; and upon the continent it is artificially combined with sulphuric acid, in order to form alum. But we possess the compound, or alum slate, ready formed in abundance. It is procured on the sea-coast of the northeast part of Yorksire, from Whitley to Stockton, a distance of about fifty miles. The slate, when taken from the bed, is broken to pieces by the aid of fire, and afterwards further acidified by being frequently moistened, and by exposure to the air. When the efforescence has taken place it is put into lixiviating vessels for the extraction of the salt. The saline liquor is then boiled down to the proper strength for crystallization; previous to which is added a portion either of sulphate or muriate of potash. Alum, indeed, cannot be made without ammonia or potash, as it is a triple salt."

Parkes Elements of Chemistry

448 (Popup - DOCUMENT AND RECORD PROTECTOIN FROM FIRE)

This is the earliest development of record and data protection containers from the effects of fire. Not a great deal has changed within the past 150 years.

449 (Popup - POWDER-PROOF AND GUNPOWDER PROOF LOCKS)

You may wish to search for this topic under gunpowder, gunpowder proof, powder proof, and powder-proof, as these terms appear differently in each text.

450 (Popup - PICKING, DECODING, AND SIMULATION OF A KEY)

This discussion complements that which appears in Chapter 29-31 with respect to the simulation of a key to open a lock. Various decoding systems provide the critical information regarding the position of the "security parts"; the John Falle variable key

generation system allows the simulation of the correct key using the decoded information.

451 (Popup - WARDED LOCK DEFINITION)

Definition of a warded lock.

452 (Popup - DOUBLE DETAINER LOCKING THEORY)

This is the definition of the double detainer locking theory described elsewhere in this text.

453 (Popup - LETTER OR PUZZLE LOCK)

This reference also describes the letter or puzzle lock, or permutation lock. It is also used to describe the padlock, letter lock, or finger ring lock.

454 (Popup - FENCE AND GATE RELATIONSHIP)

Note the description applies equally to the modern combination lock.

455 (Popup - PROGRAMMABLE COMBINATION LOCK)

This is likely the first instance of a programmable combination lock, much like the Corbin Sessamee that is so common on luggage today.

456 (Popup - COMBINATION LOCK)

This term refers to a combination lock.

457 (Popup - FALSE NOTCHES AND GATES)

This provides an interesting history of the use of false notches and gates within combination locks to enhance security.

458 (Popup - PROGRAMMABLE COMBINATION LOCK)

This is another description of the programmable combination lock.

459 (Popup - MANIPULATION AND EARLY COMBINATION LOCKS)

This refers to the manipulation of early combination locks.

460 (Popup - PROTECTION AGAINST FORCED ENTRY FOR LOCKS)

This is an equally applicable definition for safes produced today and those of almost two centuries ago, with respect to forced entry techniques and security enhancements to protect against such methods of forced entry.

461 (Popup - DAY LOCKING OF COMBINATION LOCKS)

Perhpas the earliest definition of "day locking" of a combination lock.

462 (Popup - DIFFERS OR PERMUTATIONS WITHIN A COMBINATION LOCK)

The subject of permutations or differs for a combination lock was just a relevant two centuries ago as it is today.

463 (Popup - TENTATIVE METHOD OF LOCK PICKING)

This is a description that encompasses the tentative method of lock picking, described elsewhere in this text.

464 (Popup - MANIPULATION OF COMBINATION LOCKS)

This is a discussion of the manipulation technique as applied to a combination lock almost two centuries ago.

465 (Popup - BIT AND BARREL KEYS)
This is the definition of the bit or barrel key, defined elsewhere in this text.

466 (Popup - DEVELOPMENT OF WARDS)
This description examines the development of the ward to block entrance into the keyway by all but the proper key.

467 (Popup - BULLETS)
This describes the development of bullets or variations in the ward pattern within a keyway.

468 (Popup - IMPRESSION OF WARDED LOCK)
This description shows how easy an impression of the mechanism can be produced from a warded lock.

469 (Popup - FALSE NOTCHES IN WARDED LOCK)
False notches in warded locks were the forerunner to the utilization of this technique in lever locks.

470 (Popup - WARDED LOCKS AND A SECURITY ANALYSIS)
It can be seen that the same problem existed almost two centuries ago in the analysis of locks for their security and resistance to bypass. In many ways, little has changed between then and now.

471 (Popup - LOCKS AS WORKS OF ART)
It will be recalled from the discussion in Chapter 1 of **Locks, Safes, and Security** that warded locks were considered to be works of art, and defined wealth and prestige of the owner by their design.

472 (Popup - DIFFERS IN THE WARDED LOCK)
The warded lock is inherently insecure because of the limited number of differs that are available.

473 (Popup - APPEARANCE OF THE WARDED KEY PROVIDED A FALSE SENSE OF SECURITY)
The intricate design of the warded key provided a false sense of security to its owner, believing that the complexity meant that the internal mechanism was equally secure. Unfortunately, this was not the case.

474 (Popup - PICKING AND IMPRESSIONING WARDED LOCKS)
A description of how to pick or impression a warded lock illustrates the development of the technique for later, more secure mechanisms.

475 (Popup - FALSE KEYHOLES IN THE WARDED LOCK)
One of the measures of security in the warded lock was the false keyhole. Another was the design an extremely intricate keyway.

476 (Popup - H GATING WITHIN A LEVER)
Note the increasd security provided by the H gating.

477 (Popup - PICKING LEVER LOCKS)
This is an excellent description of the difficulty in picking a

lever lock.

478 (Popup - DIFFERS)

This description refers to the inherent problem with warded locks in particular; their being very few differs available, regardless of the design of the keyway and key.

479 (Popup - CALCULATION OF DIFFERS)

The calculation of differs for a lever lock.

480 (Popup - IMPRESSIONING OF WARDED LOCKS)

This is an excellent analysis regarding the capability to impression warded locks, and the procedures that were employed almost two hundred years ago.

481 (Popup - SECURITY OF THE BARRON LOCK)

This is an interesting and relevant discussion of the security defects that are inherent in the Barron lock.

482 (Popup - TENTATIVE METHOD OF PICKING)

This is a description and reference to the tentative method of picking of lever locks, still in use today.

483 (Popup - FALSE NOTCHES IN THE BRAMAH LOCK)

This is a description of the employment of false notches within the Bramah lock. They were utilized to frustrate the tentative method of picking. Not much has changed in the the modern lock design. The reader may also be interested in the video segment with Jeremy Bramah that describes the development of the Bramah lock by his ancestor.

484 (Popup - KNOCK-OFF LOCKS)

This is an early instance of the problem of knockoff locks and their lack of security. It is easy to see how the public would be confused and deceived into believing that they were purchasing an original Bramah high security mechanism.

485 (Popup - BRAMAH AS A PROLIFIC INVENTOR)

Joseph Bramah was a prolific inventor, having secured over twenty patents for wide ranging inventions.

486 (Popup - INVENTOR OF FALSE NOTCHES AND GATES)

This individual may well be the inventor of the security enhancement known as false notches and gates. That simple premise, now taking many forms on both levers and pin tumblers as notches, gates, and security tumblers, has significantly contributed to the security of all locks.

487 (Popup - CHANGEABLE OR PROGRAMMABLE LOCK)

This may be one of the first instances of a changeable key or programmable lock.

488 (Popup - NIGHTLATCH AND LOIDS)

This section describes a nightlatch, and how such a mechanism can be opened with a loid or flexible card.

489 (Popup - DOUBLE LOCKS PROVIDE ADDED SCURITY)

As described in Chapter 31, John Falle has developed a system to bypass the mechanism developed by CISA which is a double lock similar to that described in this section. The CISA mechanism provides for a pin tumbler lock to be inserted so as to block entry of the lever lock until the secondary lock is removed.

490 (Popup - MOFIDIED PIPE KEY)

This is an interesting modification to the design of the traditional pipe key for the warded lock. There are no wards on the key or within the lock because of its design.

491 (Popup - MULTI-POINT LOCKING DOOR ASSEMBLY)

This is one of the first instances of a multipoint locking system.

492 (Popup - CHUBB DETECTOR LOCK)

This appears to be the first instance of the Chubb Detector within a patent issued to Chubb. It was a revolutionary concept.

493 (Popup - CALCULATION OF DIFFERS IN THE LEVER LOCK)

This is an excellent description of the calculation of the number of differs, change keys, or key combinations within a lever lock.

494 (Popup - BARREL AND CURTAIN)

This is an excellent description of the barrel and curtain design.

495 (Popup - KNOCK-OFF LOCKS)

It would appear that the problem of knockoff locks is as old as the craft itself.

496 (Popup - RUTHERFORD TIME LOCK)

This is the original patent for the time lock, invented by William Rutherford jr. of Scotland. Information regarding this mechanism is found elsewhere in the text.

497 (Popup - PROGRAMMABLE LEVER LOCK)

This is another example of a programmable or changeable lever lock. Some of the modern locks utilize this same principle.

498 (Popup - PROGRAMMABLE LOCK AND KEY)

This is another example of a programmable lock and key.

499 (Popup - BASIS OF THE SIDEBAR DESIGN)

This appears to be the early beginnings of the sidebar design, as employed by Abloy in their disklock.

500 (Popup - note)

This ingenious workman, who is e self-taught musician, a repairer and tuner of orgams, pianofortes, musical bores, clocks, watches, etc., is the inventor of percussion-cap, a circular percussion-cap box, which is a beautiful contrivance for carrying two or three dozen caps in a circular disc, so that a cap is always ready to fix on the nipple of the gun. By forcing the side of the box against the nipple it fixes a cap upon the latter; when withdrawn, the mechanism of the box brings forward another

cap ready for immediate use, and so on till the whole are expended. As it is difficult to handle a percussion cap with cold fingers, besides the risk of losing it, this novel contrivance must prove useful; and had its inventor made it known earlier (instead of keeping it to himself since 1827), it might have been of considerable value to our army in the late war.

501 (Popup - note)

The slide forming part of this lock makes an excellent sash fastener piece of iron, inserting it in the knob, then securing the knob on to the spindle close to the door, and fastening it in such position by a small setscrew in the neck of the knob. Previous to this invention a carpenter could not fit a spindle to a door, unless the spindle happened to be of the exacyt size to suit the particular thickness of the door; but this simple invention permits the carpenter to fit all doors alike with these spindles, whether of one or twelve-inch or any intermediate thickness.

502 (Popup - note)

[1] "But is there not his danger, that at the same time we shall be giving lessons to thieves? It is not very probable that they will seek instruction of us, or that they have any need of it; they are greater masters in the art of opening doors than we can pretend to be. Let us then learn the art of opening locked doors, in order that we may acquire that of securing them in such a way as to leave little or nothing to be feared on account of their security."

503 (Popup - Popup)

[2] It may be stated as a remarkable fact that a locksmith has seldom been convicted of a burglary.

504 (Popup - Popup)

[3] See our remarks on this subject in the chapter on keys.

505 (Popup - TUMBLER LOCKS)

The use of the term "tumbler lock" and lever tumbler lock is the same.

506 (Popup - IMPRESSIONING OF LEVER LOCKS)

This is an interesting method to impression lever locks, and is quite different than the use of plasticine, discussed elsewhere in this text.

507 (Popup - ON THE CONSTRUCTOIN OF LOCKS)

[4] Tomlinson's Rudimentary Treatise on the Construction of Locks.

508 (Popup - TENTATIVE METHOD OF PICKING)

This is an excellent summary of the theory underlying the tentative method of picking.

509 (Popup - TENTATIVE METHOD OF PICKING: BACKGROUND INFORMATION)

[5] We believe the method of picking locks with movable obstructions to the passage of the bolt by the tentative process was first made publicly known in this country at a special general meeting of the Society of Arts on the 30th of June, 1851, when a paper was read by Mr. Paul R. Hodge "On the progress of improvements in locks in the United States of

America."

510 (Popup - TOW-IN-ONE PICK FOR LEVER LOCKS)

This is the precise design of modern two-in-one picks that are utilized to manipulate lever locks.

511 (Popup - ALFRED HOBBS ON THE TENTATIVE METHOD OF PICKING LEVER LOCKS)

This is another excellent description of the tentative method of picking a lever tumbler lock, provided by Alfred C. Hobbs.

512 (Popup - Popup)

[6] The picking of these locks led Mr. Chubb to construct his locks with a serrated stump and false notches in the levers, as will be described in the next chapter.

513 (Popup - ALFRED C. HOBBS PICKS THE BRAMAH LOCK)

The reader may wish to view the video inerview between the author and Jeremy Bramah that was conducted in London in 2001, wherein the challenge to Bramah and the bypass of the Bramah lock was discussed.

514 (Popup - ALFRED C. HOBBS OPENS THE BRAMAH LOCK)

This is an excellent description of the events that surrounded the famous Bramah challenge and subsequent opening of the lock that had defied picking for almost fifty years. The storefront of 124 Piccadilly is replicated in the British Science Museum in London, and sets the backdrop for the introduction of the Alfred Hobbs book that is contained within this Infobase.

515 (Popup - DESCRIPTION OF THE BRAMAH LOCK)

This is a description of the original Bramah lock that was opened by Hobbs, and was seen in the interview between the author and Jeremy Bramah.

516 (Popup - COMMENT BY ALFRED C. HOBBS)

[7] "Much larger than any lock Messrs. Bramah make for sale."

Mr. Hobbs

517 (Popup - Popup)

[8] The late Mr. Maudslay is intended to be here alluded to.

518 (Popup - DESCRIPTION OF THE SPRINGS IN THE BRAMAH LOCK)

[9] The springs do not, as has been stated, afford a pressure of thirty or forty pounds, but only thirteen pounds." Bramah and Co.

519 (Popup - Popup)

[10] "A thing quite impossible to be done in the lock." Mr. Hobbs

520 (Popup - Popup)

[11] The same lock is now being fitted up with the improvements which Bramah and Co. have adopted for some years past, and some trifling change suggested by the recent trial." Messrs. Bramah

521 (Popup - Popup)

12 This does not accord with the previous statement "that portions of the sliders presented the appearance of having been bent and straightened again."

522 (Popup - HOBBS OPENS THE BRAMAH LOCK: THE RESULT)

To this day, nobody knows precisely how Hobbs was able to open the Bramah lock. See the video interview between the author and Jeremy Bramah, a descendent of Joseph Bramah.

523 (Popup - Popup)

13 Mr. Smith was in the room several times, and on my second visit to the lock he introduced Lord---; and on my third visit I Allowed Mr. Smith and the foreman of Messrs. Bramah's lock manufactory to examine the lock." Mr. Hobbs

524 (Popup - Popup)

14 This was in strict accordance with the agreement.

525 (Popup - Popup)

15 "This was exactly what I did." Mr. Hobbs

526 (Popup - Popup)

16 "The price of the lock to which Mr. Hobbs' certificates, contained in his pamphlet, refer, appears as before stated to be upwards of 50 pounds."

527 (Popup - COMMENT BY ALFRED HOBBS)

17 "Compare this letter and objections with the terms and conditions agreed upon before commencing the trial." Mr. Hobbs

528 (Popup - COMMENTS BY BRAMAH)

18 Mr. Hobbs stated he preferred no one being present, as it made him nervous. If the operation was so delicate, what chance would a burglar have?" Messrs. Bramah.

529 (Popup - COMMENT BY BRAMAH)

19 "This means as far as he could through the keyhole." Messrs. Bramah

530 (Popup - COMMENTS BY BRAMAH REGARDING THE CONTEST)

20 "The lock remained in the window for four months expressly for Mr. Hobbs to make a second trial. He did not make the attempt; it was then only removed to stop the idle applications of men and boys which took up one person's time to attend to." Messrs. Bramah

531 (Popup - COMMENT BY ALFRED HOBBS REGARDING THE BRAMAH LOCK)

21 "The lock was the same in every particular as the locks made and sold by Messrs. Bramah at the present day." Mr. Hobbs

532 (Popup - COMMENT BY ALFRED HOBBS)

22 "The lock was fitted with a trap so that anything but its true key or the true key with the least dust in it would so disarrange the lock that it could not be opened by any means applied through the key-hole." Mr. Hobbs

533 (Popup - DESCRIPTION OF THE TECHNIQUE USED BY HOBBS TO OPEN THE BRAMAH LOCK)

This is a hypothetical description of how Hobbs was able to open the Bramah lock.

534 (Popup - SEPARATE KEY BIT FROM SHANK OR STEM FOR SAFE LOCKS)

This is now a common practice for high security lever locks

utilized on safes. The bit of the key simply unscrews from the shank, and is convenient to carry.

535 (Popup - NOTES ON THE HOBBS LOCK)

For the figures here referred to see the sheets Nos. 1 and 2 annexed to the complete specification, at the Patent Office, London.

536 (Popup - RINGING THE COMBINATION OF A LOCK)

This term is often used in this text. It refers to the practice of generating a key for every differ or permutation until the proper bitting pattern is discovered.

537 (Popup - Popup)

[1]The real writers of these anonymous letters are known to many, as they are to ourselves.

538 (Popup - FOOTNOTE 8)

In a six-lever lock, constructed with one of the levers "dead" (that is, the dead lever always remains in the same position, and does not require to be lifted in locking and unlocking), will tease even an expert and practiced lock-picker more than all the other five added together.

539 (Popup - MANIPULATION OF COMBINATION LOCKS)

The reader should view the materials in **Chapter 36**, including the excellent discussion of manipulation by Mark Bates.